



**Australian Government**  
**Productivity Commission**

# Vulnerable Supply Chains

# Productivity Commission Study Report

July 2021

© Commonwealth of Australia 2021

ISBN 978-1-74037-727-0 (online)

ISBN 978-1-74037-726-3 (print)



Except for the Commonwealth Coat of Arms and content supplied by third parties, this copyright work is licensed under a Creative Commons Attribution 3.0 Australia licence. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/3.0/au>. In essence, you are free to copy, communicate and adapt the work, as long as you attribute the work to the Productivity Commission (but not in any way that suggests the Commission endorses you or your use) and abide by the other licence terms.

### Use of the Commonwealth Coat of Arms

Terms of use for the Coat of Arms are available from the Department of the Prime Minister and Cabinet's website: <https://www.pmc.gov.au/government/commonwealth-coat-arms>

### Third party copyright

Wherever a third party holds copyright in this material, the copyright remains with that party. Their permission may be required to use the material, please contact them directly.

### Attribution

This work should be attributed as follows, *Source: Productivity Commission, Vulnerable Supply Chains, Study Report.*

If you have adapted, modified or transformed this work in anyway, please use the following, *Source: based on Productivity Commission data, Vulnerable Supply Chains, Study Report.*

### An appropriate reference for this publication is:

Productivity Commission 2021, *Vulnerable Supply Chains*, Study Report, July.

### Publications enquiries

Media, Publications and Web, phone: (03) 9653 2244 or email: [mpw@pc.gov.au](mailto:mpw@pc.gov.au)

### The Productivity Commission

The Productivity Commission is the Australian Government's independent research and advisory body on a range of economic, social and environmental issues affecting the welfare of Australians. Its role, expressed most simply, is to help governments make better policies, in the long term interest of the Australian community.

The Commission's independence is underpinned by an Act of Parliament. Its processes and outputs are open to public scrutiny and are driven by concern for the wellbeing of the community as a whole.

Further information on the Productivity Commission can be obtained from the Commission's website ([www.pc.gov.au](http://www.pc.gov.au)).

---

# Foreword

Resilient supply chains are a vital part of a well-functioning economy. They support the efficient production, and distribution of goods and services that are the basis for Australians' wellbeing. Typically, they are taken for granted, but the onset of COVID-19 brought into the spotlight the workings of supply chains. There were immediate impacts on logistics and transport, as well as panic buying and a few economies placing export restrictions on some essential goods. While our supply chains proved generally resilient, these experiences highlighted concerns about our ability to supply Australia's basic needs and about our preparedness as a nation to respond and recover from major disruptions to supply chains.

Against this background, the Commission was asked to examine the nature and source of risks to the effective functioning of the Australian economy and Australian's wellbeing associated with disruptions to global supply chains. The report considers the factors that make supply chains vulnerable, with a focus on the international linkages and dependencies from trade. Significantly, we have developed and piloted a 'data-with-experts' approach for identifying those supply chains and products that are vulnerable to disruptions and whose absence would jeopardise our economy and wellbeing.

We have found that few imports — one in twenty — are vulnerable to concentrated sources of supply. And many of these products are clearly not essential or critical to the wellbeing of Australians — for example, festive decorations, toys or swimwear. Other vulnerable imports require further investigation to assess whether they are essential or critical. A qualitatively similar picture holds for exports.

Our consultations with stakeholders through roundtables, bilateral meetings and written submissions put forward sometimes differing views or emphasis on where supply chain vulnerabilities lie and their significance. This is why specialised expertise is vital in stress testing the data-led approach. Expert knowledge is also required to identify whether an import is technically critical in the sense that its absence would interrupt the supply of an essential good or service. The Commission's method for assessing supply chain risks is best seen as a tool that complements an approach that relies on expert consultation.

Jonathan Coppel  
Commissioner

Dr Catherine de Fontenay  
Commissioner

July 2021

---

# Terms of reference

I, the Hon Josh Frydenberg MP, pursuant to Parts 2 and 4 of the *Productivity Commission Act 1998*, hereby request that the Productivity Commission undertake a study into Australia's resilience to global supply chain disruptions.

## **Background**

Australia's experience with the COVID-19 pandemic has highlighted Australia's potential vulnerability to global supply chain disruptions. While Australia's supply chains have held up relatively well during the COVID-19 pandemic, future shocks to supply chains will likely be different in nature.

## **Scope**

The purpose of the study is to examine the nature and source of risks to the effective functioning of the Australian economy and Australians' wellbeing associated with disruptions to global supply chains, identifying any significant vulnerabilities and possible approaches to managing them.

In undertaking the study, the Commission should consider Australia's part in global supply chains as an importer and exporter, and:

- consider the factors that make supply chains vulnerable
- develop a framework for identifying supply chains that are vulnerable to the risk of disruption and also critical to the effective functioning of the economy, national security and Australians' wellbeing
- use trade and other relevant data to identify supply chain vulnerabilities
- explore risk management strategies, including the roles of, and options for, government and businesses to manage supply chain risks.

## **Process**

The Productivity Commission should undertake appropriate consultation, and provide an interim report focusing on Australia's role as an importer in March 2021; and a final report including Australia's role as an exporter in late May 2021.

**The Hon Josh Frydenberg MP**  
**Treasurer**

[Received 19 February 2021]

---

# Contents

Foreword	iii
Terms of reference	iv
Acknowledgments	vii
Abbreviations	viii
<b>Executive summary</b>	<b>1</b>
<b>Findings</b>	<b>11</b>
<b>1 About this study</b>	<b>17</b>
1.1 Background to the study	17
1.2 What was the Commission asked to do?	20
1.3 How this study relates to other reviews and government initiatives	22
<b>2 Supply chains and risks</b>	<b>23</b>
2.1 Supply chains are complex, and becoming more so	24
2.2 Firm-level supply chain risks and vulnerabilities	30
2.3 From firm-level risk to market-level risk	35
<b>3 A framework to identify vulnerable supply chains</b>	<b>41</b>
3.1 The links between wellbeing and supply chains	42
3.2 The approach to identifying goods and services that are vulnerable, essential and critical	44
<b>4 Applying the framework to Australian imports</b>	<b>53</b>
4.1 How important are imports to economic activity?	55
4.2 How vulnerable are Australian imports to disruption?	56
4.3 How reliant is the production of essential goods and services on vulnerable imports?	68
4.4 Direct and indirect contribution of vulnerable imports to the consumption of essential goods and services	81

---

4.5	Possible extensions to this work	86
<b>5</b>	<b>Applying the framework to Australian exports</b>	<b>89</b>
5.1	Australia's exports — where and what	90
5.2	Demand-side vulnerability	92
5.3	Vulnerable imports used to produce exports	103
<b>6</b>	<b>Supply chain risk management</b>	<b>109</b>
6.1	A framework for managing risks	110
6.2	Understanding risk	114
6.3	Risk management strategies	119
<b>7</b>	<b>The role of government in risk management</b>	<b>131</b>
7.1	Responsibility for managing supply chain risks	132
7.2	Role of government in managing supply chain risks	134
7.3	A framework for determining whether government intervention is justified	149
<b>A</b>	<b>Consultation</b>	<b>153</b>
<b>B</b>	<b>Case studies in vulnerability</b>	<b>157</b>
<b>C</b>	<b>Technical application of the analytical framework to imports</b>	<b>167</b>
<b>D</b>	<b>Price elasticities of demand for imports</b>	<b>189</b>
<b>E</b>	<b>Downstream vulnerability of exports</b>	<b>201</b>
<b>F</b>	<b>Maritime shipping and ports capacity</b>	<b>205</b>
	<b>References</b>	<b>211</b>

---

# Acknowledgments

We are very grateful to all those who have given their time and shared their experiences and expertise with the Commission. We also thank the team, Marcelo Muñoz, Jess Nugent, Max Oss-Emer, Tyler Reysenbach, Melisa Bubonya, Phil Smith, Owen Gabbitas and Patrick Jomini, who provided us with expert support, many valuable insights and the drafting of the report.

---

# Abbreviations

ABS	Australian Bureau of Statistics
ABF	Australian Border Force
ACCC	Australian Competition and Consumer Commission
ANAO	Australian National Audit Office
ANZSIC	Australian and New Zealand Standard Industrial Classification
BEC	Broad Economic Classification
BLADE	Business Longitudinal Analysis Data Environment
CHAPS	Clearing House Automated Payment System
CIF	cost, insurance, and freight
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DISER	Department of Industry, Science, Energy and Resources
EU	European Union
FOB	free on board
HHI	Herfindahl Hirschman Index
HS	Harmonized System
HTISC	Harmonized Tariff Item Statistical Code
I–O	Input-Output
IOIG	Input-Output Industry Groups
IOPC	Input-Output Product Classification
IOPG	Input-Output Product Group
IoT	internet of things
LNG	liquified natural gas
NMS	National Medical Stockpile
OLS	ordinary least squares
OPEC	Organization of the Petroleum Exporting Countries
PPE	personal protective equipment
RITS	Reserve Bank Information and Transfer System

---

RTGS	real-time gross settlement
SA4	statistical area level 4
SITC	Standard International Trade Classification
SNA	System of National Accounts
TGA	Therapeutic Goods Administration
US	United States
WCO	World Customs Organization
WTO	World Trade Organisation



---

# Executive summary

Australia's supply chains proved generally resilient in response to the COVID-19 pandemic, unexpected trade restrictions, the devastating 2019-20 bushfires and 2021 floods in Eastern Australia. Nevertheless, these experiences have highlighted potential vulnerabilities in Australia's supply chains. The onset of COVID-19 saw immediate impacts on logistics and transport. A global surge in demand and panic buying of some essential goods, notably personal protective equipment, with export restrictions placed on such products by some governments, added a degree of urgency to the unfolding situation.

In this environment, understanding the nature of possible disruptions received relatively little attention, but it did prompt a host of views on Australia's degree of self-sufficiency and strident opinions on how best to manage the risks involved. The Economist Intelligence Unit, a research advisory service, projected global value chains may become shorter, less fragmented and more regional. Others were less equivocal. For example, Andrew Liveris, then special adviser to the National COVID-19 Commission, said that: 'Australia drank the free-trade juice and decided that off-shoring was OK. Well, that era is gone ... We've got to now realise we've got to really look at onshoring key capabilities'.

Regardless of the response, managing the risks of supply chain disruptions — whatever their origin — inescapably entails costs on businesses, consumers and governments. These costs vary substantially and depend on the choice of strategy — stockpiling, diversification of suppliers or markets, contingent contracting, developing domestic capability, or tolerating the residual risk, among others. They also depend on the state of preparedness of firms and governments.

The purpose of this study is to help further Australia's preparedness to deal with possible global disruptions to the supply of inputs (upstream risks) as well as global disruptions to markets for goods and services (downstream risks). The report considers the factors that make supply chains vulnerable, with a focus on the international linkages and dependencies from trade. Significantly, we have developed and piloted a framework for identifying those supply chains and products that are vulnerable to disruption and critical to the effective functioning of the economy, using trade and production data. We then explore risk management strategies for governments and businesses and provide policy guidance on the roles for government.

## Supply chains and risks

Supply chains are networks of firms participating in the process of transforming inputs into final products and delivering these to consumers. Improvements in technology and trade

---

liberalisation have made it easier and cheaper to source goods and services from overseas and equally to export our products and services to other markets. This has brought benefits from specialisation and economies of scale. It has also made supply chains more complex — modern supply chains often rely on inputs from across the globe and can consist of thousands of firms. The Dell supply chain, for example, was estimated to consist of over 7000 suppliers in 2019.

This intricate web of economic interdependencies means that a supply chain is potentially exposed to the many types of shocks that can affect every business, both in Australia and overseas: geopolitical (for example, a trade war), environmental (a natural disaster), economic (a financial crisis), societal (a pandemic) and infrastructure-related (a cyberattack).

Firm-level exposure to these risks depends on the characteristics of supply chains. A lack of flexibility, such as a dependency on one firm for a critical input, geographic clustering when all firms in an industry are in one location, and lengthy supply chains increase firm-level upstream risk. Downstream risks also arise from lack of flexibility, such as choke points in the logistics network (for example, key ports), and geographic clustering (for example, relying on a limited number of markets). To manage their exposure, those businesses that are most vulnerable use sophisticated tools and strategies, determined by their appetite for these risks and the relative costs of managing them.

From a policy perspective, however, it is not whether one firm in the market might experience disruption, but rather the exposure to market-level risk that matters most. In other words, the biggest concern arises when the whole market for a product could be at risk of disruption. For example, there is a market-level supply chain for automobiles, which includes the global supply chains that produce all automobiles for sale in Australia. Similarly, Dell's supply chain is just one part of the market-level computer supply chain. Lack of flexibility and geographic clustering shape market-level risk.

At an economy-wide level, it does not matter which firm supplies a particular good or service. If the supply chain of only one of many firms producing similar products is disrupted, that business may bear a substantial cost, but the societal cost may be small if alternatives are available. In contrast, it may be costly to society if the entire system that supplies an essential product is disrupted. For example, one brand of amoxicillin (a widely used antibiotic) disappearing from pharmacy shelves would not be a problem; but the disappearance of all amoxicillin could be a serious problem.

## **A 'data-with-experts' framework to identify vulnerable supply chains**

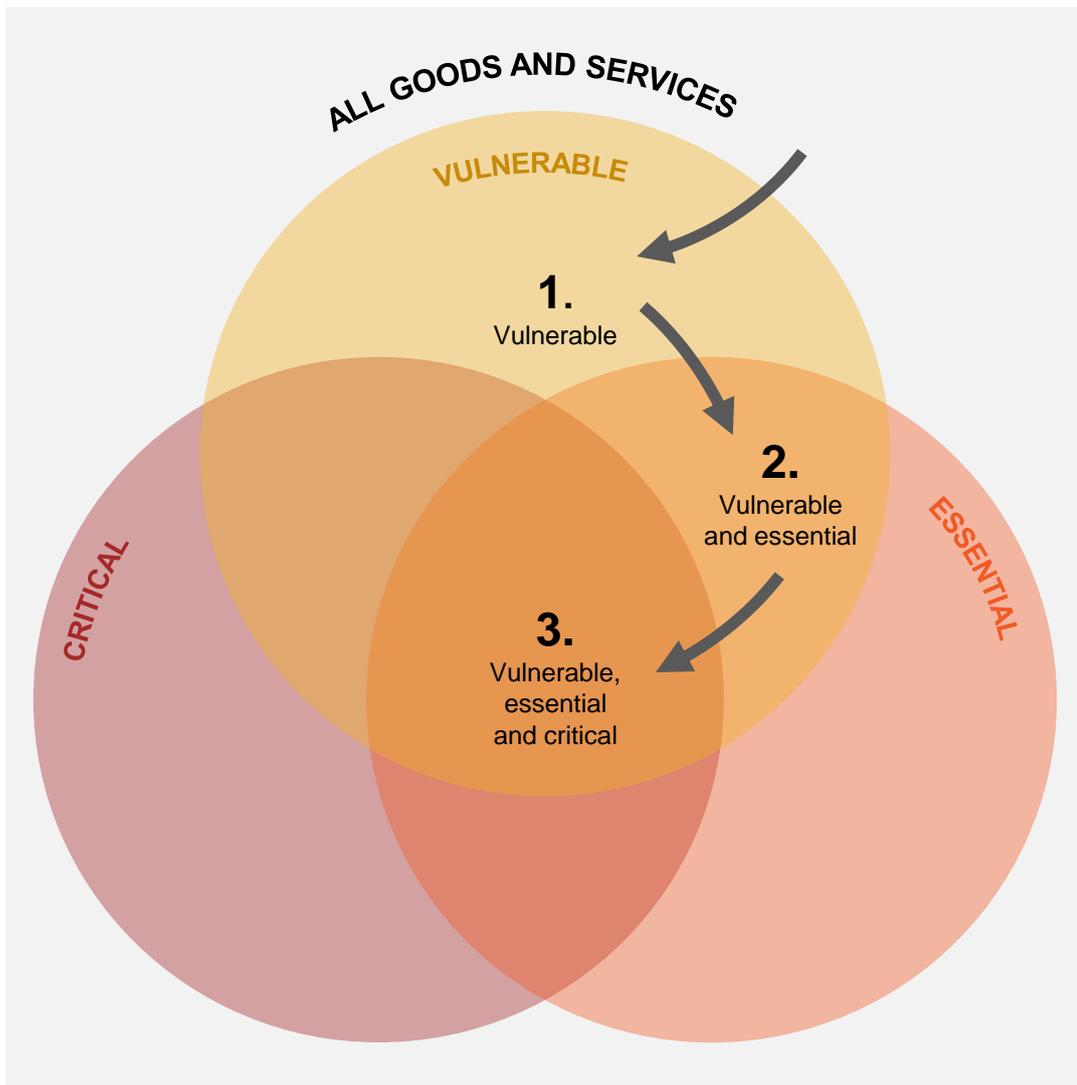
The Commission has developed a framework to identify supply chains for goods and services that are vulnerable to disruptions *and* whose absence would jeopardise the functioning of the economy, national security and Australians' wellbeing.

---

A novel feature of the framework is the development of a ‘data-with-experts’ approach (figure 1). It casts a wide net by first identifying those products that are vulnerable to supply chain disruptions using a data scan. Then it identifies which of these vulnerable products are used in essential industries. The final step relies on expert assessment to stress test the data-driven analysis and to determine, from among the vulnerable products used in essential industries, those which are critical (goods and services that cannot be substituted easily, or the production process cannot be adjusted in the short term to avoid their use).

---

Figure 1      **The Commission’s analytical framework**



---

The Commission’s method differs from the approach of relying exclusively on expert consultations to identify essential sectors and the key inputs that may be at risk. One of the strengths of first applying a data scan is that it is largely agnostic (a priori at least) on those products likely to be identified as vulnerable to disruption. This reduces the probability of

---

---

missing a good or service that *is* vulnerable. However, imperfect classifications of goods in any given dataset may still create false negatives (missing a vulnerable product) or false positives (identifying a product as vulnerable when it is not). Closer inspection and expert judgment can be used to reduce the number of false positives and capture vulnerable products missed by the data scan.

The framework still relies on some judgement, notably in specifying the goods and services that are considered essential. For the Commission's application of the framework to imports, essential goods and services were narrowly defined as those that meet the basic needs of Australians. Basic needs are part of the output of numerous industries, including food, water, health, communications, energy, logistics, finance, and government. A broader view of essential was used in our analysis of exports, which includes any goods and services that provide significant income security to Australians. Another area of judgment and choice is the time frame of analysis for assessing the economic impacts of disruption. We have focused on severe short-term (six-month) supply chain disruptions, because in the long run there is greater capacity to adjust and adapt to shocks.

The framework can be adapted to look at different scenarios. For this study, we have applied the framework to upstream and downstream disruptions in our analysis of Australian exports, and to upstream disruptions in our analysis of imports. It is also a flexible tool, with the user able to modify the key underlying assumptions. Care is needed, however, to ensure the assumptions are realistic, sensible and defensible. Otherwise, the results will be questionable and compromise the credibility of the analysis and any policy inferences drawn from them.

## **Testing the framework with imports data**

The framework developed by the Commission was piloted with Australian and global trade data to assess the upstream vulnerability of supply chains to imports.

Australia imported 5950 different products in 2016-17 with a combined value of A\$272 billion, equivalent to around 16 per cent of gross national income. These imports came from over 200 sources, although the majority by value were from the five largest suppliers — China, the United States, Japan, Thailand and Germany. The main imports by value were motor vehicles and parts; electrical, optical and other specialised equipment; fuel; pharmaceuticals; and chemicals.

As a first step to operationalise the framework and identify which imported products are vulnerable, filters are applied to the trade data. The first filter ascertains whether Australia's imports are highly concentrated (assumed to be when the main supplier accounts for over 80 per cent of imports of a product). The second filter determines whether there are limited alternative suppliers that Australia could access in the event of a disruption (assumed to be when the main exporter accounts for over 50 per cent of global exports). The third filter determines whether Australia sourced its concentrated imports from the main global supplier in a concentrated market.

---

The results of applying the first filter suggest that one-in-five products (1327 products worth A\$30 billion) imported by Australia is highly concentrated. However, the global trade data indicate that for many of these products alternative sources of supply exist and could be utilised should the need arise (filter 2). Once all three filters are applied, the result is that one-in-twenty Australian imports (292 products worth about A\$20 billion) are identified as originating from concentrated sources of global supply and, by this combination of criteria, might be vulnerable. Two-in-three of these vulnerable imports came from China.

The list of vulnerable imports arising from the broad-based data scan reveal many products that, while having high import concentrations, are unlikely to be critical — either directly or as an input into the production of essential goods and services — to the wellbeing of Australians. Examples of such products include festive decorations, sparkling wine, clothing items, and toys.

The second step in operationalising the framework involves identifying whether any vulnerable imports were used to produce essential goods and services. This involves linking trade and production data that relate to a group of essential industries. The essential industries are mainly service-producing industries that primarily use locally-sourced services in their production; vulnerable imports constitute a small fraction of all the value of inputs into essential goods and services. Further, fewer than half of all vulnerable imports are used in essential industries.

Taken together, the analysis offers suggestive — but not conclusive — evidence that many essential goods and services do not depend critically on vulnerable imported inputs. The main supply chain disruption risks that could be problematic arise from the reliance on concentrated imports of some basic chemicals, or some personal protective equipment. For example, the supplies of face shields, isolation gowns, polyethylene aprons, and surgical cloths that are predominantly used in health industries were found to be vulnerable.

A common theme in feedback on the interim report related to the exclusion of food from the analysis, given the six-month time frame used for considering supply chain disruptions. Many study participants viewed this as a significant shortcoming. For the final report, the Commission has examined how the results change when food is included. The changes are minimal, adding seven products to the list of vulnerable and essential products. One of the products is a chemical input; the other six are foods imported from a limited number of sources, including maple syrup from Canada, which is clearly not critical.

The Commission's results have limitations, mainly stemming from the lack of product detail in trade data and difficulties in linking trade and production data. This is where specialised expertise is vital in stress testing the data-led approach. Expert knowledge is also required to identify whether an import is technically critical in the sense that its absence would interrupt the supply of an essential good or service. The Commission's method for assessing supply chain risks is best seen as a tool that complements an approach that relies on expert consultation.

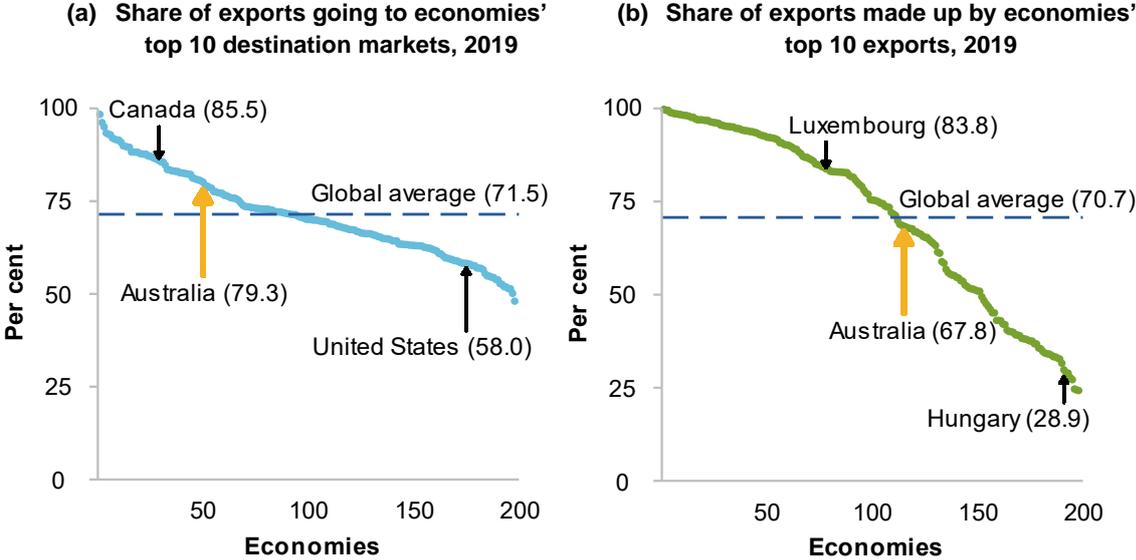
While not a substitute for expert knowledge, the Commission tested whether estimating demand elasticities for a selection of chemicals could corroborate the findings gleaned from the ‘data-with-experts’ approach. This can be informative, but data limitations made it difficult to apply the estimation approach systematically.

### Testing the framework with exports data

The framework was also applied to assess downstream and upstream risks to Australian exports. Whereas the analysis of imports took a narrow view of essential, focussing on risks to ‘life and limb’, the exports analysis adopts a broader view of essential to include any goods and services that provide a significant part of national income.

Australia is often misconstrued for having especially concentrated export markets, both in buyers and products, but in fact, Australia is not an outlier. In 2019, our top 10 destination markets accounted for 79.3 per cent of exports by value, while the global average was 71.5 per cent. And Australia’s top 10 exports accounted for 67.8 per cent of all of exports, slightly lower than the global average of 70.7 per cent (figure 2).

**Figure 2 The concentration of Australia’s exports by market and by product is close to the global average**



Data sources: CEPII (2021);OECD (2021).

As with imports data, filters were used to identify Australian exports’ downstream vulnerability. The filters chosen were designed to determine whether: Australia’s exports are highly geographically concentrated (filter 1); global trade is highly geographically concentrated (filter 2); and Australia’s main destination market is also the main global importer (filter 3).

---

This analysis revealed Australia has limited exposure to downstream disruption to its exports, with only 35 products identified as vulnerable in most years recently (less than 1-in-100 of Australia's goods exports). Nearly 81 per cent of these products went to China. By value, however, these 35 products accounted for around one quarter of Australia's goods exports. Relaxing filter 1 from 80 to 70 per cent captures liquefied natural gas and increases the value of vulnerable exports to about one third of Australia's exports of goods and services.

Iron ore accounts for the big difference in export vulnerability as measured by number of products or by value of exports. On its own, iron ore accounted for nearly 95 per cent of the value of all vulnerable exports in 2019. It has been the largest source of Australian export revenue for the last decade; over 80 per cent has been exported to China in recent years, and China regularly accounts for over two thirds of global imports of iron ore. This makes both Australia and China vulnerable to disruptions in the iron ore market. It is equally a situation that lessens the risk of geopolitically-inspired disruptions, as the two economies have a vested interest in the efficient functioning of the market for iron ore.

The economic impact from a downstream disruption to Australia's exports depends on how quickly markets adjust, which in turn will depend on the nature of the product. For example, the experience following the recent restrictions placed on some Australian exports by the Chinese government has shown that products like coal (which is not identified as vulnerable) can quickly find new markets while others, such as rock lobsters (identified as vulnerable) have greater difficulty.

The difficulty that exporters face in expanding to alternative export markets is a function of many factors not fully captured in our analysis of global trade data. For instance, the costs of finding new customers will likely be smaller for standardised commodity products like coal than for differentiated products like wine (which require significant marketing and reputation development).

The framework was also applied to examine the extent to which the imports we identified as vulnerable are used in the production of Australia's exports. This analysis found Australia has limited exposure to upstream supply chain disruptions — our main export industries use only 66 of the 292 imports that were identified as vulnerable. Of these, the main risks arise from imports of chemicals used in mining.

## **How is risk managed and is there a role for government?**

Efficient supply chain risk management balances the trade-off between the costs of a disruption and the opportunity cost of investing in risk management. To make effective decisions on the level of action to take, firms need to understand the nature of the potential disruption (likelihood, size etc.), and its impact to their supply chains.

However, it is not straightforward to gather and assimilate the information needed to understand supply chains risks. Supply chains can be long, complex, and opaque, and data

---

can be difficult to obtain. Biases can also affect the decisions of firms to invest in risk management. For example, because of their recent experience with the COVID-19 pandemic, firms may overinvest in strategies that seek to mitigate the risk of a pandemic, when other risks might be more probable and imminent.

Notwithstanding these challenges, risks are best managed by those who have direct incentives to mitigate them, and typically this means firms. Similarly, government has a responsibility to manage risks in supply chains for which they purchase and deliver goods and services directly. Key strategies used to prepare for supply chain risks include: accepting the residual risk (no action), stockpiling, supplier or market diversification, contingent contracting, and developing domestic capability. Several strategies are likely to be required to mitigate upstream risks.

There can also be circumstances where there is a rationale for government to intervene in market risk management. For example, intervention may be justified where risk management by a firm is hampered by regulation, or there is a divergence in risk appetite between firms and the community. A divergence could come about if, for instance, disruptions have spillover effects, or affect national security. In these cases, government could consider options ranging from providing information about risks that they are best informed about, to taking more direct ownership of risk management (such as supporting market diversification, maintaining government stockpiles, mandating or subsidising private stockpiles, or maintaining domestic production capacity).

That said, government intervention may crowd out private investment in risk management, imposing higher costs on the community. For example, the costs of maintaining local capability could outweigh the cost of other strategies. Further, onshoring could still rely on a critical input (such as crude oil), or Australia might lack the expertise to produce locally and be competitive. Onshoring may not reach efficient scale, particularly as firms often maintain several locations globally to diversify risks (and to control costs). Hence, even where an in-principle case for government intervention exists, any case for intervention needs to demonstrate that its benefits outweigh its costs.

One area where government could focus its efforts is on ensuring that firms do not face unnecessary constraints on how they plan for and respond to disruptions. A trusted and rules-based trading environment, for example, facilitates firms' ability to diversify their suppliers in preparation for, and their ability to find alternative suppliers in response to, a supply chain disruption. A responsive regulatory environment is another example.

Lastly, it is important that government periodically reviews and updates the list of goods and services that are vulnerable to supply disruptions and essential for the wellbeing of Australians, as it is likely to change over time. This role could be undertaken by the Office of Supply Chain Resilience, which the Australian Government established in 2021 to monitor vulnerabilities and coordinate whole-of-government responses to ensure access to essential goods.

---

The frameworks developed in this study provide a means to repeat such reviews, and preferably reviews would include expert consultation. This approach is recommended to better understand where vulnerabilities will be visible in data and which data are best suited to identify vulnerable, essential, and critical goods — thus producing the information needed to understand risks and coordinate effective responses.



---

# Findings

## Applying the framework to Australian imports

### FINDING 4.1: FEW IMPORTS ARE VULNERABLE TO CONCENTRATED SOURCES OF SUPPLY

One-in-five products imported by Australia are considered highly concentrated. Global trade data suggest that for many of these products alternative sources of supply exist and could be utilised should the need arise; one-in-twenty Australian imports might be vulnerable to concentrated sources of global supply.

### FINDING 4.2: MOST VULNERABLE IMPORTS ARE CONSUMPTION OR INTERMEDIATE GOODS

Although capital goods form the largest share of vulnerable imports by value, most vulnerable imports are consumption goods (such as personal protective equipment) or intermediate goods (such as sodium carbonate used in the treatment of water).

Disruptions to the supply of capital goods are unlikely to affect wellbeing in the short term.

### FINDING 4.3: THE MAIN SUPPLIER OF VULNERABLE IMPORTED PRODUCTS IS CHINA

China is the main supplier of about two thirds of the list of vulnerable imported products. Notwithstanding this, the main source of supply varies by product.

### FINDING 4.4: MANY IMPORTS CLASSIFIED AS VULNERABLE ARE NOT ESSENTIAL OR CRITICAL

Many imports classified as vulnerable are clearly not essential or critical to the wellbeing of Australians — for example, festive decorations, toys, or swimwear. Other vulnerable imports require further investigation to assess whether they are essential or critical.

---

FINDING 4.5: VULNERABLE IMPORTS MAY NOT BE CRITICAL TO THE PRODUCTION OF ESSENTIAL GOODS AND SERVICES

The narrow definition of ‘essential’ used in this chapter comprises of mainly service industries. Locally-sourced services are the main input to their production, rather than locally-sourced or imported goods. Consequently, vulnerable imports are a small share in their production costs. This is suggestive evidence that vulnerable imports may not be *critical* to the production of essential goods and services, but is not conclusive because criticality can be independent of value.

FINDING 4.6: ESSENTIAL INDUSTRIES USED 130 VULNERABLE IMPORTS IN PRODUCTION

Essential industries used 130 vulnerable imports in production. However, many of the vulnerable products, such as textile products (excluding personal protective equipment), are unlikely to be *critical* to production in these essential industries. This suggests that the production of essentials is not highly susceptible to short-term disruptions to the supply of imported goods that come from concentrated sources.

The main supply chain risks lie in the use of vulnerable chemical imports in health (human medicine manufacturing), energy (petrol and coal product refining) and water treatment industries. Some of these chemical products may be critical.

FINDING 4.7: THE INCLUSION OF FOOD DOES NOT QUALITATIVELY CHANGE RESULTS

Including food as an essential good does not qualitatively change the finding that the production of essentials is not highly susceptible to short-term disruptions to the supply of imported goods that come from concentrated sources. Critical inputs of fertilisers and pesticides are not found to be vulnerable in this application of the Commission’s framework. But like other essential industries, the main supply chain risks to food production lie in the use of imported vulnerable chemical products and personal protective equipment.

---

**FINDING 4.8: THE SUPPLY OF ESSENTIAL GOODS AND SERVICES IS NOT HIGHLY SUSCEPTIBLE TO DISRUPTIONS TO IMPORTED GOODS**

Combining imports and production data suggests that the supply of essential goods and services in Australia is not highly susceptible to a short-term upstream disruption to the supply of imported goods.

Vulnerable imports represent a small fraction of the value of essential goods and services consumed by Australians — whether that consumption be direct (final goods, A\$20 million out of total consumption of essential goods and services of A\$593 billion) or indirect (as inputs into Australian production, A\$2.7 billion). But this evidence is not conclusive and industry experts are required to determine criticality.

## **Applying the framework to Australian exports**

---

**FINDING 5.1: DATA SUGGESTS THAT LESS THAN 1-IN-100 OF AUSTRALIAN EXPORTS ARE VULNERABLE DUE TO CONCENTRATED SOURCES OF GLOBAL DEMAND**

Nearly one-in-five of Australia's good exports is considered highly concentrated but global trade data suggests that many of these exports could find alternative markets if needed. The result is that less than 1-in-100 of Australian exports might be vulnerable to concentrated sources of global demand.

---

**FINDING 5.2: AMONG AUSTRALIA'S MAIN GOODS EXPORTS, ONLY IRON ORE IS IDENTIFIED AS VULNERABLE**

Among Australia's main exports, data analysis identifies only iron ore as vulnerable. Including iron ore, vulnerable exports account for around 25 per cent of the value of goods exports. Excluding iron ore, only around 1.5 per cent is considered vulnerable (using the Commission's framework and thresholds).

Even for an export as valuable as iron ore, identification as vulnerable using the framework developed here has no immediate implication for public policy.

---

**FINDING 5.3: AUSTRALIA'S BIGGEST SERVICES EXPORTS ARE NOT VULNERABLE**

Education and tourism services are Australia's biggest services exports. These services are not identified as vulnerable because the main importer makes up less than 40 per cent of the market. However, both education and tourism services are vulnerable to factors that impede the movement of people.

---

FINDING 5.4: FEW IMPORTS IDENTIFIED AS VULNERABLE ARE LIKELY TO BE CRITICAL TO THE PRODUCTION OF AUSTRALIA'S MAIN EXPORT INDUSTRIES

Australia's main export industries used 66 vulnerable imports in production, but most of these products are unlikely to be *critical* to production processes. Further, vulnerable imports are a small share of the goods used in production, by value, which is suggestive evidence that they may not be critical to production, but it is not conclusive because criticality can be independent of value. Consultation with industry experts is needed to assess criticality, especially for vulnerable imports of chemical products used in mining.

## Supply chain risk management

FINDING 6.1: SUPPLY CHAIN RISK MANAGEMENT FRAMEWORK

Supply chain risk management is similar to buying insurance for other types of risk. In effect, a firm pays an insurance premium upfront to invest in strategies to insure itself against potentially large cost increases if a disruption occurs.

FINDING 6.2: UNDERSTANDING SUPPLY CHAIN RISKS

Effective risk management requires firms to invest in understanding their supply chain risks to ensure that the benefits of any investment to mitigate the costs of disruptions is at least matched by their potential effects and costs.

FINDING 6.3: HOW WELL STRATEGIES PERFORM DEPENDS ON THE TYPES OF DISRUPTIONS

Each risk management strategy has costs and, some will perform better under different types of disruptions and contexts. Firms will employ a range of strategies to effectively manage risk, such that the benefits exceed the costs.

---

## The role of government in risk management

### FINDING 7.1: RESPONSIBILITY FOR MANAGING SUPPLY CHAIN RISKS

Risks are best managed by those who have direct incentives and the capacity to mitigate against them.

Firms are primarily responsible for managing risks in their supply chain. Governments have responsibility, like any firm, to manage risks in supply chains where they purchase and/or deliver goods and services directly, particularly when these are essential goods and services.

### FINDING 7.2: GOVERNMENT INTERVENTION IN PRIVATE SECTOR RISK MANAGEMENT

Government intervention in private sector risk management may be justified when society's tolerance for a residual risk is lower than the residual risk that results from the market and where government or other impediments prevent firms from effectively managing their risks. However, government intervention can crowd out private investment in risk management — the net benefit of any intervention should outweigh the costs.

All levels of government have responsibility for ensuring regulations are fit for purpose, including making temporary changes that let firms adjust to major disruptions. The Australian Government also has responsibility for maintaining and promoting a rules-based international trading system that is respected and kept up to date.



---

# 1 About this study

## 1.1 Background to the study

The COVID-19 pandemic raised concerns about Australia’s ability to supply goods and services to meet Australians’ basic needs. Fears of shortages led to panic buying of certain goods, some firms faced input shortages and others had to devote extra effort to maintain access to supplies. Australia was not unique in this respect, with most economies manifesting concerns about how their reliance on imports could jeopardise their ability to meet their population’s needs during the COVID-19 pandemic.

COVID-19 also highlighted how many economies rely on China for many goods. The lockdown in Wuhan led to shortages for some goods. One of the biggest shortages was in face masks (box 1.1).

### Box 1.1 Face masks and COVID-19

The COVID-19 pandemic led to a surge in the global demand for face masks. This increase in global demand and limitations on supplies, due to interruptions in production and limitations on exports from several producers, led to a global shortage of face masks. That said, it was not face masks that were in shortage, but an input into their manufacturing — non-woven polypropylene, or meltblown. Only a few firms worldwide produce meltblown due to the high initial investment required. This high initial investment meant that firms could not easily or quickly start producing meltblown. Chinese exports of face masks resumed in March 2020; from January to March 2020, Chinese output expanded by a factor of ten. An OECD study estimated that the global demand surge was a much larger contributor to shortages than any export restrictions.

*Source:* OECD (2020).

The global shortage in face masks and other goods produced abroad, combined with increased awareness and sensitivity to risk, has led some to argue that Australia should develop a stronger domestic manufacturing capability (box 1.2).

---

## Box 1.2 COVID-19 prompted calls for onshoring — but not everyone agrees

Andrew Liveris, former special adviser to the National COVID-19 Commission, is a strong advocate for onshoring:

Australia drank the free-trade juice and decided that off-shoring was OK. Well, that era is gone ... We've got to now realise we've got to really look at on-shoring key capabilities. (Greber 2020)

Similar sentiments were expressed by the Secretary of the Department of Home Affairs:

... I think COVID has created a circumstance where we need to seriously think about both domestic manufacturing in limited and targeted ways, sovereign capability and, yes, stockpiles for those geo-strategic and geo-economic reasons. (Royal Commission into National Natural Disaster Arrangements 2020b, p. 2739)

In a report detailing how the Australian manufacturing sector could contribute to the Australian economy in the future, Stanford (2020, pp. 5–6) said:

... this is an opportune moment to launch a new, multi-faceted effort to revitalise Australian manufacturing:

- There is new public awareness of the importance of domestic manufacturing capability.
- Previous global supply chains have been disrupted by health measures, trade policy interventions, and other factors, forcing us to re-learn how to produce more things at home.
- The depth and speed of the economic contraction associated with the COVID-19 pandemic requires an ambitious strategy to rebuild national production and employment after the health emergency, and manufacturing could play a central role in that effort.
- Global economic adjustments, including declines in resource prices and the exchange value of the Australian currency, have enhanced the cost-competitiveness of Australian manufacturing.
- Continuing revolution in the technology and economics of energy is creating a new source of competitive advantage for Australian manufacturing: namely, our abundant resources of renewable energy, unmatched in the industrialised world.

But not everyone is calling for increased onshoring. Craig Emerson, former Australian Government Minister, argued that when thinking about improving the Australian economy, there are a few reform ideas worth considering and others that are not worth considering. The latter include:

... tariffs to protect so-called strategic industries which, by the time the rent-seekers are finished, would be every industry under the sun. (2020b)

He also argued that:

Trump-like tariff shelters for 'strategic industries' would shrink the economy and make genuine reform impossible to achieve. (2020a)

John Denton, the Australian Secretary-General of the International Chamber of Commerce argued:

This policy distortion [increased protectionism], coupled with a resurgent discussion on industrial self-reliance, will if unchecked dramatically alter the landscape of global trade for the worse. It will lead to overall higher prices, reduced production and increased product scarcity. (2020)

Other governments are considering policies to encourage firms to onshore some manufacturing processes in response to the COVID-19 pandemic. Beyond that, firms and governments are looking to diversify production processes across regions and international borders.

Governments and firms responded to the COVID-19 pandemic in a variety of ways — some governments prevented the exports of goods and prioritised supply to their own jurisdictions. In Australia, some firms pivoted their production toward goods and services in shortage whose prices had increased dramatically.

It was also during 2020 that a number of goods exported by Australia to China were interrupted, mostly due to China imposing tariff and non-tariff barriers to trade (table 1.1).

**Table 1.1 Disruptions to Australian exports<sup>a</sup>**

<i>Date</i>	<i>Australian export</i>	<i>Nature of measure/other actions</i>
May 2020	Barley	Anti-dumping tariff of 73.6 per cent and countervailing duty of 6.9 per cent.
May 2020	Beef	China suspended imports from four Australian abattoirs due to mislabelling of products and health certificate requirements.
October 2020	Cotton	Reports that customers in China had been told to stop buying Australian cotton.
End of October/early November 2020	Barley	China suspended relations with Australia's largest grain exporter, CBH, in September and another grain handler, Emerald Grain due to claims of weed seeds in a consignment.
October-November 2020	Coal	China prevented ships from unloading their cargoes citing quality reasons. There were also reports that some businesses were told to stop buying from Australian companies.
November 2020	Wine	China put a tariff of up to 212 per cent on Australian wine.
November 2020	Lobsters	China customs delayed quarantine inspection causing live lobsters to die at airports.
End of November/early December 2020	Timber	China progressively suspended timber imports first from Queensland, then from Victoria, South Australia and Tasmania.
December 2020	Wine	China put a countervailing duty of up to 6.4 per cent on Australian wine.

<sup>a</sup> This list is not exhaustive.

Sources: Birtles (2020); Conifer (2020); Evans (2021); Sullivan (2020a, 2020b); Sullivan and Barbour (2020); Sullivan, Dziedzic and Birtles (2020); Sullivan and Gunders (2020).

Some observers raised concerns that if China were to put trade sanctions on other goods, such as iron ore or education, then Australian income could decline significantly (box 1.3).

---

### Box 1.3 Views on the cost of trade frictions with China

Ben Butler from the Guardian noted:

For Australia, a lot is at stake. Exports of goods and services to China are about 7% of Australia's gross domestic product, and iron ore is the single-biggest category, at about 40% of the \$153bn in goods and services Australia sends to China every year ... (2020)

A report published by the National Security College at the Australian National University commented on how the deterioration of the China-Australia trade relationship may affect education:

... if there was a significant drop in students from China, the revenue and research loss would be impossible to fully replace through other international markets because China is the largest source of globally mobile students. (Kley and Herscovitch 2021, p. 1)

Former trade minister, Simon Birmingham, commented on the implications for the wine industry.

This is a devastating blow to those businesses who trade with China in the wine industry ... It will render unviable for many businesses their wine trade with China. And clearly, we think it's unjustified, and without evidence to back it up. (Butler and Davidson 2020)

At the Australian Grains Industry Conference, Simon Birmingham argued further:

Our Government is very much aware of how difficult decisions made by China have been for some of our barley growers.

I know it's frustrating – seeing relationships built up over the last 50 or 60 years with Chinese brewers and others being threatened. Trade is about mutual benefit; it's not about altruism. This is only a lose-lose situation, that's been created by China. It benefits no-one. (Birmingham 2020)

Others have called for an improvement in relations because of how beneficial the relationship is to Australia. Daniel Hurst reported in the Guardian Australia:

Labor MP Tim Watts cautioned on Tuesday that economic decoupling from China – an idea that is advanced by some of the most hawkish politicians in Canberra – would be 'an unprecedented act of national self-sabotage'.

His Liberal colleague, the former diplomat Dave Sharma, agreed that wholesale decoupling was not a serious proposition, because China was deeply integrated into the global economy and because Australia had been a 'massive beneficiary' of its growth and industrialisation. (2020)

## 1.2 What was the Commission asked to do?

Against this backdrop, the Australian Government asked the Productivity Commission to examine the nature and source of risks to the effective functioning of the Australian economy and to Australians' wellbeing, that are associated with disruptions to global supply chains, identifying vulnerabilities and possible approaches to managing them.

The terms of reference asked the Commission to consider Australia's part in global supply chains as an importer and as an exporter, and:

- consider the factors that make supply chains vulnerable
- develop a framework for identifying supply chains that are vulnerable to the risk of disruption and also critical to the effective functioning of the economy, national security and Australians' wellbeing

- 
- use trade and other relevant data to identify supply chain vulnerabilities
  - explore risk management strategies, including the roles of, and options for, government and businesses to manage supply chain risks.

The project has focused on a conceptual framework and data analysis, consisting of four main outputs:

- an analytical framework designed to identify goods and services that are critical to the functioning of the economy and to wellbeing. Part of this framework involves an outline of a methodology and process that could be used to identify goods and services that are vulnerable, essential and critical
  - the project outlines both data-driven and consultative approaches to identifying inputs that are critical to the functioning of the economy and to wellbeing (the consultative approach requires significant input from industry experts)
- data analysis that operationalises the framework to identify imports of goods that might be vulnerable
- data analysis to identify export markets that might be vulnerable to short-term threats such as reduced demand due to natural disasters, geopolitical reasons, or transport disruptions
- possible strategies to manage risks at the national level, rather than strategies that might be applied to specific firm-level supply chains or disruptions.

Due to security concerns and access to data, the report does not comment or analyse supply chains that relate to defence activities, beyond what is available in ABS data. That said, many of the principles discussed are transferrable to any sector of the economy.

## **Conduct of this study**

The Commission received the terms of reference for this study on 19 February 2021 and released its interim report on 26 March 2021 for comment. The Commission received 59 public submissions in total. A list of the individuals and organisations that made submissions is provided in appendix A, and all public submissions are available on the Commission's website.

Over the course of the study, the Commission met with a broad range of stakeholders, including government agencies, individual firms and industry representative bodies. Appendix A provides details.

The Commission thanks all participants for their contributions.

---

### 1.3 How this study relates to other reviews and government initiatives

The Commission has drawn on evidence from Australian and international sources and is based entirely on publicly available information. Other government initiatives and recent Australian-based work that complements this study includes:

- the Department of Industry, Science, Energy and Resources' Modern Manufacturing Strategy, which seeks to make supply chains more resilient to external shocks (DISER 2020e)
- Department of Home Affairs' Critical Technology Supply Chains Principles, which seek to assist government and businesses in making decisions about their suppliers and transparency of their own products (DoHA 2020b, p. 2)
- Australian National Audit Office's COVID-19 multi-year audit strategy (ANAO 2021)
- the Senate Select Committee inquiry into the Australian Government's response to the COVID-19 pandemic (Parliament of Australia 2020d)
- reviews by the Australian Competition and Consumer Commission's Agricultural Unit such as the *Cattle and beef market study*, the *Wine grape market study*, and the *Perishable agricultural goods inquiry* (ACCC 2017, 2019, 2020b)
- the *Inquiry into National Freight and Supply Chain Priorities* (DIRDC 2018b)
- the *Royal Commission into National Natural Disaster Arrangements* (Royal Commission into National Natural Disaster Arrangements 2020a)
- resources from the Critical Infrastructure Centre such as the *Critical Infrastructure Resilience Strategy: Plan* (DoHA 2015)
- resources from the Department of Home Affairs such as *Profiling Australia's Vulnerability* (DoHA 2018a)
- resources from the Australian Institute for Disaster Resilience such as *Guidance for Strategic Decisions on Climate and Disaster Risk* (AIDR 2021)
- the *Inquiry into national security risks affecting the Australian higher education and research sector* (Parliament of Australia 2020b)
- the *Inquiry into Diversifying Australia's Trade and Investment Profile* (Parliament of Australia 2020a).

---

## 2 Supply chains and risks

### Key points

- Firm-level supply chains are often networks across many firms and economies: they are not always a simple single flow of goods, and can cross many borders across the globe. This increases the complexity of supply chains and decreases their transparency.
- Market-level supply chains (comprised of all the firms that supply similar goods) are even more complex than firm-level supply chains.
- Improvements in technology and trade liberalisation have made it easier and cheaper to source goods and services from overseas. Increases in global trade bring large benefits such as cheaper and greater choice of goods and services for consumers. Industries also gain from specialisation and economies of scale.
- Supply chains are subject to:
  - geopolitical shocks, such as a trade war that might affect regional or global trade
  - environmental shocks, such as the 2019–2020 bushfires in Australia that affected transport and communication
  - economic shocks, such as the 1973 oil crisis that changed how firms and households use energy
  - societal shocks, such as recent labour disputes or the COVID-19 pandemic that affect labour supply and demand
  - infrastructure-related shocks, such as cyberattacks or disruptions at a port or along a road.
- Characteristics of supply chains that increase firm-level risk include:
  - lack of flexibility (dependency on one firm for a critical input)
  - geographic clustering (if all the firms in an industry are in one location)
  - long supply chains (goods changing hands often or crossing many borders).
- Lack of flexibility and geographic clustering have the potential to create market-level risk because they are more likely to affect all firms within a market.
- Policymakers should be concerned with market-level risk, rather than firm-level risk.

In 2020, bushfires and the COVID-19 pandemic tested Australia's supply chains. Many other scenarios could disrupt Australia's supply chains, ranging from global events, such as the global economic financial crisis or a trade war, to domestic events, such as the September 2020 labour dispute in the port of Port Botany, or natural disasters such as bushfires and floods.

---

This chapter describes concepts in supply chain analysis and how characteristics of supply chains make them susceptible to risks and disruptions. The chapter also introduces the notion of market-level risk.

## 2.1 Supply chains are complex, and becoming more so

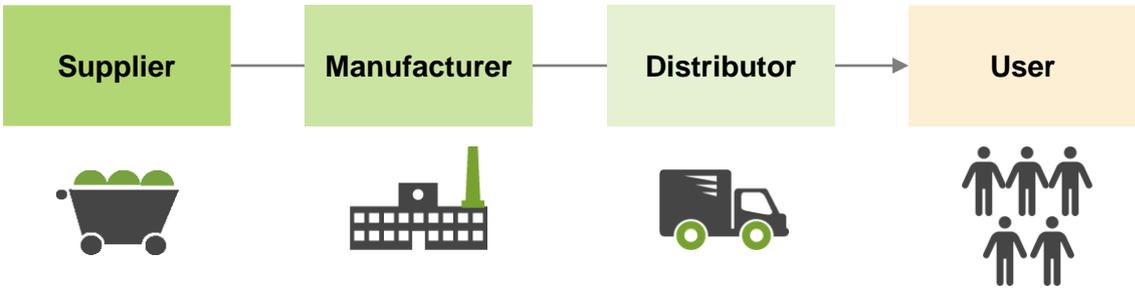
### Supply ‘chains’ are actually networks

A supply chain is the process of transforming raw materials into goods that are delivered to users, whether they be industries or consumers. Although the concept of a supply chain is thought of mainly in the context of manufacturing, all industries, including services such as utilities, construction and hospitals, rely on networks of suppliers.

The term ‘supply chain’ implies a movement of physical goods along a simple path from the supplier to the user (figure 2.1). The reality is that most supply chains are networks of firms (Christopher 2018, p. 6) and incorporate services. One reason for the network characteristic is that different types of inputs are combined in one stage of the production process; for example, making steel involves combining iron ore, coal and limestone. The other reason is that a firm might source the same input from different firms (possibly for risk mitigation).

---

Figure 2.1 From raw materials to the user



---

There can also be multiple tiers in a supply chain (box 2.1). For example, a ‘tier 1’ supplier might supply a firm directly, while a tier 2 supplier supplies a tier 1 supplier, and so on.

Supply chains can be very complex. Modern supply chains rely on inputs from across the globe, and can consist of thousands of firms. The Dell supply chain was estimated to consist of over 7000 tier 1 and 2 suppliers (McKinsey & Company 2020b, p. 9). Some supply chains

---

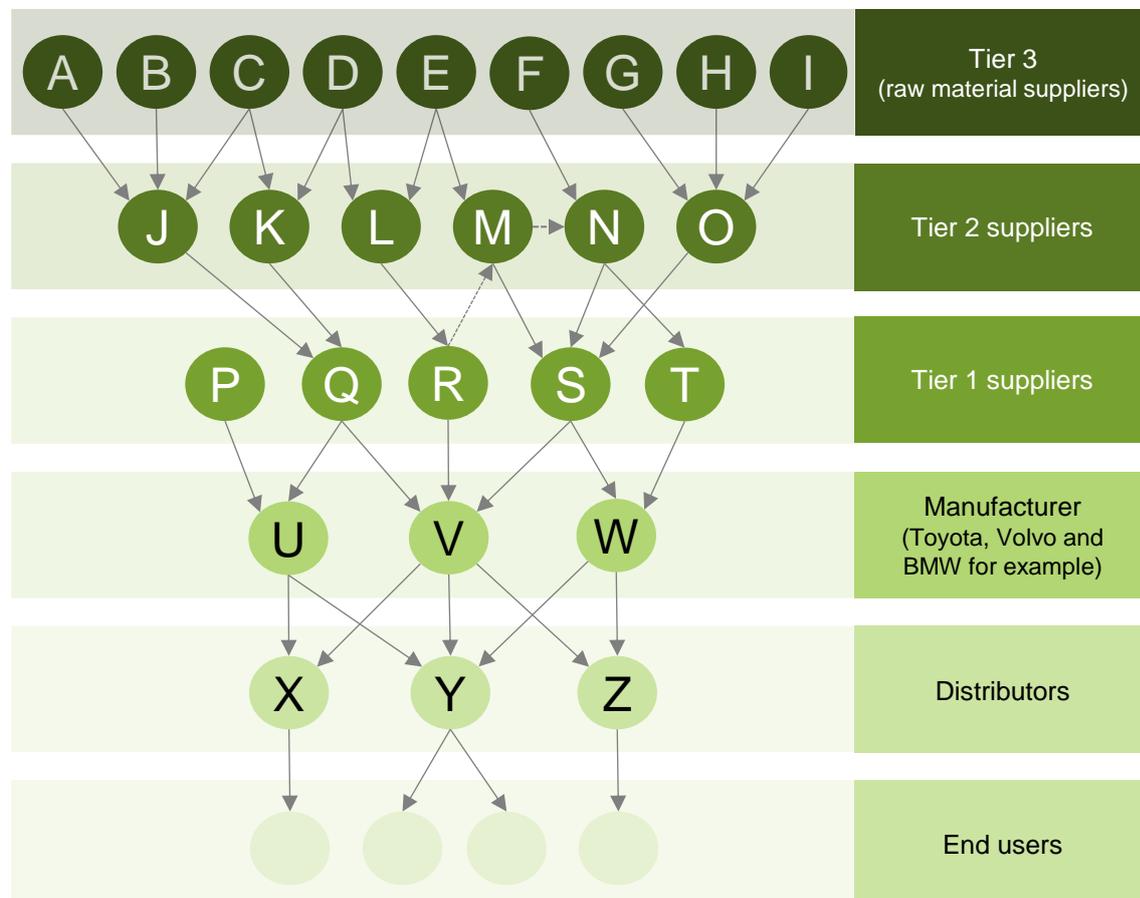
are even larger: as early as in 1986, General Motors had 35 000 tier 1 suppliers (Milgrom and Roberts 1992, p. 566).

### Box 2.1      **Supply chain terminology**

- **Node** — a node represents a stage in the production process occurring in one firm, in one geographic location (Zsidisin and Ritchie 2009, p. 3). For example, if parts are manufactured in a plant and then assembled with other parts, these processes are all represented by the same node.
- **Bullwhip effect** — where incorrect information is transmitted along a supply chain, making each firm in the supply chain increase demand for their inputs by more than is needed due to imperfect information travelling upstream. This can lead to short-term product shortages, overproduction, and logistics bottlenecks (Handfield and Graham 2020, pp. 3–4).
- **Link** — a link connects two nodes (Christopher 2018, p. 6). It represents the process of transporting the input from one production site to another. For example, a link between a factory in Malaysia to an assembly plant in Melbourne might involve trucking to the port, shipping through the Port of Singapore and the Port of Melbourne and rail transport to the assembly plant.
- **Length** — refers to the number of nodes that inputs pass through (or number of exposure points' (Stecke and Kumar 2009, p. 203)), from raw materials to end user.
- **Tier** — a tier 1 supplier supplies a firm directly, a tier 2 supplier supplies a tier 1 supplier and so on (Kito et al. 2014, p. 7).
- **Upstream/downstream** — these terms are typically used in reference to a firm within a supply chain. Upstream refers to the part of the supply chain that supplies inputs to the firm's production, including those that might originate several tiers away. Downstream is the part of the supply chain that is closer to the end user, including any distribution and retail steps (Zsidisin and Ritchie 2009, p. 2).

Even more complex are market-level supply chains (figure 2.2). These are the supply chains that supply a set of firms that sell competing end products in a market (firms U, V and W). For example, there is a market-level supply chain for automobiles, which includes the global supply chains that produce all automobiles sold in Australia. Some firms might have exclusive suppliers and exclusive dealers, keeping their supply chain separate from that of other firms. But in today's economy, firms often share suppliers. For example, Dell and Lenovo are estimated to share more than 2250 tier 1 and tier 2 suppliers (McKinsey & Company 2020b, p. 9). A disruption among any of these suppliers can affect the supply of the end products of both brands.

Figure 2.2 Market-level supply chain<sup>a</sup>



<sup>a</sup> Some firms can supply to firms within their own tier, and in tiers before their own. Suppliers in each tier may also supply firms outside of the supply chain. A supply chain is not always a simple flow of goods; for example, M in tier 2 supplies firm S in tier 1, but also supplies firm N in tier 2. Therefore, a disruption to firm M in tier 2 affects not only tier 1, but also tier 2.

*Data source:* based on a firm-level supply chain from Chandra and Kamrani (2004, p. 573).

From an economy-wide perspective, if the supply chain of just one of many firms producing the same product is disrupted, that business may bear a substantial cost, but the societal cost may be small if alternatives are available. Rather, it can be costly to society if the entire system that supplies or purchases an essential product is disrupted. For example, one brand of amoxicillin (a widely used antibiotic) disappearing from pharmacy shelves would not be a problem; but the disappearance of all amoxicillin could be a serious problem.

---

## Inputs to a supply chain

Supply chains rely on a number of components beyond just physical inputs. Disruption to any one component can affect the production of an end product. Components of supply chains include:

- domestic and imported goods (some examples are mentioned above), including:
  - raw materials, such as iron ore
  - intermediate goods, such as iron, steel, agrochemicals and other manufactured inputs
  - final goods that are shipped to retailers and finally reach consumers
- labour:
  - a firm’s workforce can be very diverse and composed of skills that are more or less substitutable. For example, a pharmaceutical company employs many technical assistants who might be easily substitutable, and researchers with specialised skills who are not easily substitutable. Global transport, a key part of supply chains, relies on a large, relatively low-skilled workforce of drivers, and on more skilled workers such as logisticians and air and marine pilots (a few of which are highly-specialised, such as helicopter pilots who ferry marine pilots to bulk carriers)
  - customer support and administrative workers may be working in different locations to where goods are produced. Thus, for example, a lockdown in the Philippines could disrupt the functioning of an automobile dealership in Sydney, if their back-office functions take place in the Philippines
- services (produced from labour and other inputs) such as: logistics; data processing and storage services; accounting and back-office services for financial institutions and communications; and call centres and other client services
- capital goods such as machinery
- infrastructure, such as telecommunication, electricity, road and rail networks, and ports. Infrastructure is crucial for production at each node, and transporting goods and services to consumers (WBCSD 2015, p. 9).

A shortage of any of these components makes firms vulnerable to a disruption.

## How trade and technology are transforming supply chains

Global trade has increased over the last three decades (figure 2.3), and the share of inputs (by value added) that cross international borders has greatly increased (Timmer et al. 2014, p. 100). For example, the iPhone X is assembled in Shenzhen, China, with inputs sourced from Germany, the United States, Switzerland, and Japan (figure 2.4). Global supply chains have remained a strong feature of trade, but some appear to have shortened since the 2008 global financial crisis, as indicated by a decline in the trade of many intermediate inputs (McKinsey & Company 2016, p. 26).

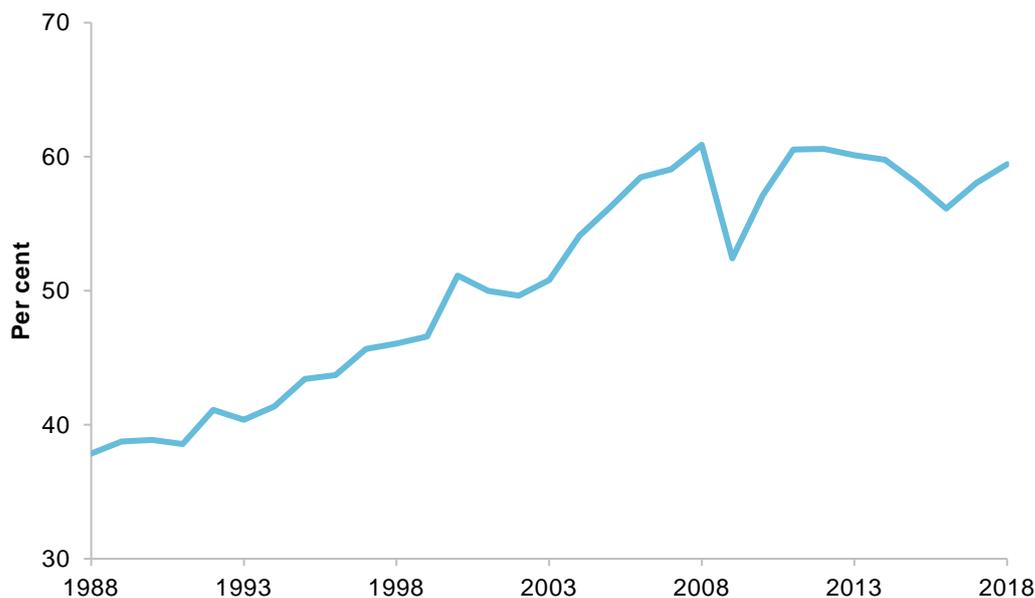
---

There are several forces contributing to the growth in trade, including:

- declines in tariffs, quotas and other trade restrictions, driven by trade agreements (Krugman, Cooper and Srinivasan 1995, pp. 337–341)
- technological innovations in transportation and logistics that have resulted in cheaper, faster and more reliable transport, particularly containerisation and telecommunications (Krugman, Cooper and Srinivasan 1995, pp. 341–343; Phillips 2014)
- improvements in computer systems and telecommunications have also led to large increases in services trade, such as financial services and customer support. Outsourcing these activities to overseas firms has become gradually more feasible (McKinsey & Company 2019, p. 25,34)
- improvements in many technologies, both physical and managerial, that have increased the reliability of supply chains and reduced delays and the amount of inventory that firms hold to keep production processes going.

---

**Figure 2.3** After increasing for decades global trade growth has slowed  
Global trade<sup>a</sup> in goods and services as a share of global GDP

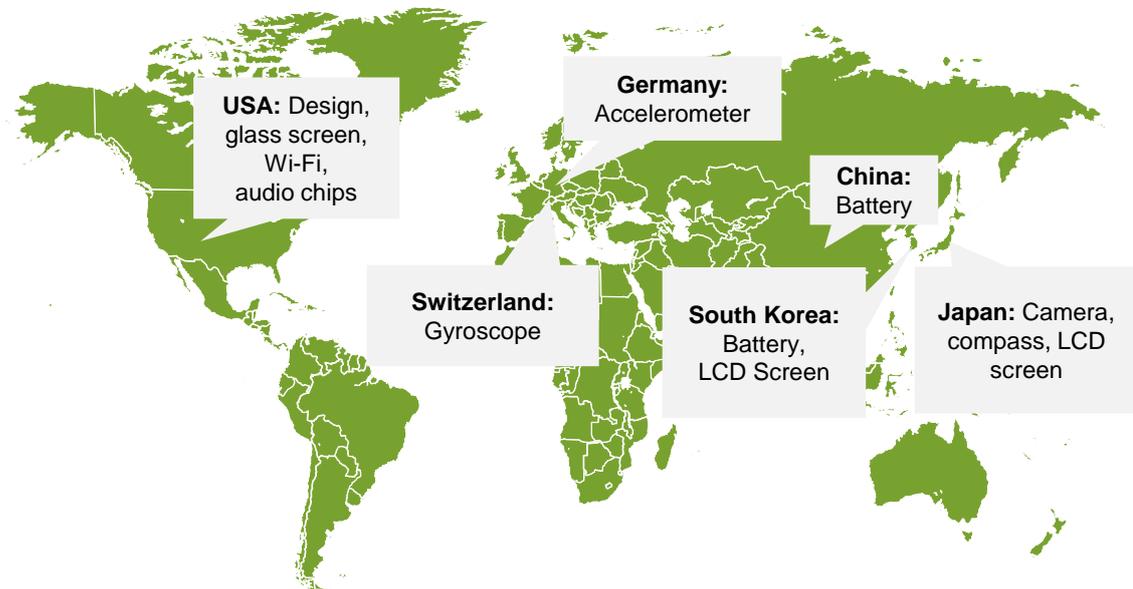


<sup>a</sup> Trade is defined as the sum of exports and imports of goods and services.

Data source: World Integrated Trade Solution (2021).

---

Figure 2.4 The iPhone uses components from across the globe<sup>a</sup>



<sup>a</sup> Supplier locations are where each firm is based. They may have production sites around the globe.

Data source: Costello (2020).

These developments mean that a product can be moved across manufacturing sites several times, and even across borders, without too much time or expense. As a result, a product will be transformed in several different locations (which may be in different economies) before the product reaches consumers.

More broadly, global trade brings large benefits. A 2018 study argued that trade has strong dynamic effects on competition, which increases the purchasing power of consumers, reallocates resources towards more productive firms and encourages innovation (Impullitti and Licandro 2018b, p. 221). Conducting simulations based on data for the US economy, the authors concluded that:

Due to the combination of these competition, selection and innovation responses to trade, the present value of long-run per-capita consumption (our measure of welfare) under trade is 50% higher than in autarky. (Impullitti and Licandro 2018a)

Trade contributes so much to income because each economy has its own efficiencies and inefficiencies, and each economy has abundant and scarce resources. Trade allows economies to specialise in producing the goods and services best suited to their resources and their capabilities. The result is cheaper goods and services for consumers, and higher per capita income from exporting goods and services.

Another benefit of trade is that firms gain from economies of scale — firms that produce large quantities of a few products can do so more cheaply and efficiently. Firms in the same industry tend to locate close together, which allows them to have access to industry-relevant infrastructure and a pool of workers and suppliers; this is known as an industry cluster.

---

Importantly, proximity helps firms share knowledge and drives innovation (Roberts 2018). Much of the gains from trade from the 1960s to the 1980s were from wealthy industrialised economies trading more with each other, achieving economies of scale and developing industry clusters (Leigh 2017, pp. 44–46).

Expanding trade has also come with costs — long supply chains that cross international borders create vulnerabilities (Stecke and Kumar 2009, p. 203). A failure anywhere along a supply chain can jeopardise final output. If most firms rely on one industry cluster for their supply, because it is the lowest-cost or highest-quality source of supply, a disaster in that location could jeopardise everyone’s supply. For example, Wuhan, the epicentre of China’s COVID-19 lockdown, is the world’s largest producer of fibre optics (Clarke 2020). While more costly than maintaining a single source of supply and thus benefitting from economies of scale, trading with a variety of partners is likely to be less costly in the long run. Further, the benefits of trade with multiple partners exceed those of relying on domestic production, the costs of which include the support required to promote it and the vulnerability that comes from a lack of diversification.

Australian exports are largely resource based (in contrast to more elaborately transformed manufactured goods); they rely on primary inputs and incorporate relatively few intermediate inputs (chapter 5). To some extent, this low reliance on intermediate inputs can mean that Australian exports are relatively resilient to upstream shocks that might affect industries that rely on more complex supply chains.

## 2.2 Firm-level supply chain risks and vulnerabilities

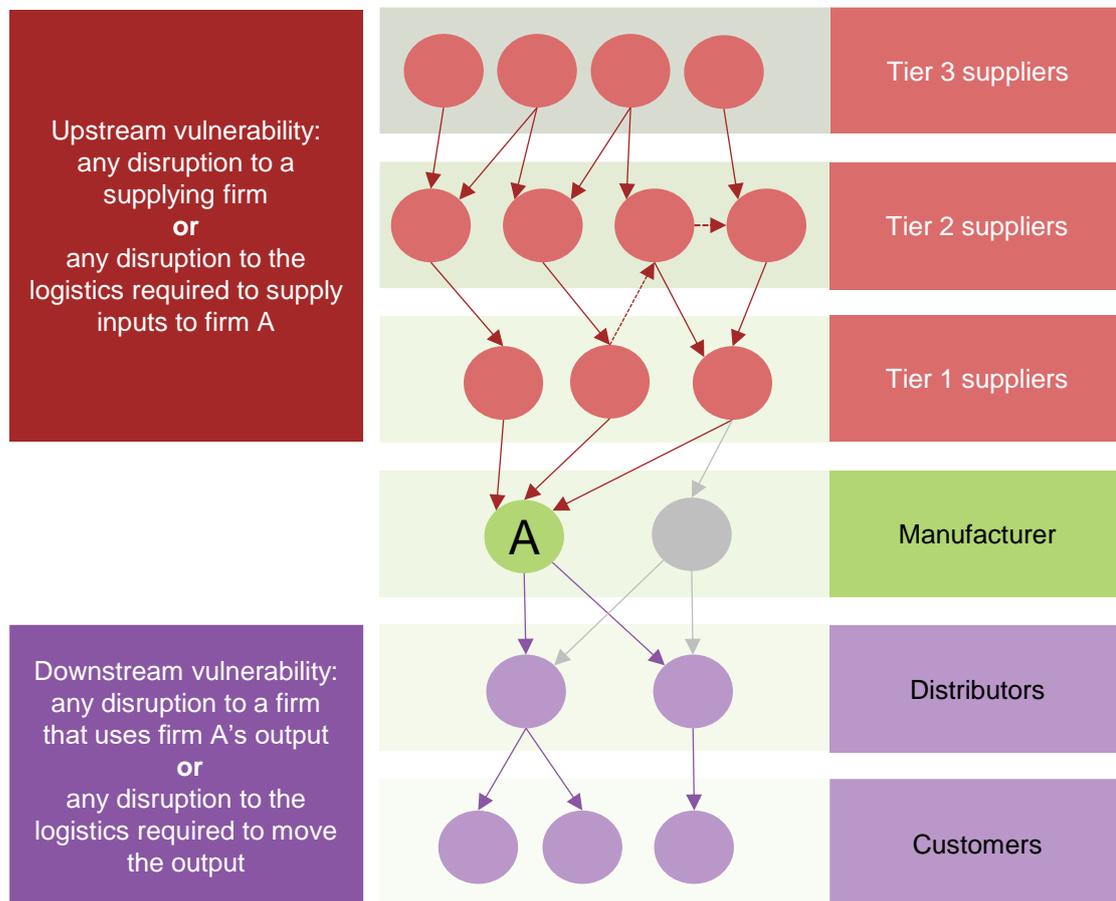
There is no single way to classify supply chain risks, yet some categorisation is useful for understanding which risks threaten the functioning of a specific firm’s supply chain and which risks threaten the entire market.

Risks and vulnerabilities can be classified as affecting upstream or downstream parts of a supply chain (figure 2.5).

- Upstream vulnerability refers to risks to the *supply of inputs* to a firm. Characteristics that make the upstream part of a supply chain susceptible to disruption include the use of a port with no easy alternative, or relying on a single supplier.
- Downstream vulnerability refers to risks to the part of the supply chain that *uses a firm’s output*, that is, the set of markets on which a firm relies for its sales and the logistics to move the good or service to the market. Characteristics that make the downstream part of a supply chain susceptible to disruption can include using a port with no easy alternative, or relying on a limited number of buyers.

Figure 2.5 **Illustrating the concepts of upstream and downstream vulnerability**

From the perspective of firm A<sup>a,b</sup>



<sup>a</sup> The red circles and lines represent firms and supply routes that should be considered in an upstream vulnerability analysis. The purple circles and lines represent firms and supply routes that should be considered in a downstream vulnerability analysis. <sup>b</sup> The grey circle and lines are not part of firm A's supply chain so are not considered in the analysis of firm A's downstream or upstream vulnerabilities. They are, however, part of the market-level supply chain so would be considered in an analysis of market-level upstream and downstream vulnerabilities.

Another classification groups supply chain risks as internal or external to a firm.

- Processes internal to a firm face risks of disruptions and poor performance. For example, a breakdown in an important machine might disrupt the manufacturing process, or a fault in the accounting software used might disrupt financial processes. Negotiations with a labour union could break down, or the firm could face delays when seeking to replace workers with unusual skill sets (for example, specialist repairers or scientists).
- External risks are any outside events that impinge on the functioning of the firm's supply chain (Ho et al. 2015, pp. 5034–5035).

---

This study focuses on external risks because these are more likely to affect the market for a good or service.

## External supply chain risks

The sources of risk external to a firm that are identified in the literature can be grouped into five categories:

- geopolitical
- environmental
- economic
- societal
- infrastructure-related (Ho et al. 2015, p. 5039; WEF 2020, pp. 86–87).

Geopolitical risks include trade wars, armed and other types of conflict, acts of terrorism and failures of political governance (WEF 2020, p. 87). At present, there are a number of geopolitical risks facing the global economy and Australia, including: a trade war between China and the United States; Brexit; and an escalation of trade tensions between Australia and China (McKinsey & Company 2020a).

Environmental risks include natural disasters and weather events. Examples of significant natural disasters that have caused disruptions to supply chains, include:

- a volcanic eruption in Iceland in 2010 that grounded planes across large parts of Europe for nearly a month causing upheaval in supply chains across Europe and beyond (Choi 2012)
- an earthquake and tsunami in Japan in 2011 — among many other disastrous effects, this event disrupted a number of companies' supply chains including Toyota who experienced a 99 per cent drop in quarterly profits, and Apple who experienced a shortage of lithium-ion batteries produced in a factory damaged by the disasters (BBC News 2011; Sanchanta 2011).

Economic risks that are most relevant to supply chains include energy price shocks and border closures. One of the biggest economic events to disrupt global supply chains was the 1973 oil crisis, which affected many aspects of life as economies adapted to new conditions. Currently, Australia's border closure in response to the COVID-19 pandemic has disrupted the arrival of international tourists and students from all our markets. Economic risks can also include demand shocks (box 2.2).

---

## Box 2.2      **The role of demand shocks**

This study is about supply chains and risks that can affect them. Many of these risks are on the input side (upstream shocks), but demand or downstream shocks can also disrupt supply chains. Demand-side shocks range from a surge in demand facing a firm or an industry, to a surge in global demand.

A surge in global demand for a good has the same effect as a shortage induced by a disruption to the supply chain of a good: the good is scarce and its price increases, which further affects the downstream supply chain. It is important to note that a surge in global demand will affect all firms within a supply chain regardless of the characteristics of the supply chain and the market (Minerals Council Australia, sub. 14, p. 2).

It is also important to note that other risks can lead to demand shocks for certain goods and services. For example, the pandemic, a societal risk, led to a demand shock for personal protective equipment.

Societal risks include social unrest, labour disputes and epidemics. Epidemics and pandemics can lead to disruptions due to the workforce becoming sick, lockdowns and other major restrictions on operations or transport (box 2.3).

Infrastructure-related risks include disruptions to critical infrastructure such as IT systems, transport systems and electricity. The 2016 South Australian blackout, which was caused by a storm damaging electricity infrastructure, is an example of an infrastructure disruption. These disruptions can interact with other disruptions and compound on one another. For example, the COVID-19 pandemic affected both the demand and the supply of maritime shipping: the freight task increased and port capacity decreased as worker densities were reduced. Airfreight capacity was also reduced as passenger traffic fell, reducing space available for cargo.

Cyber security is also an infrastructure-related risk. One survey reported that concerns over data security were growing — 30 per cent of respondents in 2016 reported to be very concerned by this threat, and grew to 44 per cent in 2017 (SCM World 2016, p. 22, 2017, p. 46). Another survey showed that many businesses were ill-prepared to respond to a cyberattack (McKinsey & Company 2017, p. 5).

Cyberattacks increased during the COVID-19 pandemic. For example, manufacturers reported a near three-fold increase in cyberattacks since the beginning of the COVID-19 pandemic (Mizen 2020). BlueScope, MyBudget and Toll Group also experienced incidents in 2020 (Borys 2020).

Most of the risks listed here can affect upstream and downstream supply chains. For example, export bans (a geopolitical risk) can affect the supply of inputs and protectionist trade policies can affect demand for Australia's exports.

---

### Box 2.3      **Disruptions to critical workers during the COVID-19 pandemic**

Participants to this study highlighted the vulnerability of the labour force during the pandemic.

The Minerals Council of Australia noted that:

... in the mining industry, critical maintenance work may rely on a handful of individuals with highly specialised skill-sets. (sub. 14, p. 2)

Total Laser Cutting Services noted similar concerns about maintenance workers:

... the specialized technicians from TCI in Spain, who supplied the machine, were due to come back to finalize the installation. They were also due to upgrade the cutting head on the first machine, update software along with setting up new cutting parameters. But due to the border closures in March 2020 they were unable to travel to Australia to complete this work. This is all specialized work which has to be carried out by the two factory trained technicians from TCI as there is no one in Australia trained to do this. (sub. 30, p. 1)

National Farmers Federation said:

Dairy ... relies on artificial insemination experts from countries like New Zealand, and disruptions to this expertise could create long-term issues in the supply of milk. (sub. 22, p. 9)

Ports Australia spoke about the importance of pilotage:

[pilotage] is a highly skilled profession which requires specific knowledge of a stationed locality and hence, only a very limited number of individuals can undertake this function. Effectively, without pilotage, a port would be made inoperable. Moreover, pilots are rarely readily transferable across ports. During COVID-19 ports were acutely aware of this, as pilots are also the first individuals to interact with crew and board a vessel. Accordingly, ports around Australia promptly implemented significant additional safety procedures to protect their pilots. As pilotage is essential for the safe carriage of vessels, approaches to support pilotage and mechanisms to allow for the continued functioning of trade in the event pilotage is compromised, is required. (sub. 20, pp. 2–3)

The consequences of being unable to access key skills depends on the duration of the disruption. For example, access to maintenance workers might not jeopardise production in the short term, but may jeopardise production if they cannot be accessed for longer durations.

Importantly, although risks in supply chains that rely on imports and global trade might be more apparent to casual observers, some of the examples above illustrate that both international and domestic supply chains are at risk of disruptions. For example, the effects of bushfires and blackouts are reminders that supply chains are vulnerable to domestic infrastructure risk.

### Out-of-scope risks

In recent years there has been an increased focus on risks associated with possible policy responses to climate change, which pose risks for exports of coal in particular. These are long-term risks and are not within the scope of this study.

Another type of risk that is not covered in this study results from so-called ‘black swan events’. For example, experts consider that a geospatial event is increasingly likely to cause a global disruption, especially given the increasing importance of electronics and

---

telecommunications in the global economy (The Economist 2020). Such events could threaten telecommunication networks and the global positioning system, both of which are critical to data transmission and freight, which in turn are critical to the smooth operation of supply chains — as well as to many other functions in modern societies.

## 2.3 From firm-level risk to market-level risk

All supply chains are vulnerable to some form of risk. But there is an important distinction to draw between firm-level risk and market-level risk. An example of firm-level risk is where an event could affect the supply chain of *one* automobile producer (such as Toyota in 2011), but if other automobile producers are unaffected, and can expand their supply, consumers will still be able to purchase automobiles. Market-level risks are risks that can disrupt an entire market for a good or service. Continuing the example, other shocks could affect parts of a supply chain that affect *all* automobile producers. Policymakers should be concerned about vulnerability to market-level risk, rather than firm-level risk, and then only market-level risk for essential goods and services (chapter 3).

The next section sets out how firm-level supply chains can be vulnerable to different risks, and the implications this has on market-level risk.

### Factors shaping vulnerability to risks

Industries are vulnerable to different risks based on their characteristics and the structure of their supply chains. For example: labour-intensive industries are exposed to the effects of labour disputes; industries that rely heavily on intellectual property, sensitive information, IT systems and communications are more likely to experience (and be more sensitive to) cyberattacks; and agriculture is particularly susceptible to weather events. Industries that rely on specialised skills are more susceptible to disruption because they can be difficult to replace or substitute (McKinsey & Company 2020b, pp. 27–30). But specialised skills are unlikely to lead to market-level risk: a global shortage of a skill would be a gradual problem, and one dealt with through skills policy and education systems.

Different locations are more or less vulnerable to external risks. For example, a supplier from New Zealand is more likely to experience an earthquake-related disruption than a supplier in France. As will be discussed below, this only creates market-level vulnerability if most firms are clustered in one location.

In addition to the natural environment, local regulations and government preparations for risks can affect the size of a disruption. Governments have differed in their level of preparedness for a pandemic. For example Singapore and Taiwan experienced the swine flu and SARS crises, and were therefore better prepared and able to contend with the COVID-19 pandemic (Lowy Institute 2021; Rogers 2020). Likewise, the level of geopolitical risk is quite different from one economy to another (Marsh 2019).

---

Operational decisions also affect exposure to risk. Just-in-time production (where a firm holds minimal inventory), minimises costs, but does not leave much room for error, such as if a supplier misses a shipment, transport is disrupted, or if the firm experiences a surge in demand. Firms face trade-offs between efficiency and resilience (a resilient supply chain is one that continues to function when exposed to shocks and adapts to changes) (chapter 6). If most firms in a market operate just-in-time processes this raises market-level vulnerability.<sup>1</sup>

Finally, the architecture of the supply chain determines vulnerability to risk. Although all supply chains are vulnerable to infrastructure-related risks, because they rely on transport systems, some characteristics of supply chains can increase risks. For example:

1. limited flexibility — a supply chain that depends on a node or a link that is not easily substitutable
2. geographic clustering — if all the firms in one tier are geographically clustered, this increases the exposure to localised environmental, geopolitical and infrastructure-related risks
3. length — a long supply chain involving inputs changing hands between many firms.

The first two have the potential to create market-level vulnerabilities because they are more likely to affect all firms within a market. Long supply chains can also cause market-level vulnerabilities; but flexibility in firm-level supply chains and a spread in the location of firms reduces the market-level risk.

### Limited flexibility

Relying on a single supplier, or on a single production site, or depending on a particular supply route, or on a unique infrastructure (such as a port or IT system), or on a high-skilled workforce contributes to limited flexibility in a supply chain. Relying on a single supplier reduces costs and complexity. But in the event of a disruption, it can be difficult or impossible to replace that component of the supply chain in a short period of time.

If there are a small number of firms in the market and one supplier is disrupted, then others may not be able to replace the disrupted firm's output rapidly, because of capacity constraints. Market concentration (and capacity constraints) in suppliers increases firm-level risk, and creates some market-level risk; there is a risk that a subset of market supply cannot be quickly replaced. In the extreme, there is substantial market-level risk if all firms have the same source of supply. If there is a monopoly supplier for a critical input (one which cannot be easily substituted) there are no alternative options if the monopolist is disrupted. Market concentration is a major source of market-level vulnerability. Competitive markets, on the other hand, improve flexibility and reduce market-level risk. Increasing the number

---

<sup>1</sup> The Minerals Council of Australia highlighted an exception to this in their submission: 'some supply chains which operate on a 'just-in-time' basis may be designed in this way not for cost minimisation, but for safety reasons. ... The design of the supply chain for explosives is to ensure volatile precursors are not stored for long periods of time creating safety risks.' (sub. 14, p. 4).

---

of firms within a market or lowering barriers to trade means there are more suppliers to pivot to if a supply chain is disrupted.

Some supply chains can be thought of as being ‘diamond’ shaped, where multiple firms rely on a single supplier in part of their supply chain. Some pharmaceutical supply chains are diamond shaped, relying on a single producer for their active ingredients; and many of these producers are in China or India (Horner 2020). A firm may not be aware of how concentrated the market actually is, and may assume it has diversified its risk if it chooses several intermediate suppliers. Likewise, it can be challenging for policymakers to identify this market-level vulnerability, due to the lack of information about key tiers in the supply chain.

Lack of flexibility is also an issue in transport. Bottlenecks in transport links increase the vulnerability of a supply chain as there may be limited alternative routes in the event of a disruption. Bottlenecks can include reliance on a port or a specific maritime, land or air route. For example, the Suez Canal is a critical trade route with about 12 per cent of global trade passing through the canal each day (Russon 2021); there is some flexibility as there are alternative routes around the canal, but these alternative routes are slower and more costly. During the COVID-19 pandemic, ports around the world experienced significant delays as they struggled with shortages of workers due to illness (Lynch 2021a), and introduced infection-control protocols to ensure goods continued to move (UN ESCAP 2020, p. 5).

Domestic infrastructure is where the highest degree of vulnerability is likely to be found (box 2.4). For example, in terms of vulnerability to market-level risk, ports can be a bottleneck that can affect many firms. Pfizer noted:

... Australia’s island geography can serve as an advantage by using our borders to quarantine arrivals and protect the local population, but it also presents a significant challenge with intense pressure on supply chains into and out of the country in times of crisis. (sub. 42, p. 2)

### Geographic clustering

If all the firms that supply a critical input are clustered in the same location, any risks to that location become much more serious.

In 1999, an earthquake disrupted Taiwan’s producers of semiconductors; these firms supplied 17 per cent of the world’s semiconductor chips which are used as inputs to electronic equipment. The resulting price increase affected some (but not all) personal computer producers, and their prices increased (Tomy 2020, p. 9). Had the earthquake been closer to the centre of semiconductor manufacturing and happened in 2017 when Taiwan accounted for two thirds of the global semiconductor market, the computer industry would have been disrupted more seriously (Statista 2020) (appendix B).

Geographic clustering is a clear source of market-level vulnerability, because every firm in the industry is affected and an event can affect supplies to a large number of downstream firms. Chapter 4 illustrates how indices of geographic concentration can be used as an indicator of vulnerability.

---

## Box 2.4 Risks to shipping and transport

Australia as a remote island nation is particularly reliant on international shipping and airfreight to connect it to international supply chains. Domestic freight also plays an important role in connecting regional and remote areas to ports and airports. The COVID-19 pandemic led to less air freight which increased the demand for global shipping.

Several stakeholders identified delays and increased shipping costs as risks to supply chains in Australia. For example, some noted their product import time has doubled (Imperial Brands Australia, sub. 21, p. 2), and others said their freight costs have increased, some by 300 per cent (Export Council of Australia, sub. 31, p. 2; FBIA, sub. 32, p. 3; MIAL, sub. 28, p. 8).

Capacity constraints in containers and shipping vessels coupled with a surge in demand for imports have caused delays and price increases (FTA and APSA, sub. 18, p. 7; IFCBAA, sub. 41, p. 3; Port of Melbourne, sub. 35, p. 2). Other disruptions have compounded these challenges, such as the blocking of the Suez Canal (MIAL, sub. 28, p. 8; Tyre Safe Australia, sub. 45, p. 5), industrial action at Port Botany (FTA and APSA, sub. 18, p. 17) and COVID-19-related restrictions on the movement of people which impacted crew changes and the movement of skilled personnel across ports (MIAL, sub. 28, p. 11; Shipping Australia, sub. 56, pp 48-49).

Despite these challenges, the Australian shipping sector proved to be resilient. For example, Port of Melbourne Operations noted:

The COVID-19 pandemic has demonstrated the overall adaptability and agility of our freight and logistics sector to keep the Australian economy going. Despite the significant disruptions experienced over the past 12 months, we have seen the freight and logistics sector respond and adapt to a range of challenges including for example; increased regulatory controls, supply constraints, elevated demand, equipment shortages, changing distribution markets etc. (sub. 35, p. 1)

However, study participants also noted that there was considerable pressure placed on the sector and that there are still vulnerabilities (Port of Melbourne Operations, sub. 35, p. 1). Other potential vulnerabilities include:

- **infrastructure:** capacity constraints of ports, vessels and routes; vulnerabilities that can affect port operations; capacity constraints also prevent inland transport from replacing any capacity shortfalls in the short term
- **operations:** specialised workforce (e.g. maritime pilots), imbalance in container flows leading to shortages in certain ports (including refrigerated and non-refrigerated containers), limited reserves of fuel, lubricants and spare parts
- interactions with **regulation** and high market entry costs, that make it difficult for shipping to adjust rapidly to changing conditions.

The idea that some market-level risk arises from **limited flexibility** suggests that a limited number of specialised ports could limit the trade of specific goods, which could be a source of vulnerability. This should be explored in further work.

---

## The length of a supply chain

When goods and services are transported across numerous regions, they are exposed to a variety of risks (Stecke and Kumar 2009, p. 203). If, for example, a supply chain crosses many national borders, it is more susceptible to geopolitical and regulatory risks (changes in policy and in the application of policies).

---

Increasing the number of tiers makes a supply chain more complex, decreases transparency and increases the vulnerability of a supply chain. While a firm's managers have strong incentives to manage risk along its entire supply chain, they have less information about risk at another site, or in another economy. This information problem is exacerbated when the other site is owned by a different firm. The supplier may have an incentive to hide information about their costs or the risks they face from the firm that buys their products. This may be because the information is proprietary or would hurt their commercial interests, such as appearing riskier to prospective purchasers or revealing who their buyers are.

While this is a significant source of firm-level risk, it will not create market-level vulnerability unless most firms in the market have long supply chains, have limited flexibility or are geographically clustered.



---

## 3 A framework to identify vulnerable supply chains

### Key points

- This chapter outlines a framework to identify supply chains that are vulnerable to disruptions *and* whose absence would jeopardise the functioning of the economy and hence Australians' wellbeing.
  - A distinguishing feature of the framework is that it uses a data-driven approach: it starts by casting a wide net to identify vulnerable product categories in the data. Then it identifies which of these vulnerable products are used to produce essential goods and services, and then relies on expert assessment and other methods to determine which products are critical.
  - The data-driven approach can be used to assess whether goods and services identified by industry experts are vulnerable. This data-with-experts approach will identify more goods and services as vulnerable, essential and critical than using the expert approach alone.
- Supply chains that continue to function when exposed to disruption and adapt to changes are resilient; they are part of a well-functioning economy, which produces the income, goods and services that are the basis for Australians' wellbeing.
- The Commission's application of the framework focuses on the short-term — a period of up to six months after a supply chain disruption. This time frame was selected because in the long run well-functioning markets allow prices and quantities to adjust and supply chains to adapt. It is up to the user of the framework to decide on the time frame used.
- The notions of *vulnerable*, *essential* and *critical* goods and services are at the core of the framework.
- A market-level supply chain that is vulnerable has characteristics which make it susceptible to risk. These characteristics include: a lack of flexibility (where a supply chain depends on something not easily substitutable) and geographic clustering.
  - Data availability will shape the application of the framework as no dataset can capture all dimensions of vulnerability.
- Essential goods and services are those that meet the basic needs of Australians, and are part of the output of numerous industries, including food, water, health, communications, energy, transport, finance and government.
  - There are two views of essential — a narrow view which includes goods and services that meet Australians' primary needs, and a broad view which includes the list of goods and services from the narrow view, and any goods and services that provide income security to Australians.
- Goods and services that are deemed critical are those that cannot be substituted in the production of an essential good or service.

---

This chapter outlines a framework to identify supply chains that are vulnerable to disruptions *and* whose absence would jeopardise the functioning of the economy and hence Australians' wellbeing. The application to Australian imports in chapter 4 and to Australian exports in chapter 5 concentrates on the data-scan part of the framework. But the framework can also be applied to whole supply chains, whether international or within Australia.

The framework is best thought of as a tool to gain insights into upstream supply chain vulnerability — disruption to the supply of inputs — and to identify strategies to manage those risks (discussed in chapter 6). The framework can also be adapted to analyse and manage downstream supply chain vulnerability — disruptions to the demand of a good or service (discussed in chapter 5).

### 3.1 The links between wellbeing and supply chains

As outlined in chapter 2, supply chains are integral to the modern production of most goods and services, in large part due to the benefits of specialisation, and all supply chains are subject to risk, to a greater or lesser extent. However, not all supply chains are essential to Australians' wellbeing. For example, a disruption to the supply of imported American peaches (which are identified as vulnerable in the data scan) is unlikely to have any marked effect on the wellbeing of Australians. From this point onwards, the discussion focuses on market-level supply chains, and the risk of disruption to an entire market.

Figure 3.1 represents how supply chains contribute to the functioning of the economy, which produces material wellbeing for Australians. Starting at the top, a resilient supply chain is one that continues to function when exposed to shocks and adapts to changes. Supply chains are comprised of many components which are all vulnerable to shocks (chapter 2). As highlighted in chapter 2, some supply chains are more vulnerable than others, in that they have characteristics that make them more susceptible to risks.

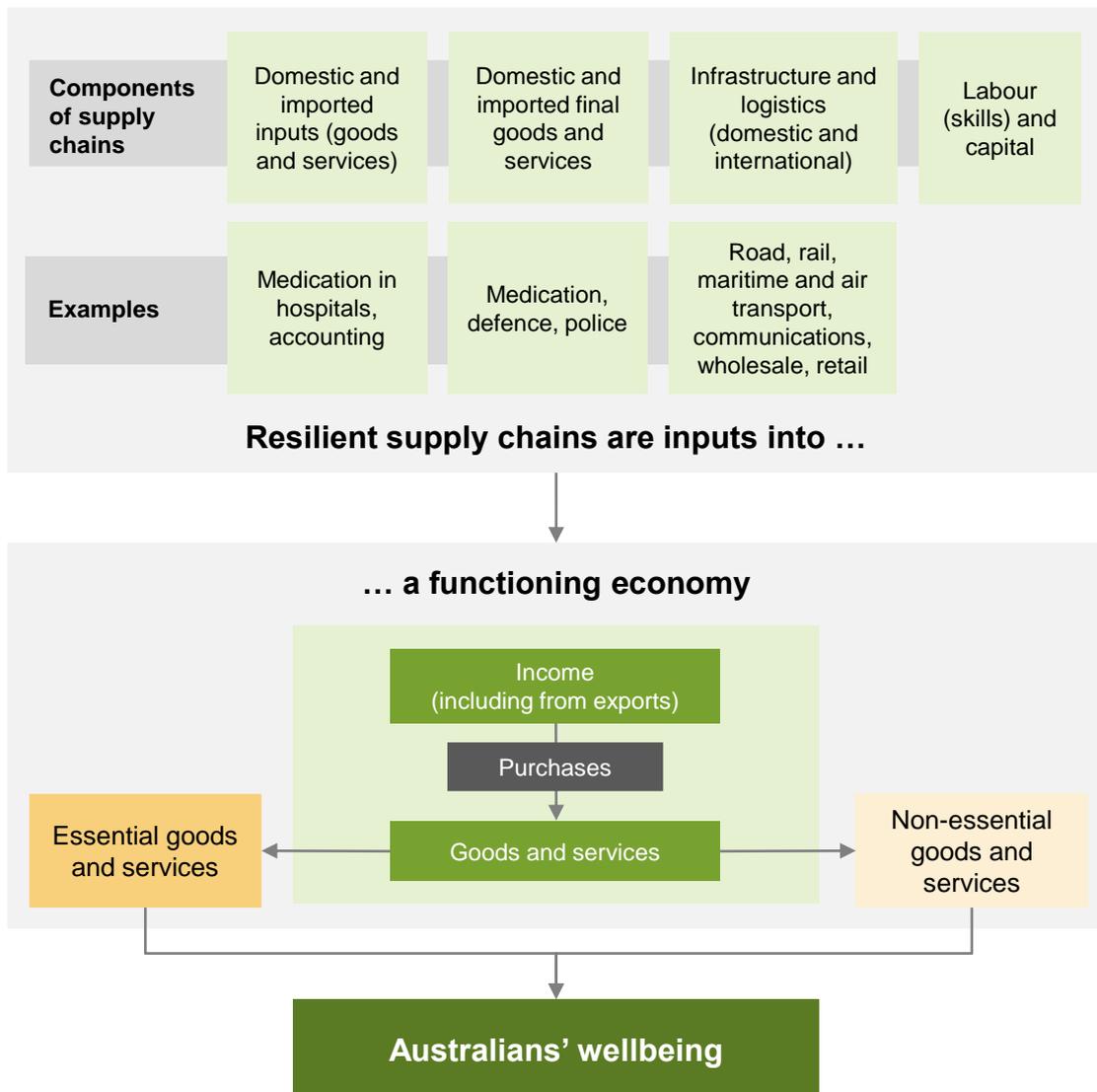
A well-functioning economy produces income that is used to buy goods and services, and resilient supply chains, within the economy and internationally, are important inputs into a well-functioning economy.

Material wellbeing is a function of goods and services consumed, and some of these goods and services are *essential*. In turn, essential goods and services are those that support the basic needs of Australians. These needs are physiological, 'vital to survival', and take priority over other needs ('all needs become secondary until these physiological needs are met' (Mawere et al. 2016, p. 5)). This implies that essential goods and services are those that support the provision of health, water, food and shelter. That said, there are different views about what specific goods and services are essential, as discussed below.

In the context of this study, distinguishing between essential and non-essential goods and services means that basic needs can be prioritised and risk management is focused on the resilience of the supply chains of essential goods and services. When supply chains break,

goods and services may be available at much higher prices, or not at all. Chapters 6 and 7 explore how supply chain resilience can be improved and the role of governments in supply chain risk management.

Figure 3.1 **The relationship between supply chains, the functioning of the economy and wellbeing**



Note: The green box surrounding goods and services and income represents the macroeconomic links between income ( $GDP_I$ ) and expenditure on goods and services ( $GDP_E$ ).

---

## 3.2 The approach to identifying goods and services that are vulnerable, essential and critical

Consistent with this broader wellbeing framework, the Commission’s analytical approach has three steps designed to identify goods and services:

1. whose supply chains might be *vulnerable* to the risk of disruption
2. are *essential* to the wellbeing of Australians
3. are *critical* to the production of an essential good or service.

The analysis of supply chains in chapter 2 highlighted the sources of risk and characteristics of supply chains that render them more vulnerable. Identifying which goods and services are *essential* is the most subjective component of the approach. The notion of *critical* defines an input as critical when there is no available substitute for that input, and if it is not available, it would shut down a supply chain of an essential good or service.

Many analyses of country-level risk begin by reversing steps 1 and 2 above and use a process of expert consultation, instead of a data scan. The consultation approach engages with experts to identify the essential sectors and key inputs that might be at risk (box 3.1).

### Box 3.1 The expert consultation approach — a recent example

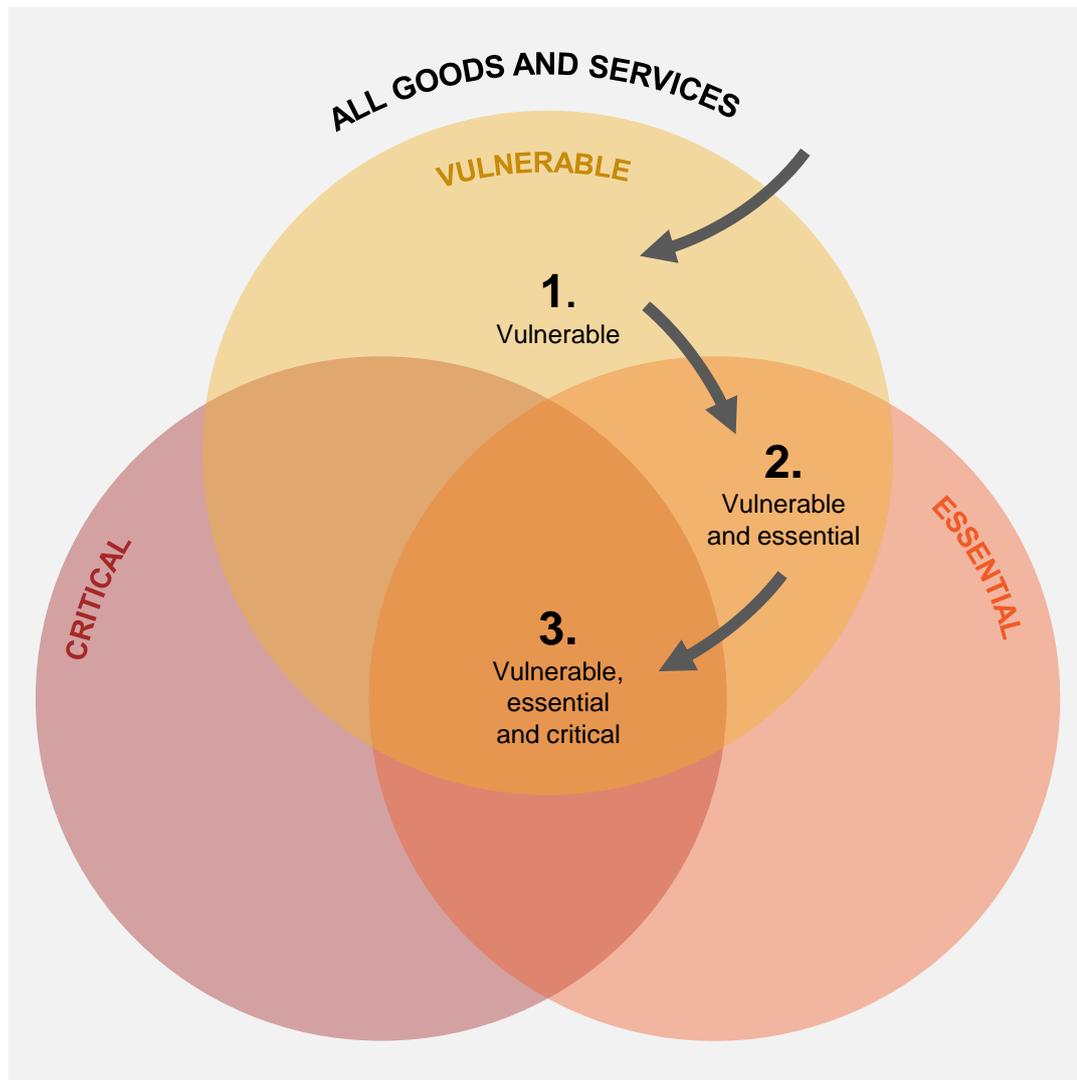
The Department of Defence recently used an expert consultation approach to identify the effects of a collapse of global governance (Engineers Australia 2019). The report is based on a workshop with 17 engineers; it outlines a timeline of effects from the collapse and determines that the majority of effects, including an increase in cyberattacks, failure of water treatment systems, fuel shortages, food shortages, social unrest and wide-spread unemployment, would occur within three months.

The Commission’s approach combines the use of data *and* experts. It uses a series of filters to narrow down a list of goods of interest, starting with a broad scan of supply chains to identify those that might be vulnerable to shocks (figure 3.2). The scan is data-driven, and thus can only identify those vulnerabilities that will show up in the available datasets. The list of vulnerable goods and services is subsequently separated into those that are part of supplying goods and services that are considered to be essential. The resulting list of goods and services can then be used as a starting point to identify whether any of the vulnerable and essential items are *critical* to the supply of essentials — this stage of the approach is based on expert consultation.<sup>2</sup> The approach is thought of as a data-with-experts approach.

---

<sup>2</sup> The third step of the framework has not been implemented in this report due to time constraints.

Figure 3.2 Analytical framework



This data-based and relatively mechanical sorting can occur before exercising judgement as to what is an essential good or service. By first identifying vulnerabilities across supply chains that might affect parts of the economy, including essential and non-essential goods and services, the framework captures a large set of goods and services. The initial broad scan for vulnerability allows for some flexibility in deciding on the breadth of the ‘essential’ step, as discussed below. A broad scan also means that the process is less prone to bias, which could arise from the selection of experts involved.

Although the framework will identify a good or service as vulnerable that in later steps is shown not to be essential or critical, akin to producing a ‘false positive’ (also known as a type 1 error), it is also likely to reduce the probability of missing a good or service that *is* vulnerable, therefore reducing the likelihood of a ‘false negative’ (also known as a type 2 error). The data part of the approach is complementary to an expert-based part, and is likely

---

to reveal some vulnerabilities that might otherwise be overlooked. Similarly, using experts to identify critical goods and services can also identify goods and services that might not be picked up in data that is too high level. The data-with-experts approach is more thorough than just using either experts or data alone as it is likely to capture vulnerable, essential and critical goods and services that might be missed using only one approach.

The analytical approach used in this study is similar to processes that businesses use to identify critical goods and services (box 3.2). However, one of the main differences is that this study concentrates on supply chains, which if disrupted might jeopardise the supply of goods or services that are essential to Australians' wellbeing, regardless of their size or value. In contrast, private sector supply chain risk management tends to concentrate on suppliers who provide goods and services over a defined value (box 3.2). Sensitivity testing to see how the number of vulnerable imports changes with different value thresholds are reported in appendix C (table C.2).

### **Box 3.2 Unilever's framework to identify critical suppliers**

One method used by Unilever to manage supply chain risk is to identify critical suppliers. This process involves Unilever:

- starting with all suppliers
- identifying suppliers with spend over a defined threshold
- examining whether there is a 'unique dependency' on the supplier, that is, a default from the supplier would result in a capacity constraint
- assessing whether there are alternative suppliers
- engaging a third party to analyse and rank the risk of the supplier; if high, this supplier is determined to be a critical supplier.

After a critical supplier has been identified, Unilever develops a business continuity plan for that critical supplier, and puts in additional support measures.

*Source:* Unilever (2020).

The European Commission uses a similar approach to identify critical supply chains that are essential to wellbeing. Its 'bottom-up' approach involves: identifying goods whose supply is concentrated; then focusing on 'sensitive ecosystems' (akin to the idea of 'essential' in this study); and finally undertaking a qualitative assessment of the risks facing specific supply chains (European Commission 2021, pp. 13–14).

## **Defining vulnerable supply chains**

As outlined in chapter 2, a vulnerable market-level supply chain is one that has characteristics that make it susceptible to disruption. Primarily these relate to the degree of flexibility and geographic clustering of the supply chain. Which of these vulnerabilities can

---

be identified from data will depend on what data is available. In chapter 4 and chapter 5 we apply the framework to import and export data.

Import and export data can help identify geographic clustering. Suppliers are geographically clustered if most imports in a category are sourced from the same economy. It may also mean that the imports are from a small number of firms, which is another source of limited flexibility (the number of supplier firms could be verified with more detailed customs data). Similarly, if most exports are bought by a limited number of economies, then the buyers are geographically clustered. But data on Australian imports and exports do not identify where products are sourced from further up the chain, or whether flexibility upstream is limited.

## **Defining essential goods and services**

The second step of the framework is to separate essential goods and services from non-essential ones.

Not all vulnerable supply chains are essential for Australians' wellbeing (figure 3.2). As noted above, essential goods and services can be defined as those that support the basic needs of Australians such as food, shelter, water and health, but there are other ways to define essential.

Some jurisdictions within Australia define essential services in legislation (table 3.1). Typically the lists include electricity, gas, water and logistics services, but there are also notable differences, with New South Wales including health and more services than other states.

Commonwealth departments and the Royal Commission into National Natural Disaster Arrangements have other definitions (table 3.2). Again, electricity, water and logistics services are included and there are other differences:

- the Critical Infrastructure Centre includes the Commonwealth Government (though interestingly, not state and territory governments)
- the COVID-19 critical sector list includes aged care
- the Royal Commission report did not explicitly list essential goods and services; those shown in the table are the main goods and services mentioned. The report has a section devoted to fire retardant being an essential good and the strain on its supply chain during the 2019-20 bushfires (Royal Commission into National Natural Disaster Arrangements 2020a, p. 233) (fire retardant is discussed in appendix B).

Table 3.1 State-level definitions of ‘essential’ vary

<i>Essential Services Act 1988 (NSW)</i>	<i>Essential Services Commission Act 2001 (Vic)</i>	<i>Essential Services Commission Act 2002 (SA)</i>
Supply or distribution of water	Water industry	Water and sewerage services
The production, supply or distribution of any form of energy, power or fuel or of energy, power or fuel resources	Electricity industry	Electricity services
Public transportation of persons or the transportation of freight	Ports industry	Maritime services
Provision of ambulance services	Rail industry	Rail services
Provision of fire-fighting services	Gas industry	Gas services
Conduct of a welfare institution	Non-cash payment transaction industry	
Production, supply or distribution of pharmaceutical products	Commercial passenger vehicle industry	
Provision of garbage, sanitary cleaning or sewerage services	Grain handling industry	
Conduct of a prison		
Provision of public health services		

The scope of essential goods and services is affected by the time frame being considered and by their role in supporting the basic needs of Australians. This study focuses on short-term disruptions to supply chains (up to six months) and their implications for the broader economy. A supply chain disruption creates a large initial increase in price, reducing demand and providing incentives to increase supply. The reduction in available quantity reduces Australians’ wellbeing. During the subsequent adjustments, supply increases, reducing prices, and Australians’ wellbeing eventually returns closer to the initial situation/equilibrium. In many markets for essential goods or services, such adjustments are likely to occur within a period of six months.

The framework can be adapted to any time period deemed relevant. Care is needed, however, to ensure the assumptions are realistic, sensible and defensible. Otherwise, the results will be questionable and compromise the credibility of the analysis and any policy inferences drawn from them.

Table 3.2 National-level definitions of ‘essential’ vary

Critical Infrastructure Centre	Department of Home Affairs COVID-19 critical sectors <sup>a</sup>	Royal Commission into National Natural Disaster Arrangements
Communications	Telecommunications	Communications
Transport	Supply chain logistics	Transport
Energy	Critical infrastructure	Electricity
Health	Medical technology	Water
Water services	Engineering and mining	Fire retardant
Banking and finance	Aged care	
Food and grocery	Agriculture	
Commonwealth Government	Primary industry	
	Food production	
	Maritime industry	

<sup>a</sup> This list was used as eligibility criteria for non-citizens to receive a travel exemption during the COVID-19 pandemic. Specifically: non-citizens with critical skills required to maintain the supply of essential goods and services (as listed here) may have been granted a travel exemption.

Sources: Critical Infrastructure Centre (2021); Department of Home Affairs (2020a); Royal Commission into National Natural Disaster Arrangements (2020a, p. 227).

### Selecting essential goods and services

When selecting a set of essential goods and services, it is useful to consider two views of different breadths:

- a narrow view might focus on goods and services that meet basic needs; for example, food and drinking water and the services required to deliver them
- a broader view might focus on which goods and services should be prioritised beyond those in the narrow definition. This subset might include goods and services that are essential to the functioning of the economy, especially as they affect the incomes of many Australians, nationally or regionally. For example, the mining industry and the construction industry contribute significantly to income and employment so might be included in a broader view.

Exports are also included within the broader view of essential. Exports generate a significant proportion of Australia’s income, which is required to purchase goods and services. For example, exports of iron ore, coal, natural gas and education are important sources of income, accounting for about 50 per cent of Australia’s exports in 2019 (DFAT 2020). But while a disruption to the export sector can be significant for those employed in the sector and more broadly through royalties, taxes, indirect demand for inputs and expenditure,

---

disruptions to the export sector would not affect the supply of goods and services that meet Australians' basic needs in the narrow sense.

In the context of exports, the framework is adapted to look at downstream vulnerability as well as upstream vulnerability. This is done by first assessing the vulnerability of each market for Australian exports using the characteristics discussed above (limited flexibility and geographic clustering of buyers), then filtering for essential goods and services, defined to be those that generate a significant proportion of national income. The third step of the framework does not apply when analysing downstream vulnerability of exports. The importer performs this step as it is their wellbeing that will be affected if the export is disrupted and cannot be substituted. Upstream vulnerability is analysed by looking at vulnerable inputs used in the production of exports.

In chapter 4, this study adopts the narrow view of essential goods and services, defined as those whose supplies are necessary to meet Australians' basic needs. That said, the list of essential goods and services is broader than most of the lists reviewed above, because those lists reflect the focus of the study or institution that made them.

The list in this study needs to cover all goods and services that are essential to the wellbeing of Australians. Some elements of the list are obvious in that Australians could not live without them for even a few weeks (such as inputs that affect the supply of water and medicines), while others are necessary to facilitate the transport and distribution of those types of goods (communications, energy, and transport). And some services support the functioning of the economy by providing essential services to firms and consumers (such as the payment system parts of the banking and finance sectors). Among government services, defence needs to maintain a state of readiness to respond to security and safety emergencies.<sup>3</sup> Further, most health infrastructure, social and related services, and services that support the tax and transfer system, ensure that Australians' basic needs can be met. Supply chains that are part of the production of all these types of services need to be maintained to ensure the continued delivery of these essential goods and services. The list adopted for this study is found in table 4.2 (also see box 3.3).

Chapter 5 extends the analysis of chapter 4 to look at Australian exports and adopts a broad view of essential goods and services. Ultimately, the set of goods and services that are deemed essential to the wellbeing of Australians is a matter of choice and depends on the focus of the analysis. For example, a study concentrating on the risks to Australians' health would have a very narrow focus, whereas a study on the risks to the Australian economy would have a broader focus.

---

<sup>3</sup> While defence is essential to the wellbeing of Australians, it is not in scope for this study because the Commission does not have access to the information required due to national security reasons. That said, the economic and risk management principles in this study are relevant managing supply chains that support defence.

---

### Box 3.3 Food supply chains and the Commission's analysis

Food meets the basic needs of Australians and therefore is included in a narrow view of essential. That said, disruptions to global supply chains are unlikely to affect Australians' access to the food required for survival within the six month time frame chosen for the Commission's analysis. Australia produces more food than it consumes and in the event of a disruption exported agricultural production, which is about two-thirds of agricultural production (PC 2016, p. 48), could be redirected to domestic consumption.

If, on the basis of a risk assessment, it was considered likely that the adjustment period to disruption would take much longer than six months, then food would be included in the analysis.

Several participants argued for food to be included in the Commission's analysis (CropLife Australia, sub. 12, p. 3; GeneEthics, sub. 19, p. 1; NFF, sub. 22, pp. 6–8; VFF, sub. 23, p. 1; GPA, sub. 25, p. 2; GrainGrowers, sub. 33, p. 2; MUA, sub. 38, p. 7; NSW Farmers, sub. 52, p. 3). Submissions also mentioned the importance of fertilisers to the food supply chain and that if they are not available, crops for the next year could be jeopardised (NFF, sub. 22, pp. 8–9; VFF, sub. 23, p. 1; Grain Producers Australia, sub. 25, p. 4; MIAL, sub. 28, p. 12; GrainGrowers, sub. 33, p. 2; MUA, sub. 38, pp. 14–16; NSW Farmers, sub. 52, p. 1). As a result of this feedback, chapter 4 includes an analysis of the effects of including food supply chains.

## Defining critical goods and services

The third step of the framework is to identify goods and services that are *critical*, in that they are required in supplying a good or service, cannot be substituted easily and cannot be designed out of the production process (within the time frame selected by the framework user). This step is needed when assessing upstream vulnerability.

This last screening relies on consulting with experts to identify (from the list of vulnerable inputs into the supply of essential goods and services) which ones might be critical. A good or service is substitutable if it:

- can be sourced from an alternative supplier
- can be replaced by another good or service.

Identifying such inputs requires consultation with experts who are familiar with the relevant production processes, such as engineers and inventory and production managers. Experts can identify which goods and services are critical by answering the following questions.

- Are alternate sources of supply for the good readily available or can supply be increased quickly — from foreign or domestic sources?
- Can the input or good be substituted relatively easily by another (that is, with relatively little need to redesign)?

There are also data-driven approaches to identifying critical inputs. One is to measure the price elasticity of demand for the input within the industry: if the world price of the input has undergone a large change, how did demand from the industry respond? A lack of

---

responsiveness to changes in the price of an input is an indication that it is very difficult to substitute away from this input. That said, this approach would not fully capture the critical criterion: that is, if the good or service were unavailable, the supply of an essential good or service would be shut down. Appendix D shows how elasticities can be used to help identify critical goods.

Once goods and services that are critical to production are identified, the next step in the framework is to identify appropriate risk management strategies; chapter 6 reviews such strategies. There are some conditions under which governments might intervene or facilitate risk management strategies; chapter 7 investigates when this might be required.

Before that, chapter 4 applies the first two steps of the general framework developed here to Australian imports as an illustration of how it works. And chapter 5 extends the chapter 4 analysis to look at Australian exports; by first applying the framework to consider downstream vulnerabilities that affect Australia's export markets, and then analysing upstream vulnerabilities in imports that are used to produce Australian exports.

---

## 4 Applying the framework to Australian imports

### Key points

- The Commission has illustrated how the analytical framework developed in chapter 3 can be applied to detailed data for imported goods. Applying the first step of the framework revealed that:
  - one-in-five imports is predominantly sourced from one trading partner
  - global trade data suggest that for many of these products, alternative sources of supply exist and could be utilised should the need arise
  - one-in-twenty Australian imports (292 products) might be vulnerable to concentrated sources of global supply (worth A\$20 billion)
  - the main supplier of vulnerable imports is China, accounting for about two thirds of these products.
- The second step of the framework examined how reliant the Australian supply of essential goods and services is on vulnerable imports, based on a narrow definition of 'essential'. Applying this step revealed that:
  - essential industries used 130 vulnerable imports in production
  - vulnerable imports play a limited role in meeting final demand either directly (as final goods) or indirectly (as inputs into production).
- Taken together, this suggests the supply of essential goods and services is not highly susceptible to short-term upstream disruptions of imported goods that come from concentrated sources.
  - Including food as essential does not qualitatively change this conclusion.
- The results suggest that the main supply chain disruption risks are to the health, water and energy industries which use imports of chemical products in production, some of which are likely to be vulnerable to a single source of supply. Health also uses vulnerable imports of personal protective equipment, such as face shields, isolation gowns, polyethylene aprons, and surgical cloths.
- These vulnerable imports are a small proportion of the cost of inputs for producing essential goods and services, which suggests that in many cases they may not be 'critical'. But this evidence is not conclusive as criticality can be independent of value. Industry experts are required to determine criticality (the third step of the framework).
- The application can be extended and improved by, for example, using more timely data, analysing more tiers upstream, and using the more detailed data from the Business Longitudinal Analysis Data Environment, BLADE.

---

The analytical framework developed in chapter 3 is intended for scanning data as a first step in identifying supply chains that are vulnerable to disruption *and* where their absence would jeopardise the functioning of the economy and, hence, the wellbeing of Australians.

This chapter applies the first two steps of the analytical framework to Australian imports to identify:

- which Australian imports are *vulnerable* to disruption
- whether these imports play a material role in the delivery of *essential* goods and services in Australia.

The third step of the framework seeks to identify whether these imports are *critical* to the delivery of essential goods and services. The chapter does not formally apply the third step. Instead it examines whether vulnerable imports represent a large share of the production costs of essentials as an indication of whether these inputs are important. Industry experts are best placed to determine criticality using their knowledge of production processes and the extent to which substitute products can be used in the event of any disruption (chapter 3).

The chapter begins by outlining the importance of imported goods to Australian economic activity (section 4.1). It then applies the first step of the analytical framework to ascertain how vulnerable Australian imports are to disruption (section 4.2). It then applies the second step of the analytical framework to examine whether essential goods and services are vulnerable to upstream disruptions in the supply of imports. In doing so, the chapter examines how reliant the Australian *production* of essentials is on vulnerable imports (section 4.3) and how reliant the *use* (that is, final demand by households and government) of essentials is on vulnerable imports (section 4.4). The chapter then identifies how this work could be extended (section 4.5).

Applying the framework involves linking data on Australian imports, global trade, and Australian production to determine which industries use each product (appendix C). The analysis focuses on data from 2016-17 — the latest year for which data are available from all three sources.

No comparable dataset exists on Australian imports of services, and therefore it is not possible to assess the vulnerability of the supply of imported services.<sup>4</sup> However, imports of services are susceptible to disruption in much the same manner as imports of goods. The COVID-19 pandemic, for example, has restricted the movement of people across borders. Supply chain disruptions may occur where these people have specialist skills that Australia or its states and territories may lack. Given the lack of data, supply chain vulnerability to imported services and the movement of skilled labour should be assessed by industry experts and the best available information.

---

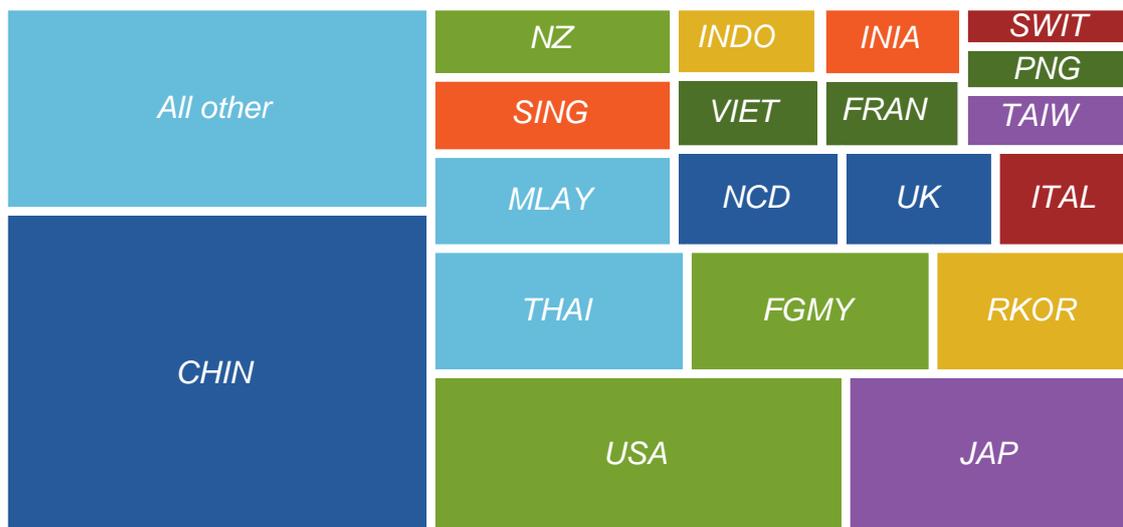
<sup>4</sup> Hereafter, imports refers to merchandise (goods) imports. It does not include imports of services. Services trade is inherently more complex to record than goods trade. The OECD-WTO Balanced Trade in Services dataset collects global trade flows of services, but only records flows in 12 broad categories.

## 4.1 How important are imports to economic activity?

Australia imported 5950 different products in 2016-17.<sup>5</sup> The value of these goods imports was A\$272 billion, or about 16 per cent of gross national income. Australia is a relatively small importer of each product in the global market, accounting for an average of only 1.5 per cent of global imports for each product.

Australian imports came from 223 trading partners.<sup>6</sup> China and the United States were the primary suppliers, collectively accounting for just over one third of the value of all imports (figure 4.1). Other notable partners included Japan, Thailand, and Germany (each accounting for over 5 per cent of the value of all imports). The ten largest suppliers accounted for A\$197 billion of imports (about 70 per cent of all imports). Although imports came from 223 partners, most came from a relatively small number sources. This suggests some susceptibility to disruption.

Figure 4.1 **Australian imports come from many sources**  
Share of Australian imports from each source, by value, 2016-17<sup>a,b</sup>



<sup>a</sup> CHIN: China; USA: United States; JAP: Japan; THAI: Thailand; FGMY: Germany; RKOR: Republic of Korea; MLAY: Malaysia; NCD: no country details supplied; UK: United Kingdom; ITAL: Italy; SING: Singapore; VIET: Vietnam; FRAN: France; NZ: New Zealand; INDO: Indonesia; INIA: India; TAIW: Taiwan; PNG: Papua New Guinea; SWIT: Switzerland. <sup>b</sup> The ABS confidentialises certain records, which prevents the product or origin from being identified.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

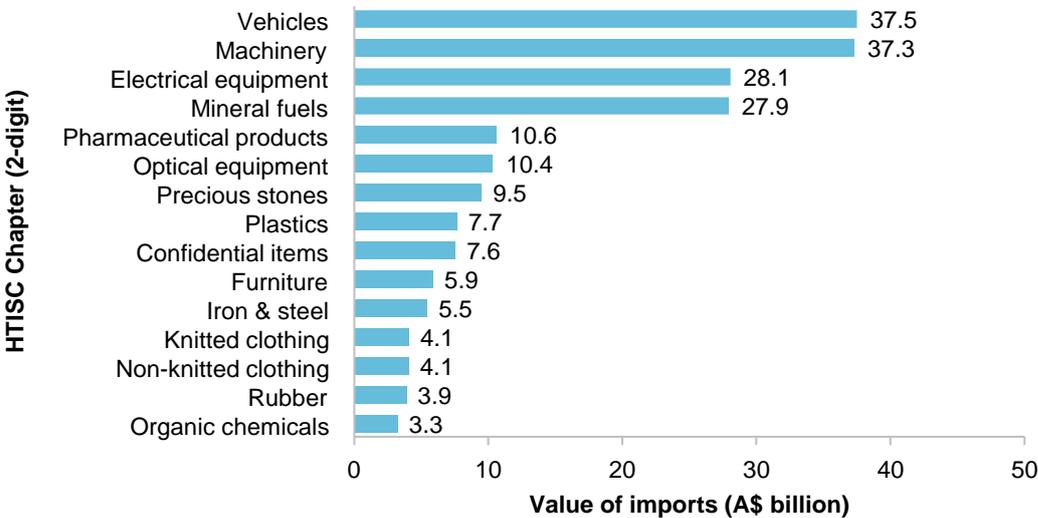
<sup>5</sup> 'Product' refers to each HS Subheading (8-digit) under the Harmonized Tariff Item Statistical Code (HTISC) classification unless otherwise stated (see appendix C for product classification details).

<sup>6</sup> The definition of trading partner used reflects that used in the Australian imports data to record the origin of the goods entering Australia.

The main imports by value were: motor vehicles and parts; electrical, optical and other specialised equipment; fuel; pharmaceuticals; and chemicals (figure 4.2).

Not all imports are of similar importance to Australian industry, the Australian economy, and the national interest. The consequences of any disruption to imports of most clothing items, for example, would be less than the consequences of a disruption to the imports of fuels and pharmaceuticals.

**Figure 4.2 Imports are dominated by vehicles, machinery, and fuels**  
 Top imports by value, 2016-17<sup>a</sup>



<sup>a</sup> The ABS confidentialises imports of certain products, which prevents the products or supplier from being identified.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

## 4.2 How vulnerable are Australian imports to disruption?

Supply chain vulnerability may arise from the reliance of Australian producers (and consumers) on goods sourced from overseas, as their supply chains will be more susceptible to certain sources of disruption than those sourced locally. Imported goods are, for example, more susceptible to geopolitical events (such as trade disputes), and disruptions to transport corridors that they pass through (such as the Strait of Hormuz, the Suez Canal or one of Australia’s main ports). If most of the supply is from one location, vulnerability is greater: a natural disaster or other shock in that location can disrupt supply. The degree of vulnerability would generally increase when the number of *actual* and *potential* suppliers decrease, and when suppliers have market power. In the language of chapter 2, vulnerability is greater if there is geographic clustering, or limited flexibility.

---

Consumer welfare would suffer if essential Australian production ceased due to a sustained disruption to the supply of a critical imported input (for example if imported anaesthetics were not available, surgeries would cease) or if imports of final consumption goods were disrupted (such as imported medicines).

This section assesses supply chain vulnerability arising from sourcing imports from concentrated global markets. That is, it focuses on imports with high levels of market concentration. By implication, well-developed and diversified trading networks (networks of supply from multiple sources) are one way of reducing vulnerability.

### **Applying the framework to determine potential import vulnerability**

As described in chapter 3, the process for identifying vulnerable imports is mechanical and data driven. The mechanical sorting involves progressively applying filters to assess whether:

- a single source accounts for a large share of Australian imports. This considers vulnerability arising from existing suppliers and trade flows, which provides an indication of *actual* supply risk
- there are limited alternative suppliers that Australia could access in the event of any disruption to existing suppliers. This considers vulnerability in terms of *possible* sources of supply, which provides an indication of *potential* supply risk.

The imported products that remain after applying these filters may be more susceptible to disruption, as Australia is reliant on limited sources of supply. There may be imported products that are susceptible to other types of vulnerabilities (such as complex supply chains) or to specific types of disruptions, but these products are not identified by these filters.

Australian imports data and global trade data for 2017 are used in the application of these filters (box 4.1 and appendix C).

#### **Box 4.1 Trade data and classifications**

The trade data used in this chapter are classified according to the international Harmonized System (HS), or its Australian extension known as the Harmonized Tariff Item Statistical Code (HTISC).

All trade data classify products at different levels of detail, ranging from highly aggregated to highly disaggregated categories (with more digits indicating progressively more disaggregated data). The analysis in this chapter assesses:

- Australian imports at the 8-digit level (known as the HS Subheading level). This level of detail is fine-grained enough to enable vulnerable products to be identified, and typically groups substitute products under one product code
- the global trade data at the 6-digit HS level (which is the same as the 6-digit HTISC). This is the most disaggregated product classification available in global trade data.

---

## Filtering process and results

Three filters are applied to the trade data to identify vulnerable imports, with supply chain risks progressively increasing with the application of each filter.

### *Filter one: concentrated Australian imports*

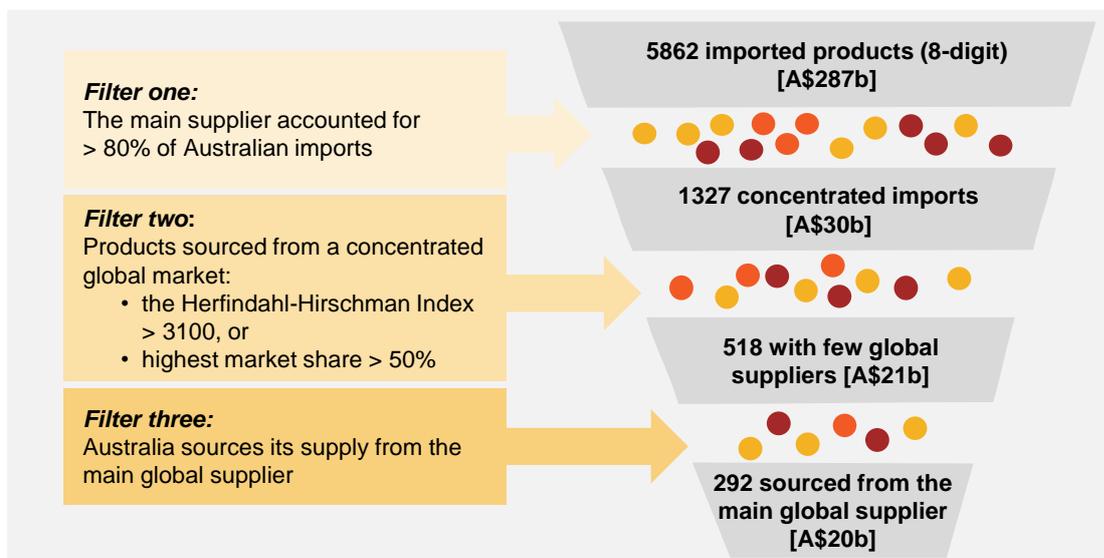
The first filter determines whether the market for each product that Australia imports is highly concentrated, as concentrated sources of supply entail additional risk. Imports are considered concentrated when the main supplier accounted for over 80 per cent of Australian imports of a product. The threshold selection is a judgement call and depends on a number of factors such as the degree of product aggregation. Care is needed to ensure the threshold used is sensible and defensible. Otherwise, the results will be questionable and compromise the credibility of the analysis and any policy inferences drawn from them.

The first filter indicates that 1327 products (worth A\$30 billion) of the 5862 products (A\$287 billion) that Australia imported in 2017 came from concentrated local import markets (figure 4.3). That is, the market was concentrated for one-in-five imports.

The number of concentrated imports identified is sensitive to a number of decisions made during the analysis including the threshold used to identify concentrated imports (80 per cent), the degree of product aggregation, possible minimum value thresholds, the exclusion of product groups (2-digit Chapters) that are less likely to be critical to national activities, and the selected year (2017). (Sensitivity analysis to gauge the robustness of the analysis is reported in appendix C.)

---

**Figure 4.3 The filtering process to identify vulnerable imports**



Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); UN Comtrade (2020).

---

---

Most concentrated imports relate to chemicals (both organic and inorganic), iron and steel, and different types of equipment. Imports of some other products, such as seafood and some types of clothing apparel like women’s jackets, men’s shirts, or swimwear, were also highly concentrated. Agricultural products also accounted for many of the concentrated imports.<sup>7</sup> These imports often complement Australian production by maintaining year-round supply out of the Australian growing season (such as imports of peaches from the United States).

Concentrated products are found across many product groups, including:

- chemicals (such as pseudoephedrine, sodium hydroxide, toluidine, hydrogen peroxide, anti-knock preparations, and 2-ethoxyethyl acetate)
- fuels (such as natural methane gas)
- pharmaceutical products (such as sterile surgical and dental adhesion barriers)
- minerals (such as unrefined copper)
- metals (such as iron and steel, and nickel oxide)
- fertilisers (such as superphosphate)
- plastics (such as polyethylene)
- transport equipment and parts
- military equipment.<sup>8</sup>

Other products might be vulnerable but may be missed in the analysis due to limitations inherent to trade classifications (box 4.2).

#### **Box 4.2      Limitations of trade classifications**

There are limitations in the trade data that may point to areas of vulnerability that cannot be identified in the present analysis.

- Import data are confidentialised for some products, suggesting that a product might be sourced from a limited number of suppliers. Some patented products (such as some medicines) are likely to be confidentialised: there are few producers, or one producer in extreme cases.
- The coarseness of some product classifications may lead to groupings of vulnerable and non-vulnerable products. Active ingredients, for example, may be grouped with other chemicals that are not critical to the production of medicines that might be essential to the wellbeing of some Australians.

These limitations also apply to production data, where product classification is even broader than for imports data. For example, the more aggregated nature of production data makes it difficult to determine the amount of specific products that is produced locally versus imported.

---

<sup>7</sup> The number of concentrated agricultural imports also reflects the highly disaggregated categories used to classify imports that differentiate between effectively similar agricultural products.

<sup>8</sup> Although some military equipment appears in the imports data, it is only a partial view as other items are not recorded. This study does not analyse supply chains that relate to defence activities (chapter 1).

---

*Filter two: concentrated global markets*

The second filter determines whether global trade in a product is also concentrated, as fewer potential sources of supply exist that could be utilised in the event of any disruption to existing supplies. This filter is concerned with the *availability* of alternative sources regardless of the possible extra costs associated with finding new sources of supply (such as higher prices, increased transport costs, etc.). It is assumed that all alternative suppliers are viable options for Australia and that their products are of similar quality. However, this is not always the case, for example, strict biosecurity measures result in fewer alternative suppliers for some products, and political and trading relationships with alternative suppliers may influence Australia's ability to source products in the event of a disruption.

Global markets are considered highly concentrated when the main supplier accounted for over 50 per cent of global exports or when the Herfindahl-Hirschman Index (HHI) is greater than 3100 points (box 4.3).

**Box 4.3      The Herfindahl-Hirschman Index**

The HHI is the most commonly used measure of market concentration. It is popular because it summarises information about both the number of suppliers and their respective market shares. It is calculated as the sum of the square of the market shares of each supplier (limited to the largest 50 economies). The HHI ranges from 0 (not concentrated) to 10 000 (extremely concentrated).

In US antitrust law dealing with firm-based concentration, a HHI between 1500 and 2500 is interpreted as moderate concentration and over 2500 indicates high concentration (U.S DoJ and FTC 2010).

Since the global trade data describe flows between economies rather than between firms, a value above 3100 (which captures 25 per cent of all products in this dataset) is used to indicate that a global market is concentrated (appendix C).

The second filter reduces the number of concentrated imports from 1327 to 518.<sup>9</sup> This represents 9 per cent of the total number of products imported and about A\$21 billion of value. This filter reduces the number of vulnerable imports to one-in-ten. This indicates that alternative sources of supply, which could be used in the event of a disruption, exist for well over half of all concentrated imports. For example, Australia sources chlorine primarily from China, but the global market for chlorine is not concentrated and China is not the leading exporter of chlorine. This suggests that Australia could source chlorine from another economy in the event of a disruption to Chinese supply.

The 809 products removed by the second filter indicate that many agricultural, food, wood, chemical, textile, and mineral products (such as fuel) have alternative sources of supply that

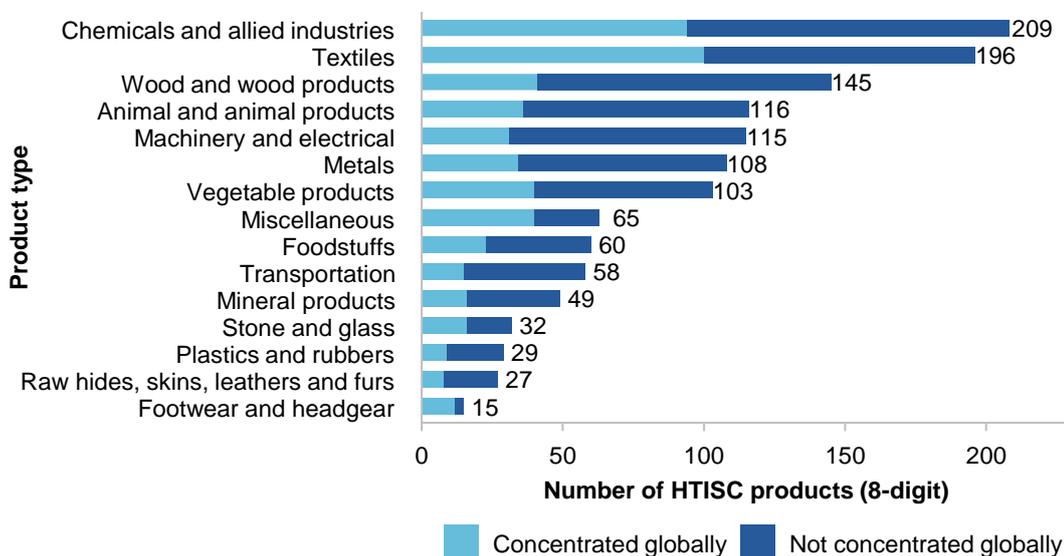
---

<sup>9</sup> Since the global trade data are available at a higher product aggregation than the Australian imports data (6-digit versus 8-digit), each concentrated import is linked to measures of global market concentration which are constructed at more aggregated product levels.

could be utilised if the need arises (figure 4.4). However, the presence of biosecurity and other domestic restrictions may reduce the number of markets potentially accessible to Australia, such that they may be more concentrated than the mechanical data processing indicates. For example, imported bulk grain poses a biosecurity risk due to the possibility of importing pests and diseases (NFF, sub. 22, p. 8). Suppliers must be from a low-risk exporter and be assessed and cleared by the Department of Agriculture, Water and the Environment before trade can occur.

**Figure 4.4 The analysis of global trade data identified alternative suppliers for 809 of the 1327 concentrated imports**

Concentrated imports by product type<sup>a</sup> and whether global supply is concentrated. Products defined at the HS Subheading level (8-digit)



<sup>a</sup> Product type is based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups. 'Miscellaneous' includes products like: clocks and watches; musical instruments; bedding and lighting; toys; arms and ammunition; and works of art, and collectors' pieces.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); UN Comtrade (2020).

*Filter three: Australia sources concentrated imports from the main global supplier*

The third filter determines whether Australia sourced its concentrated imports from the main global supplier in a concentrated market. This filter works on the assumption that if Australia does not source a product from the main global supplier, that global supplier is still available to meet the shortfall if Australia's main source of supply is disrupted. The filter retains products that are vulnerable because they are sourced from the main global suppliers in concentrated markets. Such products are more susceptible to supply disruptions and global

---

demand spikes, as occurred with the supply of face masks and personal protective equipment (PPE) during the COVID-19 pandemic.

The third filter reduces the 518 vulnerable imports to 292. This represents 5 per cent of the total number of products imported by Australia and about A\$20 billion of value. The filter reduces the number of vulnerable imports to one-in-twenty.

**FINDING 4.1: FEW IMPORTS ARE VULNERABLE TO CONCENTRATED SOURCES OF SUPPLY**

One-in-five products imported by Australia are considered highly concentrated. Global trade data suggest that for many of these products alternative sources of supply exist and could be utilised should the need arise; one-in-twenty Australian imports might be vulnerable to concentrated sources of global supply.

### Characteristics of vulnerable imports

Vulnerable imports are classified by their *main* end-use, notwithstanding that some products are likely to have multiple end-uses. Most vulnerable imports are classified as either consumption or intermediate goods, with fewer capital goods (figure 4.5).

Vulnerable consumption goods comprise of mostly textile, miscellaneous, food, and clothing products (figure 4.5a). A closer inspection of textile, and plastic and rubber products, reveals that they include some PPE products (which suffered some supply chain disruptions during the COVID-19 pandemic).<sup>10</sup> While this provides some validation of the filtering approach, the labelling of products in trade data makes it difficult to precisely identify which HTISC product classifications PPE products belong to without detailed knowledge of the HTISC.<sup>11</sup>

Vulnerable intermediate goods are inputs into Australian production and tend to encompass chemical, wood, metal, machinery and electrical, stone and glass, and mineral products. For example, sodium carbonate<sup>12</sup> is identified as a vulnerable import used in the treatment of drinking water. That said, there are several alternatives to sodium carbonate, and there are many non-essential uses from which it could be diverted for some time (appendix D).

---

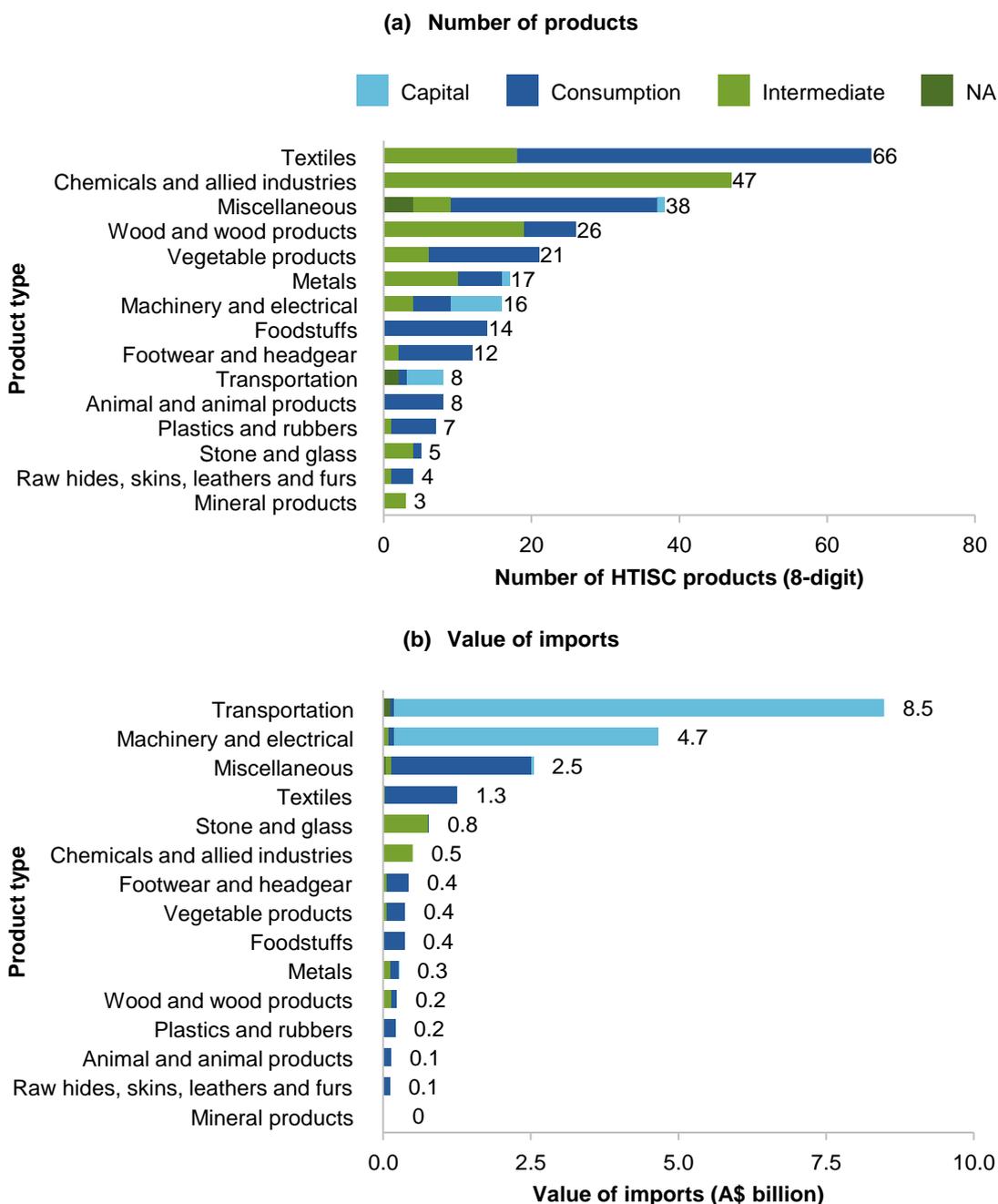
<sup>10</sup> Supplies of face masks were also disrupted during the COVID-19 pandemic but are not identified as vulnerable to limited sources of supply in the Commission's application of the framework. Face masks are captured under four product codes in the trade data (ABS 2020c). About 70 per cent of two products (63079029 and 63079099) came from China which is also the largest supplier in the concentrated global market. A lower threshold for filter 1 would result in face masks being identified as vulnerable.

<sup>11</sup> PPE products that are identified as vulnerable imports are classified under HTISC codes 39262029 and 62101090.

<sup>12</sup> The product commonly known as 'sodium carbonate' is referred to as disodium carbonate by the International Union of Pure and Applied Chemistry and in trade classifications.

Figure 4.5 **Characteristics of vulnerable imports**

Vulnerable imports by product type and main end use.<sup>a,b</sup> Products defined at the HS Subheading level (8-digit)



<sup>a</sup> Product type is based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups. 'Miscellaneous' mainly includes products like: clocks and watches; musical instruments; bedding and lighting; toys; arms and ammunition; works of art, collectors' pieces. <sup>b</sup> NA's have no main end-use classification and are imports of defence products typically from the United States.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); UN Comtrade (2020).

---

Capital goods make up the largest share of vulnerable imports by value. These goods include transportation equipment (for which the value changes year-to-year depending on economic activity and infrastructure projects) and machinery and electrical equipment (primarily laptops and computers) (figure 4.5b). Imports of drilling platforms for natural gas accounted for A\$8.1 billion of the transportation category. This is an example of an irregular import; removing this product would reduce the value of vulnerable imports by almost half to A\$12 billion.

Disruptions to imports of capital goods are unlikely to cause severe losses in the short term because Australia has an existing stock of machinery, such as trucks, along with the ability to repair them or purchase from second-hand markets. That said, disruption to the availability of parts can delay some servicing and repairs, and disrupt the use of machinery.

Although the value of most chemical imports is generally small, they are likely to be important in the production of many goods. For example, some chemical imports (such as active ingredients) are used in domestic production of pharmaceutical products. Therefore, the value of imports may not reflect their importance in production. Nevertheless, ranking the relative importance of products by value provides a starting point for further investigation.

**FINDING 4.2: MOST VULNERABLE IMPORTS ARE CONSUMPTION OR INTERMEDIATE GOODS**

Although capital goods form the largest share of vulnerable imports by value, most vulnerable imports are consumption goods (such as personal protective equipment) or intermediate goods (such as sodium carbonate used in the treatment of water).

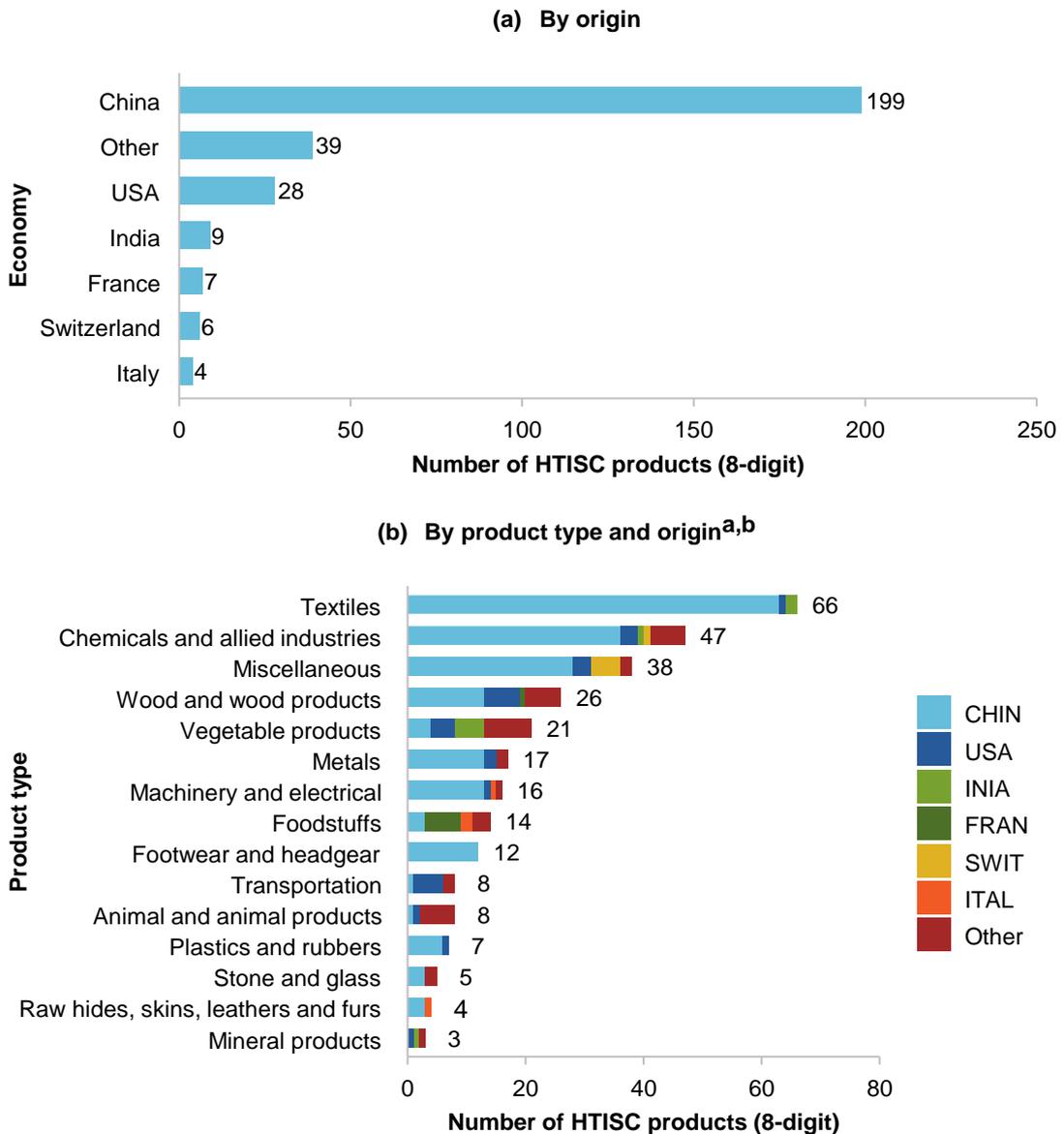
Disruptions to the supply of capital goods are unlikely to affect wellbeing in the short term.

The majority of vulnerable imported products are sourced from China (68 per cent of vulnerable imports) (figure 4.6a). China was the main supplier of most vulnerable textiles (which includes some PPE), chemical, metal, and machinery and equipment products to Australia in 2017, worth a total of A\$9.6 billion (figure 4.6b). The United States and India were the next largest suppliers of vulnerable imports.

**FINDING 4.3: THE MAIN SUPPLIER OF VULNERABLE IMPORTED PRODUCTS IS CHINA**

China is the main supplier of about two thirds of the list of vulnerable imported products. Notwithstanding this, the main source of supply varies by product.

**Figure 4.6 Most vulnerable imports come from China**  
 Number of products, defined at the HS Subheading level (8-digit)



<sup>a</sup> CHIN: China; USA: United States; INIA: India; FRAN: France; SWIT: Switzerland; ITAL: Italy. <sup>b</sup> Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); UN Comtrade (2020).

---

The broad-based data scan identifies many products that, while having high import concentrations, are unlikely to be essential — either directly or as an input into the production of essential goods and services — for the wellbeing of Australians. Examples of such products include festive decorations, sparkling wine, swimwear, and toys.

However, numerous other vulnerable imports are more likely to be inputs into producing essential goods and services (table 4.1). These include laptops, some chemicals, some PPE, and some products used in the drilling for oil and refining of iron and steel. But not all shocks to the supply of these vulnerable imports will lead to short-term supply chain disruptions. For example, a supply shock to imports of laptops may not result in any short-term supply chain disruptions as Australia has an existing stock and the ability to repair and purchase laptops from second-hand markets, but a supply shock to imports of chemicals used in water treatment or the production of pharmaceuticals could have severe short-term impacts on supply chains (if no substitutes are available and no reallocation of existing supplies is possible).

**FINDING 4.4: MANY IMPORTS CLASSIFIED AS VULNERABLE ARE NOT ESSENTIAL OR CRITICAL**

Many imports classified as vulnerable are clearly not essential or critical to the wellbeing of Australians — for example, festive decorations, toys, or swimwear. Other vulnerable imports require further investigation to assess whether they are essential or critical.

**Table 4.1 A sample of vulnerable imports, 2017<sup>a</sup>**

<i>HTISC</i>	<i>HTISC label</i>	<i>Product type<sup>b</sup></i>	<i>Main end use</i>	<i>Australia's main supplier</i>	<i>Value (A\$ m)</i>
84713000	Portable automatic data processing machines, weighing not more than 10 kg consisting of at least a central processing unit, a keyboard & a display	Machinery and electrical	Capital	China	3 993
71129100	Waste & scrap of gold, metal clad with gold & other waste & scrap used principally for the recovery of gold (excl. ash & sweepings containing other precious metals)	Stone and glass	Intermediate	Japan	638
29319010	Glycine derivatives containing phosphono groups (excl. mercury compounds of 2852)	Chemicals and allied industries	Intermediate	China	107
28362000	Disodium carbonate <sup>c</sup>	Chemicals and allied industries	Intermediate	USA	73
39262090	Articles of apparel & clothing accessories (incl. gloves, mittens & mitts) of plastics or of other materials of HS 3901 to 3914 (excl. corset busks; garments; anti-radiation or anti-contamination suits & sim protective garments; & HS 9619)	Plastics and rubbers	Consumption	China	57
73042400	Casing & tubing, of stainless steel, of a kind used in drilling for oil or gas (excl. drill pipe)	Metals	Intermediate	Japan	47
73261100	Forged or stamped, but not further worked grinding balls & similar articles for mills of iron or steel	Metals	Intermediate	China	41
29336900	Heterocyclic compounds with nitrogen hetero-atom(s) only, containing an unfused triazine ring, whether or not hydrogenated, in the structure (excl. melamine, cyanuric acid & its derivatives & atrazine)	Chemicals and allied industries	Intermediate	China	31
39262029 <sup>d</sup>	Garments, of plastics or of other materials of HS 3901 to HS 3914 (excl. corset busks; & anti radiation suits, anti contamination suits & similar protective garments; & goods of HS 9619)	Plastics and rubbers	Consumption	China	12
62101090 <sup>d</sup>	Garments made of fabrics of 5602 or 5603.00.00 (excl. knitted or crocheted or of non-wovens, being fabric not impregnated or coated)	Textiles	Consumption	China	5

<sup>a</sup> The main supplier accounted for over 80 per cent of Australian imports of each product in 2017. <sup>b</sup> Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups. <sup>c</sup> Term used by the International Union of Pure and Applied Chemistry and in trade classifications to refer to product commonly known as 'sodium carbonate'. <sup>d</sup> HTISC codes that include PPE.

Sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); UN *Comtrade* (2020).

---

### 4.3 How reliant is the production of essential goods and services on vulnerable imports?

This section focuses on the application of step two of the framework which is to assess whether any of the vulnerable imports identified in section 4.2 are inputs into the Australian production of essential goods and services. These supply chains are potentially susceptible to upstream disruptions where vulnerable imports play a significant role in their delivery or are a critical input to their production.

#### Applying the framework to the production of essential goods and services

Which goods and services are considered essential?

Operationalising the framework involves deciding which goods and services are considered essential. This decision depends on the purpose of the analysis and the time frame for disruption considered.

- The purpose of this supply chain analysis is to ensure that the basic needs of Australians are met. This means that the narrow view of essential goods and services (developed in chapter 3) is adopted.
- The time frame considered here focuses on disruptions to supply lasting up to six months that would jeopardise the wellbeing of Australians.

Taking this into consideration, the following goods and services are deemed essential: the provision of water, communications, energy, defence, health, logistics, transaction banking services, and government services.<sup>13</sup>

While food is essential for meeting the basic needs of Australians, it is not included in the central analysis (box 3.3); however, given the importance of food supply chains, the effect of including food in the analysis is explored below.

More generally, the application of the framework can be altered to consider vulnerabilities in the supply chains of, for example, the production of a broader set of goods or services (rather than the narrow set used here) or industries that are important for supporting national employment (such as construction). If these alterations are pursued then the selection of goods and services (and the industries that produce them) under consideration would increase and the list of vulnerable imports of interest would change.

---

<sup>13</sup> The broader industries that produce these goods and services account for roughly one third of all Australian production in value-added terms.

---

## How to assess whether vulnerable imports are used in production

Australian producers of essential goods and services may source their inputs locally or from imports. Some of those imports will be vulnerable.

In this section, trade data are linked with production data to ascertain the extent to which the production of essential goods and services relies on vulnerable imports.

Conceptually, this process involves:

1. identifying those industries that produce essential goods and services
2. assessing whether any vulnerable imports are inputs into the production of these industries
3. assessing the degree to which these industries rely on vulnerable inputs, as a share of total inputs.

Linking the datasets indicates which vulnerable imports are used in which industry but it does not indicate whether the vulnerable imports are *critical* to the functioning of the industry. As a preliminary step toward assessing criticality, the share of inputs to an industry that are imports is measured, and what share of those imports is vulnerable. An industry that primarily uses imports, and vulnerable imports, is more likely to be significantly affected by a disruption in the supply of imports.

### Data used

The analysis draws on Australian production data from the ABS Input-Output (I–O) tables for 2016-17. The I–O tables provide detail on the production and final use of goods and services in the Australian economy, covering 114 industry and product groups.

The list of essential goods and services are mapped to the 114 industry and product groups (table 4.2). These include: health, energy, water, logistics, communications, banking, and government. Generally, multiple industry classifications make up an ‘essential industry’ (similarly, multiple products make up an ‘essential good or service’). For example, ‘communications’ is comprised of three industry classifications: broadcasting, internet, and telecommunications.

The Commission used the I–O tables to separate the use of imported products in production and final use from those sourced locally for the 114 product groups (known as IOPGs). This disaggregation enables the identification of whether inputs into essential industries are mostly sourced locally or from imports. The Australian imports data (5950 products) are then mapped to the more aggregated products used in the Australian production data (114 products) to approximate the use of vulnerable imports by essential industries (see appendix C for a detailed explanation of the method).

The ABS does not publish a concordance or mapping from the HTISC classifications used in the trade data to the classifications used in the I–O tables. The absence of such a concordance impedes the analysis of supply chain vulnerability. To overcome this, the Commission has constructed a concordance from the trade data (HTISC) to the I–O tables (IOPG). This process is complicated, and hampered by widespread changes to the trade and production classifications over time (appendix C).<sup>14</sup>

**Table 4.2 Mapping of essential goods and services to Australian production data**

<i>Essential good or service</i>	<i>Input-Output group<sup>a</sup></i>
Banking	Finance
Health	Human pharmaceutical and medicinal product manufacturing Veterinary pharmaceutical and medicinal product manufacturing Health care services Residential care and social assistance services
Water services	Water supply, drainage and drainage services
Communications	Broadcasting (exc internet) Internet service providers, internet publishing and broadcasting, websearch portals and data processing Telecommunication services
Energy	Coal mining Oil and gas extraction Petroleum and coal product manufacturing Electricity generation Electricity transition, distribution, on selling and electricity market operation Gas supply
Logistics	Road transport Rail transport Water, pipeline and other transport Air and space transport Transport support services and storage Wholesale trade Retail trade
Government	Public administration and regulatory services Defence Public order and safety

<sup>a</sup> These industries form part of the 114 industries categorised in the Input-Output tables (see appendix C).

<sup>14</sup> Timing differences between the global trade data (2017) and Australian imports and production data (both 2016-17) meant that 11 vulnerable imports could not be mapped to the I–O tables. The 11 products were imported irregularly (only in the latter part of 2017), which suggests that disruptions to the supply of these products are unlikely to cause short-term supply chain issues.

---

## How reliant are essential industries on imported inputs?

For each industry, the I–O tables indicate the value of each input into production, including goods, services, and payments to labour (wages) and to capital owners. For example, the I–O tables list the value of basic chemicals (domestic and imported, separately) used by each industry. Given that sodium carbonate is identified as a vulnerable import and classified as a basic chemical (according to the concordance), each industry is assigned a share of the value of the sodium carbonate imports (from the 2016-17 trade data) based on the share of imported basic chemicals that each industry uses.<sup>15</sup> So only part of the value of the imported basic chemicals product group will be classified as vulnerable — the part that corresponds to sodium carbonate imports.

Imports form a very small part of the cost structures of the essential industries that produce essential goods and services (figure 4.7). In 2016-17, inputs of domestically-sourced labour and capital (primary factors) were typically the largest components, while inputs of domestically-sourced services were also substantial. Imported inputs, especially those that are vulnerable, played a very small role in the production of essential goods and services. The health industry had the greatest use of vulnerable imports by value at almost A\$2 billion, but all other industries used less than A\$800 million each.

Inputs of goods — sourced domestically and from imports — were typically the smallest component in the production of essential goods and services (figure 4.7). This is because the essential industries largely consist of service industries, rather than manufacturing industries that typically use relatively more goods. For example, health is predominantly a service industry; it is comprised of health care and residential care, which are both large service industries, and the much smaller human and veterinary medicine manufacturing industries.

The cost of goods inputs was largest for energy, health, and logistics industries when compared with communications, government, and water industries (figure 4.8a).

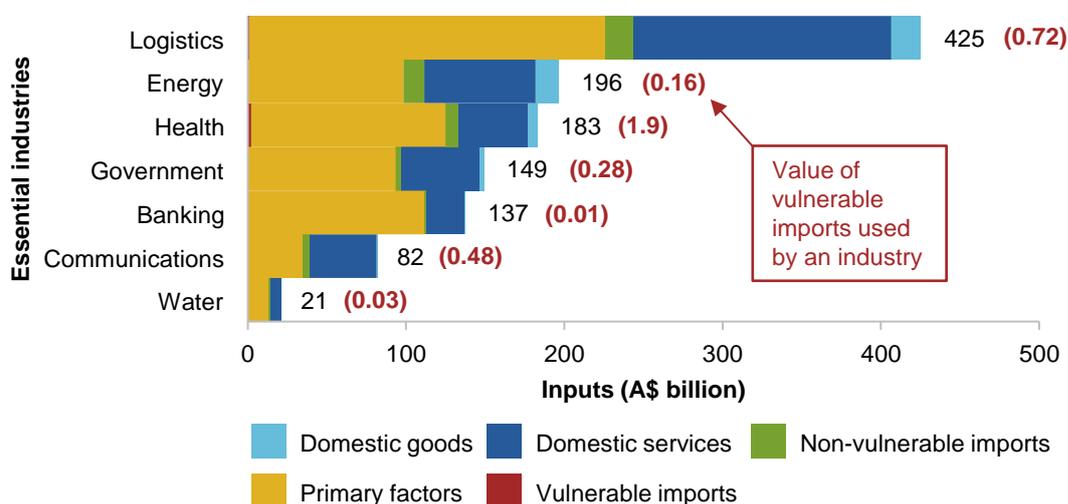
Typically, around half of the goods used in production by an essential industry were sourced from within Australia, but the relative importance of imported inputs varies across industries (figure 4.8a). For example, communications and banking were more reliant on imported inputs than logistics. The more detailed industry classifications reveal that inputs of imported goods account for more than 65 per cent of the value of all goods used in the production of broadcasting, internet, and telecommunications services; petrol and coal products; electricity distribution; veterinary medicines; and health services.

---

<sup>15</sup> This means that the use of imported products — based on the HTISC trade classification — is approximated based on an industry’s use of the broader Input-Output Product Group (IOPG) in which the HTISC product belongs. As a result, an industry’s actual share of vulnerable imports and the number of vulnerable imports used may be larger or smaller than our estimate suggests.

**Figure 4.7 Imported inputs form a small part of essential industries' cost structures**

Input use by essential industries, A\$ billion, 2016-17<sup>a,b</sup>



<sup>a</sup> Primary factors are domestic and include payments to labour, the owners of capital, and taxes on production. <sup>b</sup> Imports may include some services as a result of the mapping of HTISC imports to I–O industries.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

Most essential industries used: imported fuels; professional, scientific, computer and electronic equipment; and basic chemical products (based on the broad product groups of the I–O tables). But the types of products that were imported varies by industry. For example:

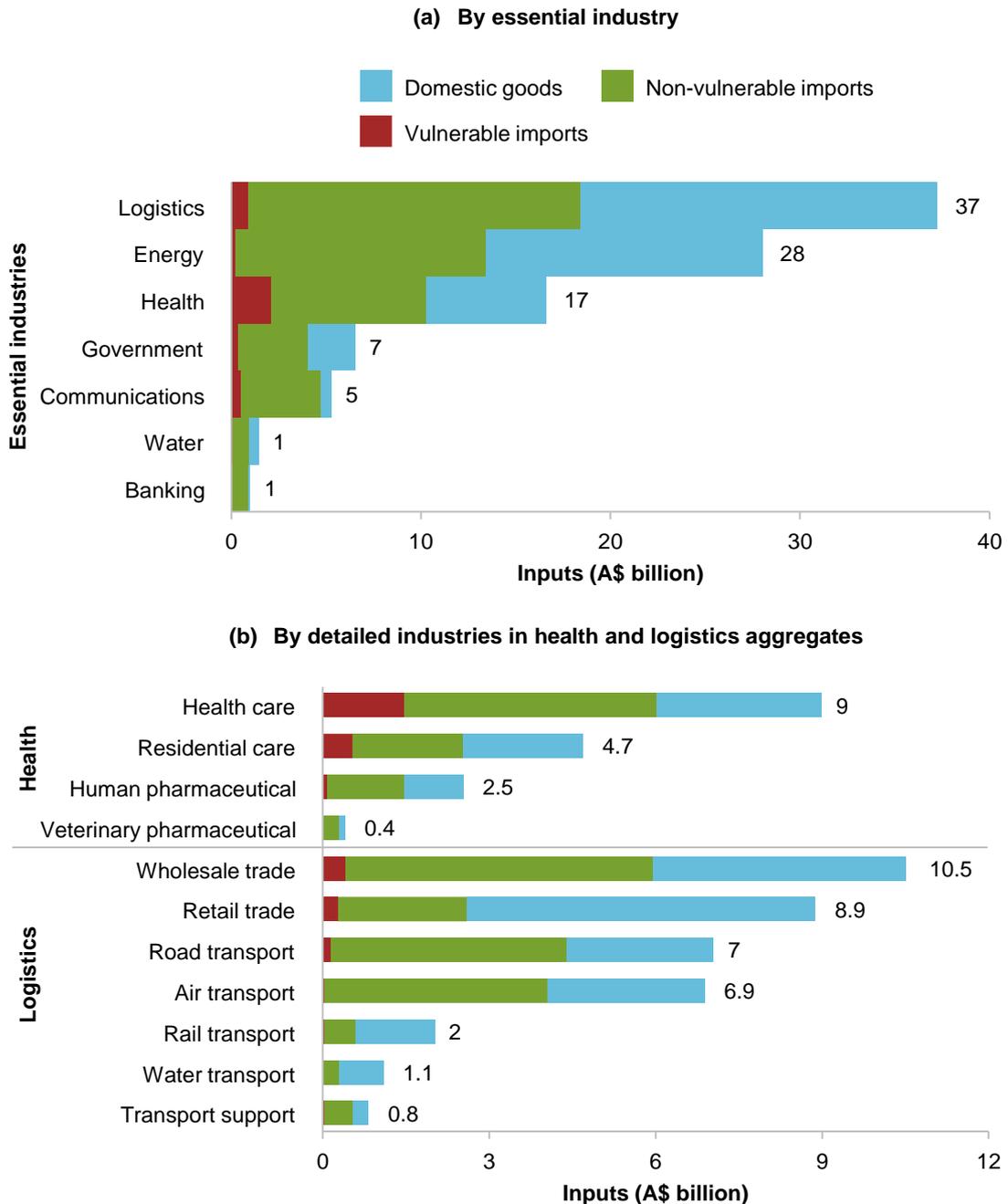
- health used imports of pharmaceutical and medicine products, and clothing and footwear (which likely includes some PPE)
- energy used imports of crude oil, and specialised machinery and equipment
- logistics used imports of motor vehicles and parts, aircrafts, other transport equipment, and polymer products.

If the vulnerable imports identified in section 4.2 (based on the finely-grained trade data) fall into these broad product groups, then the industries that rely on them may be relatively more exposed to import disruptions and susceptible to supply chain disruptions, particularly if the imported goods are also critical inputs (that is, there are no substitutes).

The industries of health, logistics, and to a lesser extent communications, energy, and government, used vulnerable imports in their production — although these imports represent a small fraction of the cost of all imported inputs (figure 4.8a). A more detailed inspection of the industries that make up health and logistics reveals that health services, residential care, and wholesale trade use the highest value of vulnerable imports (figure 4.8b).

Figure 4.8 **Vulnerable imports are a small fraction of essential industries' cost of goods inputs**

The use of goods inputs, A\$ billion, 2016-17<sup>a</sup>



<sup>a</sup> Imports may include some services as a result of the mapping of HTISC imports to I-O industries.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

---

The finding that vulnerable imports are a very small share of the value of goods used in essential industries is suggestive evidence that these inputs are not critical to production, but not conclusive because criticality can be independent of value. If the results had shown that 99 per cent of goods used in the health industry were vulnerable imports, this would suggest a significant vulnerability, but the results show the opposite. That said, the analysis used very broad product categories, and it is still possible that, for example, an active ingredient for the production of medicine that is critical for the treatment of one condition is vulnerable (see box 6.3 for a discussion of medicine shortages).

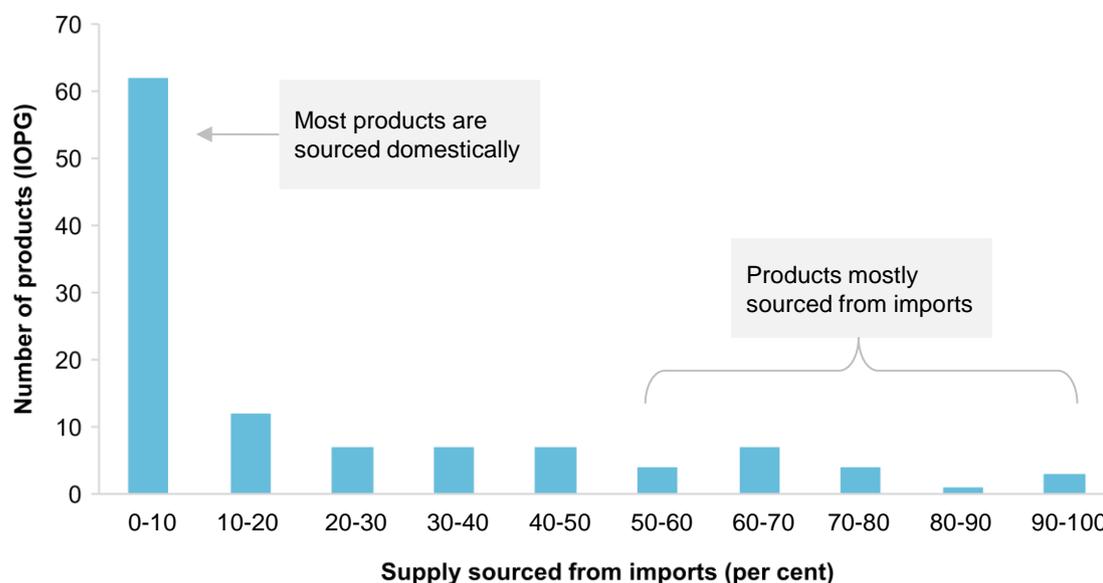
**FINDING 4.5: VULNERABLE IMPORTS MAY NOT BE CRITICAL TO THE PRODUCTION OF ESSENTIAL GOODS AND SERVICES**

The narrow definition of ‘essential’ used in this chapter comprises of mainly service industries. Locally-sourced services are the main input to their production, rather than locally-sourced or imported goods. Consequently, vulnerable imports are a small share in their production costs. This is suggestive evidence that vulnerable imports may not be *critical* to the production of essential goods and services, but is not conclusive because criticality can be independent of value.

While essential industries used imported goods as inputs into production, many products could be sourced domestically (figure 4.9). There were 19 broad product groups for which imports accounted for over 50 per cent of Australian supply such as clothing and footwear; equipment and machinery; human and veterinary pharmaceuticals and medicines; motor vehicles and parts; cleaning compounds; natural rubber; and fuels. If products within these product groups are vulnerable, their supply chain would be more susceptible to disruption, as there is limited local supply to alleviate disruptions. (These product groups are much broader than those used to assess vulnerability in the trade data, and as such, some finer-grained products might be entirely sourced from imports even if the broad product group is mostly domestically sourced.)

Figure 4.9 **Most inputs used by essential industries are locally sourced**

Share of Australian use of each product sourced from imports, 2016-17.  
Products defined using Input-Output Product Group (IOPG) classification



Data source: ABS (Australian National Accounts: Input-Output Tables, 2016-17, Cat. no. 5209.0.55.001).

### Which vulnerable imports were used in production by essential industries?

Returning to the finer-grained import categories used in the trade data (HTISC), essential industries used 130 of the vulnerable imports identified using the filtering method in production.<sup>16,17</sup> The remaining vulnerable imports were used by ‘non-essential’ industries.

Use of vulnerable products varied widely across essential industries (figure 4.10). Health and logistics used more vulnerable inputs than all other essential industries, with each using about 100 products. In contrast, banking and water used the least.

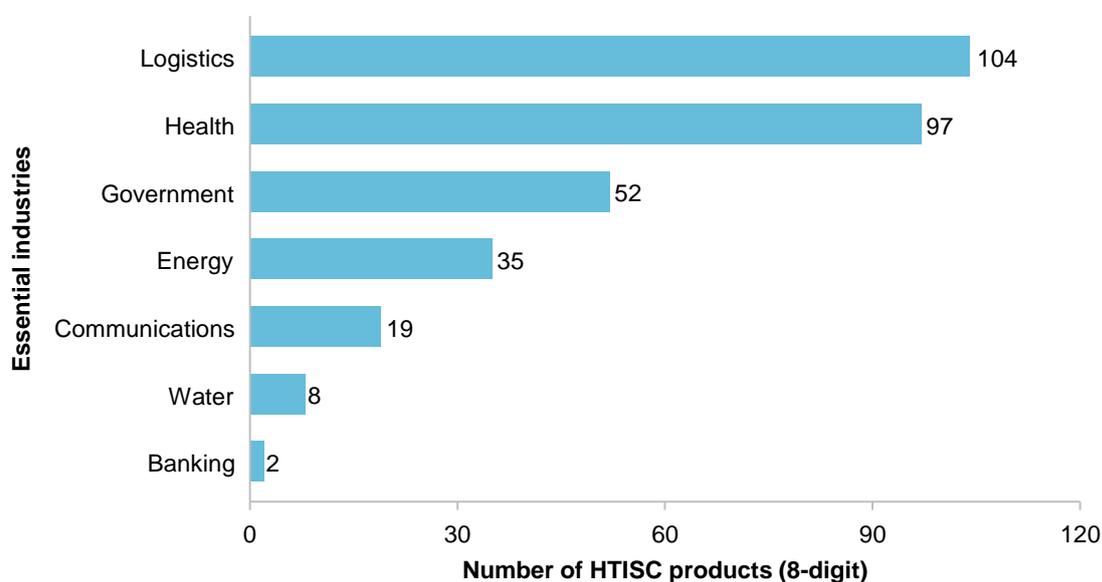
Many of the 130 products are unlikely to constitute critical inputs into these (or other) industries. Examples of such products include women’s swimwear from China and wristwatches from Switzerland.

<sup>16</sup> Only 281 of the 292 vulnerable imports identified in section 4.2 could be mapped to product groups (IOPGs) in the production data.

<sup>17</sup> A minimum value filter of A\$1 million was used to screen out products that otherwise met the criteria for being considered a ‘vulnerable import used by essential industries’. Very small import values arise for some products as a result of the coarser nature of the mapping of imports and production classification changes over time (as the I–O products are at a higher level of aggregation than the imports data).

Figure 4.10 **Health and logistics are the greatest users of vulnerable imports**

Number of vulnerable imports used in essential industries, 2016-17<sup>a</sup>



<sup>a</sup> Products identified as vulnerable if the imports used by an industry were more than A\$1 million.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

The I–O tables suggest that laptops and computer equipment were common inputs across most essential industries. Some products (such as sodium carbonate) were used by only a handful of industries (such as water, health, and energy). Other products were predominantly used by a single essential industry, for example, the use of isolation gowns and surgical cloths (HTISC 62101090) by the health industry.

Essential industries use many vulnerable imports of textiles and miscellaneous products (table 4.3). Most of these products, however, are unlikely to be critical inputs (such as electric blankets, camping gear, and toys). This suggests that a greater number of vulnerable imports used by an essential industry does not always reflect a higher degree of vulnerability to upstream supply chain disruptions.

**Table 4.3 Essential industries use many vulnerable imports of textiles and miscellaneous products**

Number of vulnerable imports used in essential industries, by product type.<sup>a</sup>  
Products defined at the HS Subheading level (8-digit)

<i>Product type</i>	<i>Logistics</i>	<i>Health</i>	<i>Government</i>	<i>Energy</i>	<i>Communications</i>	<i>Water</i>	<i>Banking</i>
Animal and animal products	4	3	1	0	0	0	0
Chemicals and allied industries	4	7	0	5	0	3	0
Foodstuffs	4	1	2	0	0	0	1
Footwear and headgear	5	8	2	3	1	0	0
Machinery and electrical	6	4	2	8	5	2	1
Metals	3	1	2	3	0	2	0
Mineral products	0	0	0	0	0	0	0
Miscellaneous	23	20	16	4	6	1	0
Plastics and rubbers	4	4	2	2	0	0	0
Raw hides, skins, leathers and furs	3	2	3	0	0	0	0
Stone and glass	5	4	1	1	0	0	0
Textiles	31	36	16	7	5	0	0
Transportation	4	2	2	2	0	0	0
Vegetable products	4	5	1	0	0	0	0
Wood and wood products	4	0	2	0	2	0	0
<i>Total</i>	<i>104</i>	<i>97</i>	<i>52</i>	<i>35</i>	<i>19</i>	<i>8</i>	<i>2</i>

<sup>a</sup> Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups.

Sources: ABS (*Merchandise Imports and Import Clearances, 2020*, unpublished); Australian National Accounts: *Input-Output Tables, 2016-17*, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

The analysis suggests that the main supply chain disruption risks are to industries that use:

- chemical products in production as many imported chemical products are identified as vulnerable. These include health (mainly human medicine manufacturing), energy (mainly petrol and coal product refining), and water
- PPE products, such as face shields, isolation gowns, polyethylene aprons, and surgical cloths, as these products are identified as vulnerable; predominantly used in health industries.

These types of products point to avenues for further investigation with industry experts to determine whether any are critical inputs in the production of essential goods and services.

The analysis of import vulnerability presented here is based on past production data. Changes to Australian production capabilities may make Australia more or less vulnerable to supply chain disruption than is currently the case. This implies that the analysis needs to be periodically updated.

---

#### FINDING 4.6: ESSENTIAL INDUSTRIES USED 130 VULNERABLE IMPORTS IN PRODUCTION

Essential industries used 130 vulnerable imports in production. However, many of the vulnerable products, such as textile products (excluding personal protective equipment), are unlikely to be *critical* to production in these essential industries. This suggests that the production of essentials is not highly susceptible to short-term disruptions to the supply of imported goods that come from concentrated sources.

The main supply chain risks lie in the use of vulnerable chemical imports in health (human medicine manufacturing), energy (petrol and coal product refining) and water treatment industries. Some of these chemical products may be critical.

### Does food production use vulnerable inputs?

A prominent theme from consultations with stakeholders on the interim report related to the Commission's exclusion of food from the application of the framework based on the time frame under consideration (see box 3.3). In response to this feedback, the Commission has examined how the results on vulnerable imports presented above would differ if food were added to the list of essential industries considered.

In several respects the food industry differs from other essential industries:

- the value of goods inputs is much larger in the production of food relative to the other essential industries, which are mainly service industries (figure 4.11a)
- goods inputs used in the food industry are predominantly sourced locally, unlike in other essential industries in which imports represent around half of all goods inputs (figure 4.11a).

But the food industry is similar to other essential industries in that vulnerable imports represent a small fraction of the value of goods inputs — an average of about 1.3 per cent across food industries (figure 4.11b). This suggests that these inputs are likely not critical to production, but this is not conclusive evidence because criticality can be independent of value.

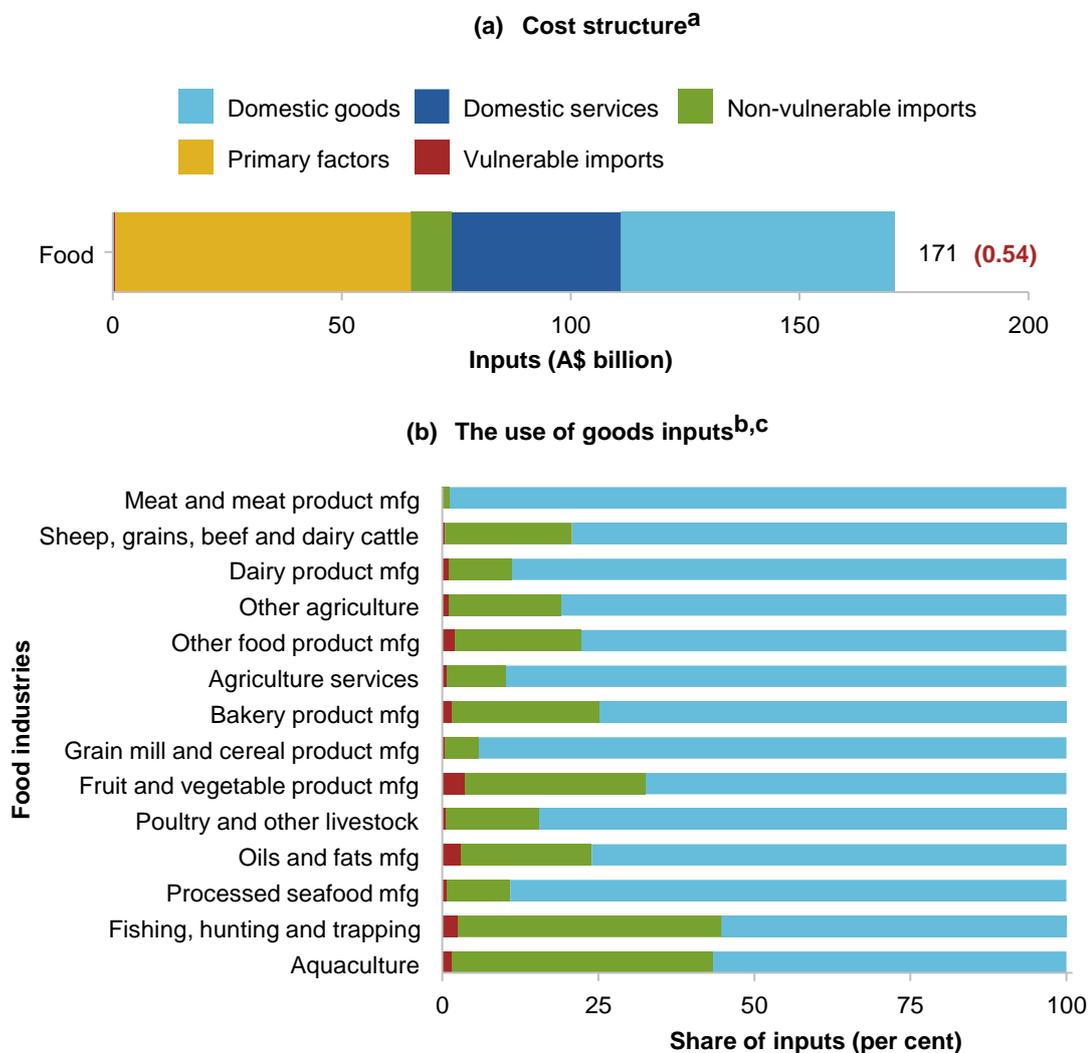
If the vulnerable imports identified in section 4.2 are among the food industry's imported product inputs<sup>18</sup>, then food may be relatively more exposed and susceptible to disruption, particularly if the imported goods are also critical inputs (that is, there are no substitutes). It turns out that including food as an essential industry increases the number of vulnerable imports used in production by just seven (from 130 to 137). Specifically, food used 56 vulnerable imports, which is less than health and logistics, but more than all other essential industries (see figure 4.10 for comparison with other sectors).

---

<sup>18</sup> The food industry's imported products include other food products, petroleum and coal, veterinary pharmaceuticals and medicines, basic chemicals (such as fertilizers and pesticides), specialised and other machinery and equipment products, and polymer products (such as plastic packaging).

Figure 4.11 **Food production relies primarily on local inputs**

Input use by food industries, A\$ billion, 2016-17



<sup>a</sup> Primary factors are domestic and include payments to labour, the owners of capital, and taxes on production. The value of vulnerable imports used by the food industry is in parentheses. <sup>b</sup> Imports may include some services as a result of the mapping of HTISC imports to I-O industries. <sup>c</sup> Industries are ranked based on the total value of all goods inputs used, from highest to lowest. That is, meat manufacturing uses the largest value of goods inputs.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished); *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

Like other essential industries, the vulnerable imports used in food production include laptops, some chemicals, and some PPE. And not surprisingly, many of the imports that are inputs into food production and that are identified as vulnerable include other food products (such as olive oils, tomatoes, milk and cream), for which Australia has domestic supply channels that could be used if imports were disrupted. Vulnerable imports of PPE (such as polyethylene aprons and face shields) are likely to be more important to agriculture and food manufacturing.

---

While some chemical imports identified as vulnerable are used in the production of food, our list does not include fertilisers or pesticides as finished products.<sup>19</sup> This is at odds with multiple submissions that mentioned the vulnerability and importance of fertilisers and pesticides to the food supply chain (see box 3.3). Moreover, the submissions noted that imports are a major source of supply for these products (MUA, sub. 38, p. 14) and that ‘limited stocks are usually held onshore’ (VFF, sub. 23, p. 1).

The apparent incongruity begs questions as to why the results of our data analysis differ from the views expressed in submissions. The likely explanation lies in the observation that even though Australian industry might rely on imports of fertiliser and pesticides from China, the global trade data suggests that Australia could source these products elsewhere if trade with China was disrupted. For example, while almost all Australian imports of phosphatic mineral or chemical fertilisers come from China, the product *could* be sourced from Morocco (with a global market share of 19 per cent in 2017), Israel (17 per cent), or the Netherlands (6 per cent). Therefore, these products are not identified as vulnerable to limited sources of supply.

The above example is a good illustration of how the Commission’s framework can be used as a tool to identify and test potential supply chain vulnerabilities. It remains true that the analysis is based on trade statistics in which aggregation can conceal some details. This reinforces the point that our data analysis is designed to identify items that might require further expert investigation.<sup>20</sup>

In summary, the inclusion of food industries does not qualitatively change the finding that essential industries are not highly susceptible to short-term disruptions to the supply of imported goods that come from concentrated sources. Like other essential industries, the main risks to food production lie in the use of PPE and some chemical products. However, this is not to say that imports of fertilisers and pesticides are not vulnerable to other disruptions. Further discussions with experts are required to determine whether any of the inputs identified in this analysis are critical to production and whether critical inputs, such as fertilisers, are susceptible to other potential vulnerabilities.

---

<sup>19</sup> These products are captured under the 2-digit HTISC product classification of Chapter 31 (fertilisers) and Chapter 38 (pesticides, insecticides, fungicides, herbicides, and rodenticides).

<sup>20</sup> That said, a certain degree of product aggregation is useful in avoiding differentiation in the global data that would prevent the filters from identifying possible substitutes.

---

FINDING 4.7: THE INCLUSION OF FOOD DOES NOT QUALITATIVELY CHANGE RESULTS

Including food as an essential good does not qualitatively change the finding that the production of essentials is not highly susceptible to short-term disruptions to the supply of imported goods that come from concentrated sources. Critical inputs of fertilisers and pesticides are not found to be vulnerable in this application of the Commission's framework. But like other essential industries, the main supply chain risks to food production lie in the use of imported vulnerable chemical products and personal protective equipment.

#### 4.4 Direct and indirect contribution of vulnerable imports to the consumption of essential goods and services

The narrow definition of essential goods and services includes only those that are necessary to meet the *basic needs* of Australians (chapter 3).

Meeting the basic needs of Australians is about the *final consumption* of essential products by Australians (households) or by government (which provides goods and services on behalf of households). That is, it is about the use of essential goods and services by, or on behalf of, consumers.

The wellbeing of Australian consumers will be materially impacted by a sustained upstream disruption to the supply of imports if:

- they *directly* consume imports of essential goods and services (that is, imports form part of final demand) or
- they consume Australian-produced essential goods and services whose production relies on imported inputs (imports are consumed *indirectly*).

For example, Australian consumers would be adversely affected if an imported critical medicine was unavailable (*direct*) or if an imported critical active ingredient used to domestically manufacture a critical medicine was unavailable (*indirect*).

The I–O tables enable the users of essential goods and services to be identified at a relatively high level (such as individual industries, households, and government).

---

## Importance of essential goods and services in meeting the wellbeing of Australian consumers

Due to the coarse classification of the I-O tables, Australian household and government consumption of essential goods and services accounted for almost half of their consumption of all goods and services in 2016-17 (\$600 billion out of A\$1.3 trillion).

Households and government used about 56 per cent of the production of all essential goods and services, the remainder was used by industries.<sup>21,22</sup> Households and government were the main users of health and government goods and services, in contrast to banking, communications, and energy, where industry was the main user. The use of water and logistics was evenly divided between household/government and industry.

The vast majority of essential goods and services used by households and government in Australia in 2016-17 were produced in Australia — 96 per cent of total use (figure 4.12). This high share reflected, among other things, the high proportion of services among the list of essential products. Imported final goods and services played a small role in meeting household and government demand for essential goods and services, and vulnerable imports played an even smaller role.

Households *directly* consumed some imports of energy, health, and logistics products (figure 4.12). For example, some households filled their car using petrol refined in Singapore (box 4.4) and consumed medicines manufactured in Belgium or the United States. Notwithstanding this, the value of these imports found to be vulnerable in 2016-17 was tiny (A\$20 million).

As outlined in section 4.3, the *indirect* use of vulnerable imports in Australian production in 2016-17 was also found to be very small (figure 4.12). As Australian households used only a share of this Australian production, their indirect use of vulnerable imports is valued at about A\$2.7 billion.

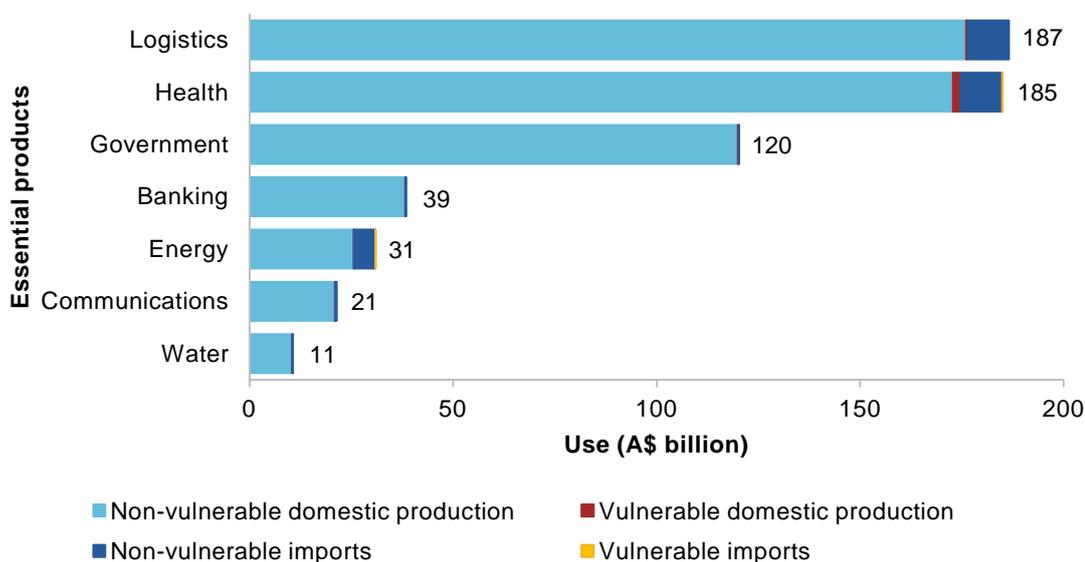
---

<sup>21</sup> The coarse nature of these product categories overstates their importance for the wellbeing of Australians, as the categories also implicitly include other goods and services that go beyond those needed to meet the basic needs of Australians.

<sup>22</sup> Total use of each product is the total supply of that product in the I–O tables less exports.

Figure 4.12 **The vast majority of essential goods and services used in Australia were produced in Australia**

Household and government use of essential products by source, 2016-17<sup>a</sup>



<sup>a</sup> Essential products are either produced domestically or sourced from imports. The value of vulnerable imports used in the domestic production of essential products is shown in red (covered in section 4.3). The value of vulnerable imports used to directly meet final demand for essential products is shown in yellow.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN Comtrade (2020).

While the shares of expenditure on vulnerable imports in aggregate Australian consumption might be tiny, the effect on individuals may be large. For example, the absence of lifesaving medicines jeopardises the wellbeing of Australians whatever the value of these medicines or their share in consumption or production.

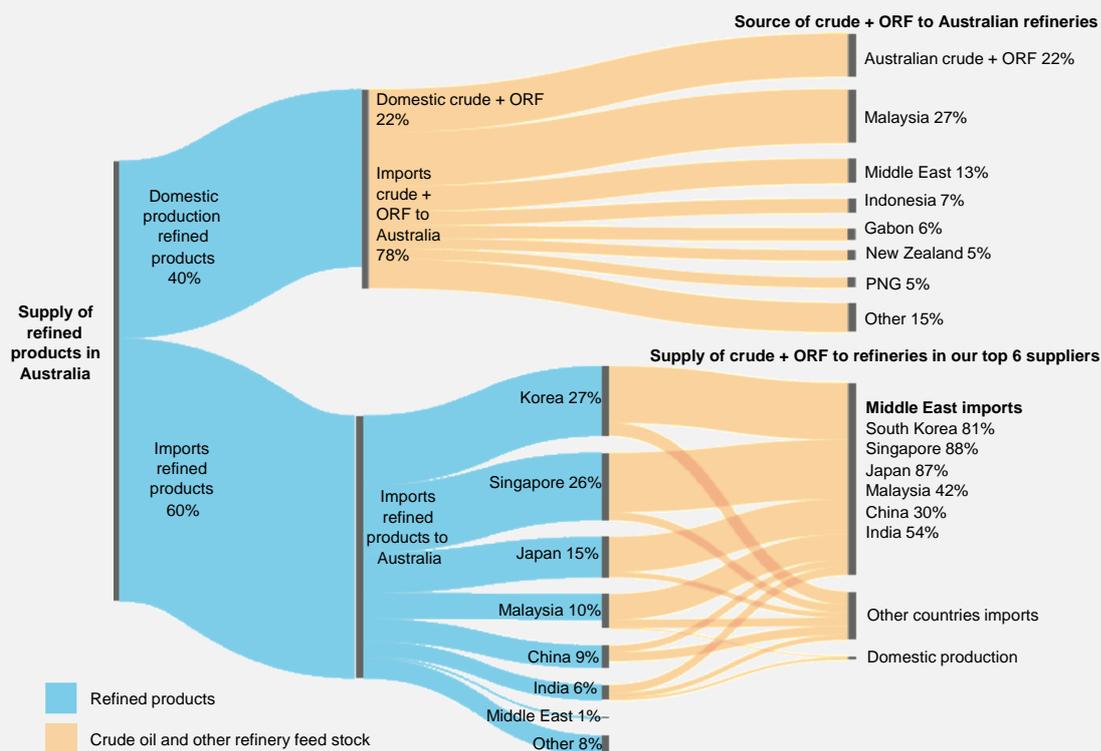
Overall, the low share of essential goods and services that Australians use and that are sourced from imports is suggestive evidence that most supply chain disruptions may not have a material and sustained impact on the wellbeing of Australians. Moreover, the fact that most essential products — whether used by households or by industry — were produced locally points to alternative (domestic) sources of supply that could be accessed in the event of a disruption to imports, or whose production could be ramped up (if not immediately, then over time). However, this is not conclusive evidence because the industry categories and products considered are broad; in some very narrowly defined essential industries, imports could be critical. Further, where an import is critical, and its absence would jeopardise the supply of an essential good or service, then wellbeing would be affected.

## Box 4.4 Sensitivity of the analysis and the importance of experts — an illustration with oil products

The analysis with the chosen thresholds does not identify petroleum products as vulnerable. With the thresholds used, the analysis only identifies 'Petroleum coke, not calcined' (HTISC 27131100, A\$3 million worth of imports in 2017) as vulnerable. Identifying other fuels as vulnerable would require changing the analysis significantly. For example:

- broadening the geographic scope and product classifications in filter 1 would identify refined fuels as vulnerable, since six economies within Asia accounted for over 90 per cent of imports of refined fuels, which meets the 80 per cent threshold for identifying imports as vulnerable in filter 1 used in this report (figure below)
- examining more tiers in the supply chain as some concentration occurs beyond tier 1 suppliers: 70 per cent of imported refined fuels originate from crude oil produced in the Middle East (figure below)
- using much lower thresholds of market concentration, the global market for crude oil and refined fuels may also be considered concentrated: about 50 per cent of global exports of crude oil (OEC 2019a) and about 40 per cent of global exports of refined fuels (OEC 2019c) come from five economies.

### Source flows for Australia's fuel products



Source: (DEE 2019, p. 23).

(continued next page)

---

#### Box 4.4 (continued)

Industry experts are required to complement the analysis of recent data. This is especially true when trends are hard to identify (for example, identifying issues beyond tier 1 suppliers), or when a supply chain displays idiosyncrasies, or when events or recent developments cannot be observed in the data. For example, data analysis cannot reveal that:

- two Australian refineries are set for closure, which will increase reliance on imports of refined fuel. The Australian Government has argued that domestic refinery capacity contributes to fuel security and has announced production subsidies of up to 1.8 cents per litre of petrol, diesel, and jet fuel produced (DISER 2021c)
- Australia's stockpiles of crude oil are located offshore in the US Strategic Petroleum Reserve, which makes them vulnerable to shipping disruptions. That said, the main reason for the mandated stockpiles is 'to mitigate the negative impacts of sudden oil supply shortages by making additional oil available to the global market, not necessarily to improve Australia's energy security' (BP, sub. 53, attach. 1, p. viii)
- Australia sources oil and fuels primarily from the Middle East, North-East Asia and South Asia, regions that are susceptible to geopolitical and other risks (Marsh 2020, p. 7)
- although the risk is smaller than in the 1970s, it is still possible for the Organization of the Petroleum Exporting Countries (OPEC) to coordinate to disrupt global oil supplies.

The Department of the Environment and Energy (DEE 2019) considered these issues in consultation with experts in its latest review of liquid fuel security.

---

#### FINDING 4.8: THE SUPPLY OF ESSENTIAL GOODS AND SERVICES IS NOT HIGHLY SUSCEPTIBLE TO DISRUPTIONS TO IMPORTED GOODS

Combining imports and production data suggests that the supply of essential goods and services in Australia is not highly susceptible to a short-term upstream disruption to the supply of imported goods.

Vulnerable imports represent a small fraction of the value of essential goods and services consumed by Australians — whether that consumption be direct (final goods, A\$20 million out of total consumption of essential goods and services of A\$593 billion) or indirect (as inputs into Australian production, A\$2.7 billion). But this evidence is not conclusive and industry experts are required to determine criticality.

---

## 4.5 Possible extensions to this work

The framework and its application with specific thresholds is a tool that could be extended and improved in several ways.

First, and most importantly, further work is needed to conclusively determine which vulnerable imports are *critical* to essential industries. Industry experts are best placed to determine which of the concentrated inputs identified and used by essential industries are critical in the sense that production could not occur without them. These experts have detailed knowledge of the production processes involved and what substitute products, if any, could be used in the event of a disruption. There are also data-driven methods, such as estimating demand elasticities to gauge the potential for substitution, that could complement experts' advice if suitable data are available (appendix D).

The pursuit of such analysis and expert advice would provide a more complete picture. For instance, substitute inputs for key mechanical, pharmaceutical, or chemical products may exist but require the existing production process to be redesigned or adapted. Experts are best placed to assess the costs involved and whether the substitution of inputs is feasible in the short term. For example, there are substitutes for the chlorine used in the treatment of drinking water (such as sodium hypochlorite), but 'many Australian water treatment facilities are currently not configured for their use and would require significant capital investment in many cases to be capable to do so' (Water Services Association of Australia, sub. 10, p. 3).

Second, the analysis could be improved with a closer inspection of product classifications to ensure substitute products are grouped together. For example, for some agricultural products a higher product aggregation is adequate, but for specific chemicals a fine-grained classification would improve the analysis.

Third, extending the analysis to other years would improve the robustness of the analysis. Imports in any one year will be influenced by factors specific to that year and changes to suppliers over time, which can affect the analysis. This may particularly be an issue where the items are large and ad hoc in nature. Examples of such imports may include aeroplanes, ships, trains, military equipment, and natural gas platforms. The use of multiple years is made challenging by changes to the finely-grained product classifications over time (8-digits or more), whereas using multiple years is easier for coarser product aggregations (6-digits or fewer). Preliminary analysis suggests that 2016-17 appears to be a reasonably representative year (appendix C).

Fourth, the analysis only considers tier 1 suppliers (that is, economies that supply a good directly to Australia, chapter 2); that said, it could be linked into work on global supply chains. This would help to better gauge the potential for supply chain disruption arising from our foreign suppliers being at risk of disruption themselves (that is, consider tier 2 suppliers and above). These risks could arise from many sources, including:

- disruption to their own upstream suppliers (whether local or from abroad)

- 
- when different stages of production are located in different economies
  - where our suppliers are owned by another firm located abroad, such that, if the parent firm experiences financial or other difficulties, it may flow through to the subsidiary that supplies Australia
  - where global supply comes from similar parts of the world (such as from the Middle East, East Asia, North America or Europe).

Fifth, more detailed production data could improve the analysis of vulnerable inputs. The analysis used I–O tables which are highly aggregated and are difficult to link to trade data. An alternative is the Business Longitudinal Analysis Data Environment (BLADE), which allows detailed trade data to be linked with firm level data (Hansell and Rafi 2018). The Commission’s exploratory analysis revealed that the BLADE data form a better basis than the I–O tables for this type of analysis, mainly because it provides greater industry detail, based on the 4-digit Australian and New Zealand Standard Industrial Classification codes. The structure and detail of the BLADE data mean that users can avoid having to rely on imperfect concordances to link trade and production data. In addition, the release of BLADE data is more timely than the release of I–O tables. Analysis with BLADE could also be used to inform policy formulation in much greater detail.

Finally, the fact that the ABS confidentialises details for some imports — in both trade data and in BLADE — suggests that sources of supply are limited and, hence, indicate potential vulnerability to disruption. These products should be investigated further.



---

## 5 Applying the framework to Australian exports

### Key points

- Australian exports are part of global supply chains and they generate income that contributes to Australians' wellbeing.
  - In 2019-20, Australia exported \$475 billion worth of goods and services, equivalent to nearly a quarter of GDP. Australia's top 10 exports account for around two thirds of the value of all our exports, less than the global average of 71 per cent.
- Export income can be jeopardised by downstream disruptions to demand.
  - The Commission has used the framework described in chapter 3 to identify vulnerable exports. In this context, the potential negative outcome associated with vulnerability is a loss of export income.
- Nearly one-in-five of Australia's goods exports are highly concentrated, but global trade data suggest that many could readily find alternative markets, so are not identified as vulnerable.
  - Recent disruptions have shown that some exports — like coal, which is not identified as vulnerable using the Commission's framework and thresholds — quickly found new markets. Others had real difficulty — like rock lobsters, which are identified as vulnerable.
- Among Australia's main goods exports, only iron ore is identified as vulnerable. It has been Australia's most valuable export for the last decade and over 80 per cent has been exported to China in recent years. China regularly accounts for over two thirds of global imports.
  - Identifying an export as vulnerable has no immediate implication for public policy and this is especially so with respect to iron ore. Firms are well placed to evaluate market risks and opportunities. Governments, for their part, have a role providing a low-cost regulatory environment and access to global markets.
- Australia's main services exports, education and tourism, are not considered vulnerable using the Commission's framework and thresholds, because historically our biggest market for both (China) accounts for much less than half of the export income that these sectors generate. However, they depend on the ability to travel and are vulnerable to the near-complete closure of Australia's international borders to non-residents associated with the COVID-19 pandemic.
- Export income could be jeopardised by disruptions to the supply of imported inputs. Australia's main export industries use 66 vulnerable imports in production. The main upstream disruption risks are to mining industries which use imported chemical products in production, some of which have been identified as vulnerable (chapter 4).
- Although vulnerable imports are a small share of production costs, this is only suggestive evidence that these inputs are not critical because criticality can be independent of value. Industry experts are best placed to assess criticality.

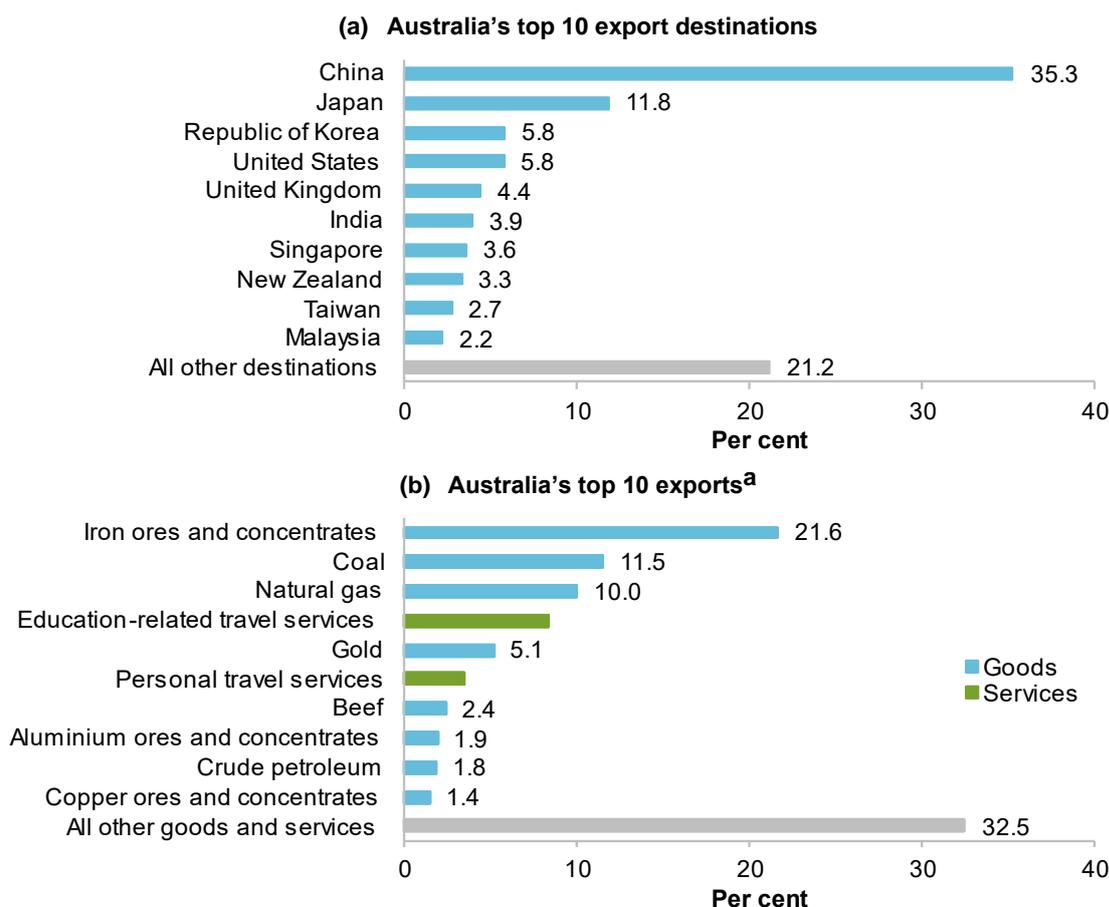
## 5.1 Australia's exports — where and what

Australia exported \$475 billion worth of goods and services in 2019-20, equivalent to nearly a quarter of GDP (ABS 2020b; DFAT 2021a). Exports include many different products going to many different markets (figure 5.1).

- Australia's exports went to over 200 markets in 2019-20, but the top 10 destinations accounted for nearly 80 per cent of all exports. China was our single largest destination market, accounting for over a third of exports.
- Natural resources dominated Australia's top 10 exports in 2019-20, with iron ore alone accounting for over a fifth of all exports. This will be accentuated in 2020-21, with iron ore prices reaching record levels and education and tourism exports negatively impacted by the COVID-19 pandemic.

Figure 5.1 **China and natural resources dominate Australia's exports**

Share of Australia's exports, by value, 2019-20

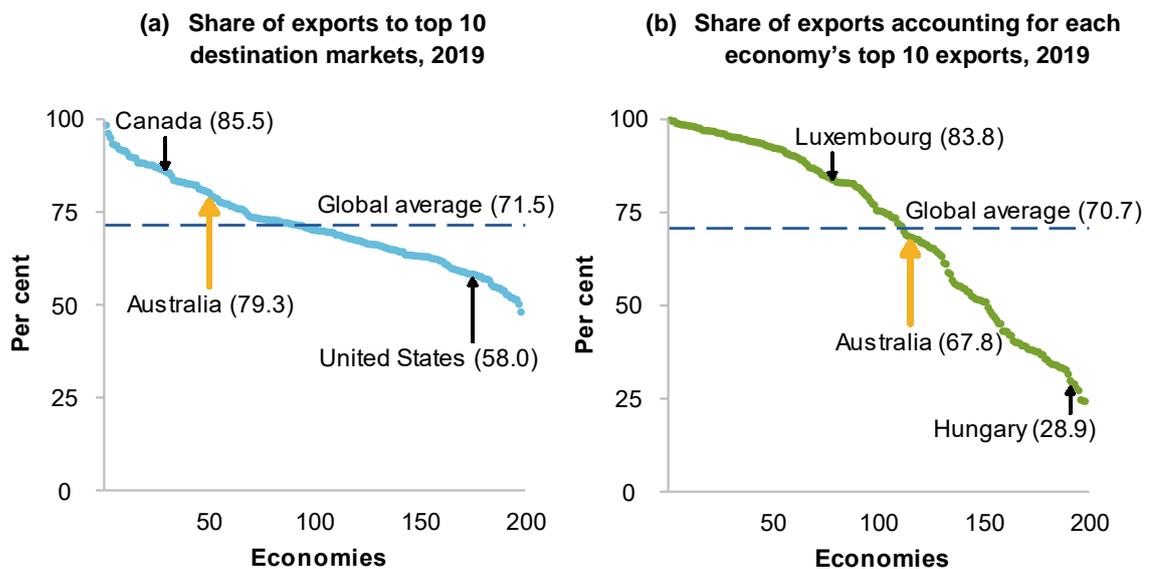


<sup>a</sup> Top 10 exports as defined by DFAT (2021a) using the Standard International Trade Classification system, a more highly aggregated classification system than what the Commission has used in most of the analysis.

Data source: DFAT (2021a).

Australian exports are often thought of as being concentrated in where and what is exported, but Australia is not an outlier in either regard (figure 5.2). In 2019, Australia’s top 10 destination markets accounted for 79.3 per cent of our exports by value, while the global average was 71.5 per cent. And our top 10 exports accounted for 67.8 per cent of all of our exports, slightly lower than the global average of 70.7 per cent.<sup>23</sup>

**Figure 5.2 The concentration of Australia’s exports by market and by product is close to the global average**



Data sources: CEPII (2021); OECD-WTO (2021).

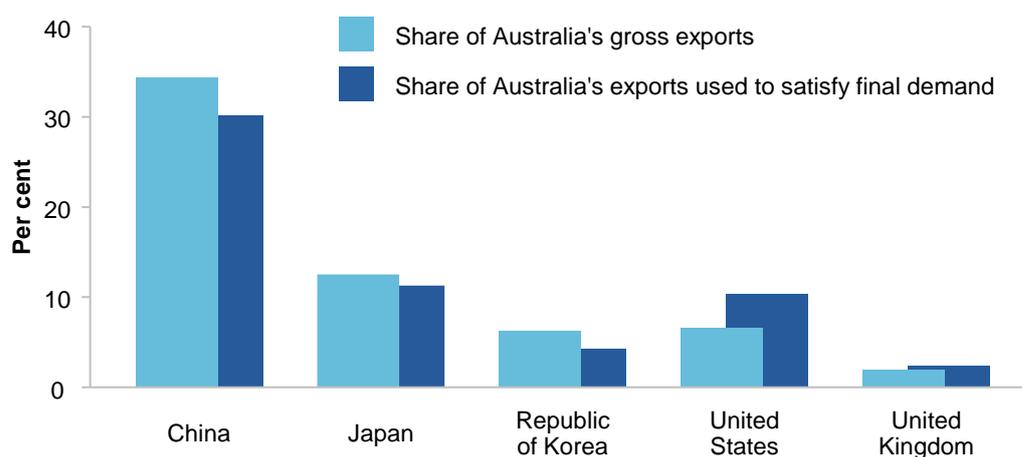
Australian firms participate in global value chains — our exports are often used as inputs to produce goods and services which are themselves exported to third markets and beyond to final consumers. For example, China uses Australian iron ore to produce steel that is exported to South Korea, which uses that steel to produce goods including cars, computers, electronic and optical equipment that it exports to China and the United States (OECD 2018).

Because of the prevalence of these global value chains, basic trade data overstates the importance of some markets as destinations for Australia’s exports and understates the importance of others. As an alternative, trade in value added data can be used to calculate the share of Australia’s exports that are embodied in final goods and services and consumed across the world. Compared to analysis based on trade in value added data, basic trade data overstates the share of Australian exports going to China by around 4 percentage points, and understates the share going to the United States by around the same amount (figure 5.3).

<sup>23</sup> The numbers for Australia in figures 5.1 and 5.2 differ because they are based on different datasets with different classification systems. Also, figure 5.1 uses financial year 2019-20 data whereas figure 5.2 uses calendar year 2019 data.

**Figure 5.3 Australia's exports are often used to produce things that are exported to third markets**

Share of Australia's gross exports going to different markets and the share of Australia's exports used to satisfy final demand in those markets, 2015<sup>a</sup>



<sup>a</sup> 2015 is the last year for which trade in value added data is available. Shown are Australia's top 5 export destinations in 2019-20.

Data source: OECD (2018).

## 5.2 Demand-side vulnerability

Disruptions that eliminate or reduce destination markets' demand for Australian goods and services are a risk to the export revenue generated by Australian firms. These demand-side or downstream disruptions include policies and administrative decisions that affect market access (including tariff and non-tariff measures), natural disasters, shocks along transport routes or other shocks (for example, rapid currency devaluation).

Independent of any other factors, exports to a small number of markets in a globally concentrated market are at greater risk of disruption. With this in mind, the filters used in chapter 4 to identify vulnerable imports have been adapted to identify vulnerable exports, with the addition of a fourth filter (table 5.1).

The filters are used to determine whether:

- Australia's exports of the product are highly concentrated in a few destinations (filter 1)
- global trade for the relevant product is highly geographically concentrated (filter 2)
- Australia's main destination market is also the main global importer (filter 3)
- products are persistently captured by the first three filters across multiple years (filter 4).

The fourth filter has been added to avoid identifying exports as vulnerable if they are captured by the first three filters as a result of temporary factors. It was not feasible to analyse import vulnerability in multiple years, mainly because of frequent changes in the finely-grained product classification system used in the imports data (appendix C).

As with the analysis of import vulnerability, the analysis of export vulnerability focuses on:

- short-term disruptions. This means that the Commission has not analysed risks associated with, for example, a long-term decline in demand for coal as governments implement policies to reduce their carbon emissions
- Australia’s first tier of trade partners. This means focusing on the first destination of Australia’s exports when applying filters 1 and 3. Australian firms participate in global value chains, so they could be impacted by disruptions further downstream — for example, reduced demand for cars in the United States would impact China’s demand for Australian iron ore — but disruptions like this are not captured in the analysis.

**Table 5.1 The vulnerability filters applied to Australia’s exports**

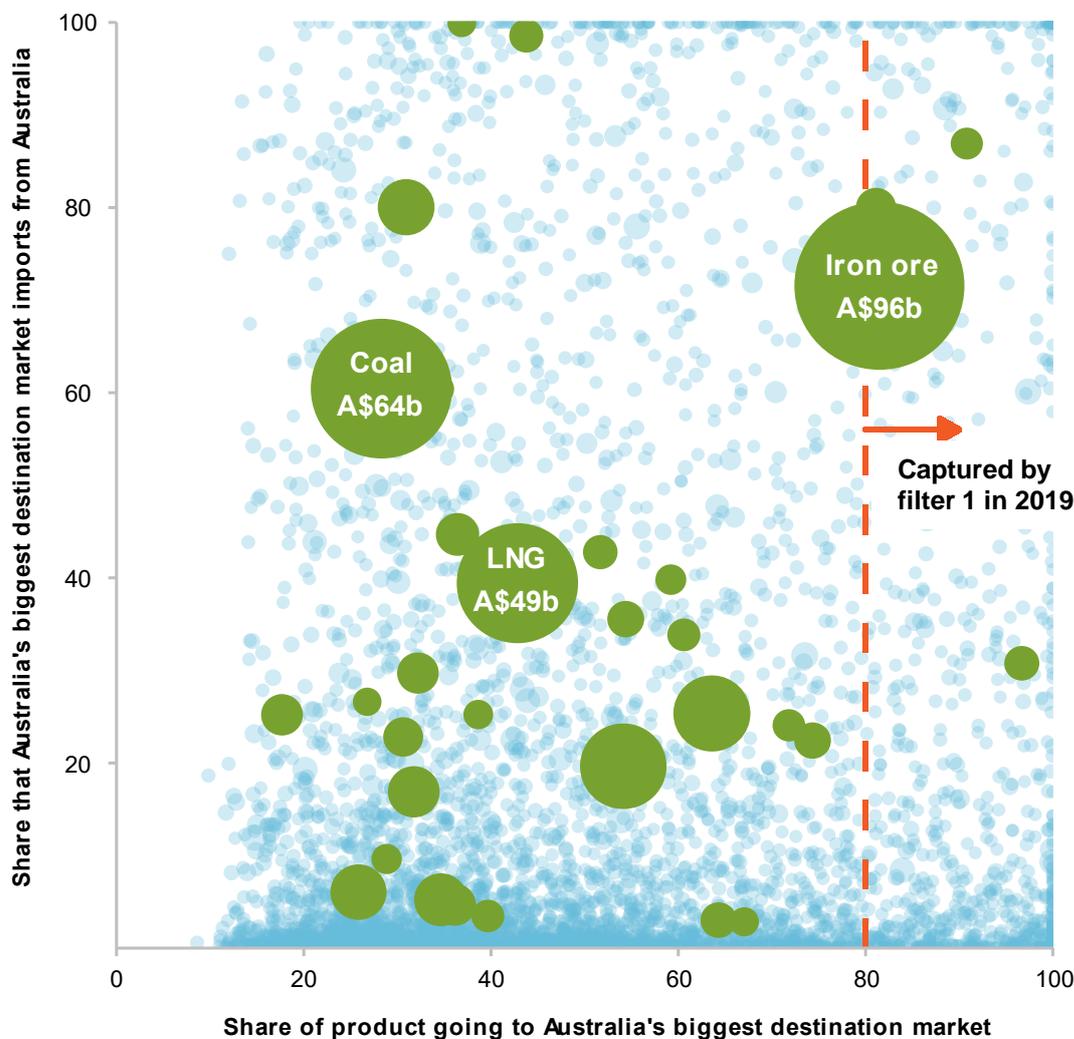
	<i>Technical description</i>	<i>Interpretation</i>
Filter 1	A single destination market accounts for 80 per cent or more of Australia’s exports of a product.	This filter identifies whether Australian exports are highly concentrated in a single market, as concentration entails additional risk.
Filter 2	The product’s Herfindahl-Hirschman Index (HHI) is in the top quartile of HHI values (calculated using importing nations’ market shares), or the biggest importer accounted for over 50 per cent of global imports.	This filter identifies whether the number of global buyers is also concentrated — fewer alternative destination markets would tend to make it more difficult to redirect exports in the case of a disruption to existing buyers.
Filter 3	Australia’s biggest destination market is also the biggest importer.	If Australia’s main destination market is not the biggest importer globally, it would be easier for Australian exporters to switch to alternative markets without experiencing large price decreases.
Filter 4	A product is captured by the first three filters in at least four of the eight years analysed (2012 to 2019).	Trade patterns vary from year to year, and products may happen to fall on the ‘wrong’ side of any of the first three filters in any one year. This filter is intended to avoid identifying exports as vulnerable as a result of temporary factors.

## Applying the framework to goods exports

Every year, Australia exports around 4900 different products (defined at the Harmonized System (HS) 6-digit level) (figure 5.4). Applying the first filter removes around 4000 of these in most of the years analysed (2012 to 2019, the years for which data are available). This means that around one-in-five goods exports are highly geographically concentrated (figure 5.5). That is, Australia’s largest destination market usually accounts for over 80 per cent of exports for around one-in-five products. (This is similar to our results for imports.)

**Figure 5.4 Around one-in-five goods exports are highly concentrated in a single destination market**

Australia's goods exports, 2019. The size of dots represents total value of exports; green dots are exports worth over A\$1 billion



Data sources: CEPII (2021); DISER (2021b).

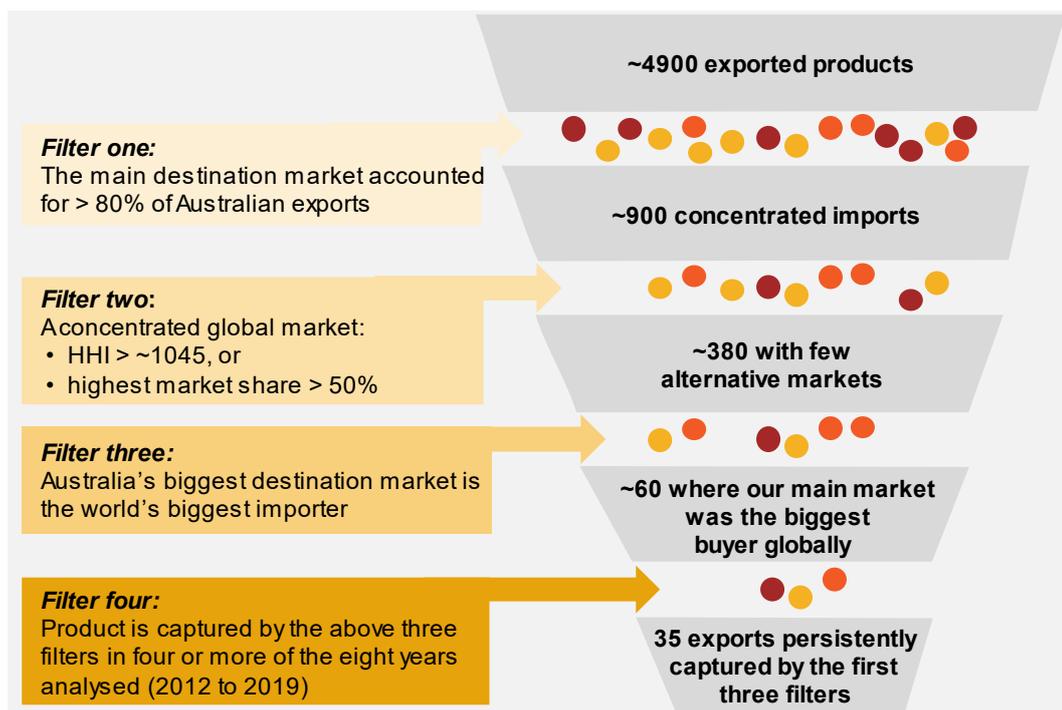
After applying the second filter, around 380 products remain in most years. This means that the second filter removes over 500 products for which data suggest that alternative markets are likely available. One such product is swine offal (as an example). In 2018, 88 per cent of Australia's swine offal exports went to the Philippines (satisfying the first filter), but the global trade was not concentrated (so the product was rejected by the second filter). The very next year, swine offal was not even captured by the first filter — the share of exports going to the Philippines went down to 69 per cent and exports to both Hong Kong and Singapore increased significantly, demonstrating why it is important to consider the availability of alternative markets when assessing vulnerability.

After applying the third filter, around 60 products remain in most years. This means that even where Australia exports over 80 per cent of a product to a single destination and the global market for that product is relatively concentrated, Australia's largest destination market is usually not the world's biggest importer. This is suggestive evidence that if Australia's main destination market was disrupted, the world's biggest importer may remain as a potential alternative market.

Many products are only captured by the first three filters in one, two or three of the eight years analysed (2012 to 2019). This is taken as evidence that there is flexibility in markets and natural variation in trading patterns over time. For this reason, products are identified as vulnerable only if they are selected by the first three filters in at least four of the eight years analysed (filter 4).

After applying the fourth filter, only 35 products remain. This means that less than 1-in-100 of Australia's goods exports have been identified as vulnerable.

Figure 5.5 Identifying vulnerable exports<sup>a</sup>



<sup>a</sup> Because the analysis is done across multiple years (2012 to 2019), the typical number of products captured by each of the first three filters is indicated.

Data source: CEPII (2021).

---

The 35 products identified as vulnerable accounted for just over one quarter of Australia's goods exports in 2019 (by value). This figure is high because iron ore is identified as vulnerable — iron ore accounted for just under one quarter of Australia's goods exports in 2019. Excluding iron ore, the identified vulnerable exports account for around 1.5 per cent of the value of goods exports.

FINDING 5.1: DATA SUGGESTS THAT LESS THAN 1-IN-100 OF AUSTRALIAN EXPORTS MIGHT BE VULNERABLE DUE TO CONCENTRATED SOURCES OF GLOBAL DEMAND

Nearly one-in-five of Australia's good exports is considered highly concentrated but global trade data suggests that many of these exports could find alternative markets if needed. The result is that less than 1-in-100 of Australian exports might be vulnerable to concentrated sources of global demand.

Iron ore made up nearly 95 per cent of the value of all vulnerable exports in 2019 (figure 5.6). Nearly 81 per cent of the value of all of the goods exports identified as vulnerable were exported to China, most of which was iron ore. China was also the largest destination market for the five most valuable exports identified as vulnerable (beyond iron ore).

- Bauxite, with exports worth \$1.6 billion.
- Fresh rock lobsters and other sea crayfish, with exports worth around \$750 million.
- 'Coniferous, in the rough' wood, with exports worth around \$620 million.
- Copper waste and scrap, with exports worth nearly \$400 million.
- Fresh or dried unshelled almonds, with exports worth around \$370 million.<sup>24</sup>

### Are Australia's main exports vulnerable?

Iron ore is the only one of Australia's top 10 goods exports identified as vulnerable. It has been Australia's most valuable export for the last decade, more than two thirds of Australia's iron ore exports have gone to China for more than a decade, and China regularly accounts for over two thirds of iron ore imports globally (mostly purchased from Australia) (CEPII 2021; DISER 2021b).<sup>25</sup>

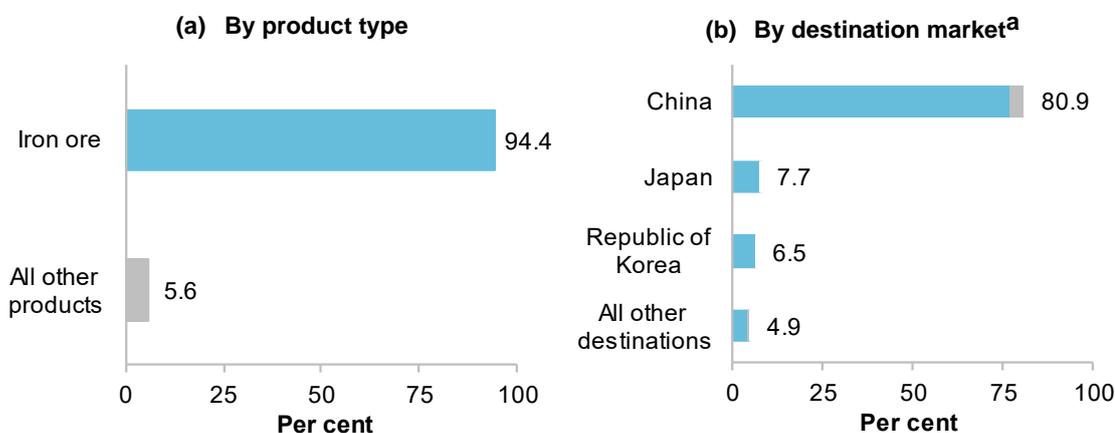
---

<sup>24</sup> The value for bauxite exports is drawn from DISER (2021b). The value of other exports is drawn from CEPII (2021), and converted from USD to AUD using the simple average of the daily USD:AUD exchange rates reported in RBA (2021).

<sup>25</sup> Bauxite, which is part of Australia's exports of 'Aluminium ores and concentrates', is identified as vulnerable. However, bauxite accounts for less than a fifth of Australia's exports of 'Aluminium ores and concentrates' and does not, on its own, belong on the list of Australia's top 10 exports. Bauxite ranks outside Australia's top 20 goods exports using either the HS 6-digit or Standard International Trade Classification 4-digit classification system.

**Figure 5.6 Iron ore accounts for nearly 95 per cent of the value of Australia’s vulnerable exports. Most goes to China**

Share of Australia’s vulnerable exports, by value, 2019



<sup>a</sup> Blue indicates iron ore, grey indicates all other products.

Data source: CEPII (2021).

Disruptions to iron ore demand would have negative impacts on Australia but firms have strong incentives to evaluate and manage that risk, and they do. Survey results from 2015-16 indicate that over 95 per cent of iron ore miners took action to manage their supply chain risks (which includes downstream risks) (ABS *Business Longitudinal Analysis Data Environment, BLADE*, Cat. no. 8178.0). Clearly, that has not entailed turning away from the world’s biggest buyer of iron ore, with exports to China reaching record levels in 2021 (DFAT 2021b). Those record exports are fuelled by China’s ongoing development and global demand for steel-using products.

Consequently, identifying iron ore as vulnerable has no immediate implication for public policy. Firms are, in general, best placed to evaluate and manage their market exposure, and to find new markets and reallocate productive resources in response to disruptions. Governments, for their part, have a role maintaining a low-cost regulatory environment that gives firms the flexibility to manage their demand-side risks and adjust to disruptions as they see fit, including ensuring firms have access to a range of international markets (chapter 7).

---

**FINDING 5.2: AMONG AUSTRALIA'S MAIN GOODS EXPORTS, ONLY IRON ORE IS IDENTIFIED AS VULNERABLE**

Among Australia's main exports, data analysis identifies only iron ore as vulnerable. Including iron ore, vulnerable exports account for around 25 per cent of the value of goods exports. Excluding iron ore, only around 1.5 per cent is considered vulnerable (using the Commission's framework and thresholds).

Even for an export as valuable as iron ore, identification as vulnerable using the framework developed here has no immediate implication for public policy.

Varying the parameters used to identify vulnerable exports can lead to other main exports being identified as vulnerable. LNG would be identified as vulnerable, for example, if the market concentration threshold (filter 1) were reduced from 80 to 70 per cent, or the number of years that a product must be captured by the first three filters were reduced from four to three (appendix E). This is because 70 per cent of Australia's LNG exports went to Japan from 2012 to 2015 (in recent years, production and exports have increased dramatically and China has become a much more important customer).

#### In most regions, employment is not concentrated in producing vulnerable exports

The effects of downstream disruptions are likely concentrated in the regions where the exports are produced. Employment and income in regions that rely on exports can be exposed to disruptions to market access. To analyse this topic, the Commission has estimated the share of market sector employment associated with the production of vulnerable exports in different statistical area level 4 (SA4) regions.<sup>26</sup>

The analysis suggests that very few regions specialise in the production of vulnerable exports (figure 5.7). Employment in industries that produce vulnerable exports accounts for less than 5 per cent of market sector employment in all but one region, where iron ore mining accounts for over a quarter of all market sector employment (Western Australia – Outback (North)).

These estimates should be treated with care. They do not account for the fact that other market activity in regions probably exists only to service industries producing vulnerable exports, which would be negatively impacted by disruption to those exports. In that sense the figures are likely lower-bound estimates of regional employment associated with vulnerable exports. But there is also no accounting for regional economies' ability to adjust, which will tend to mitigate the negative impact of any shocks.

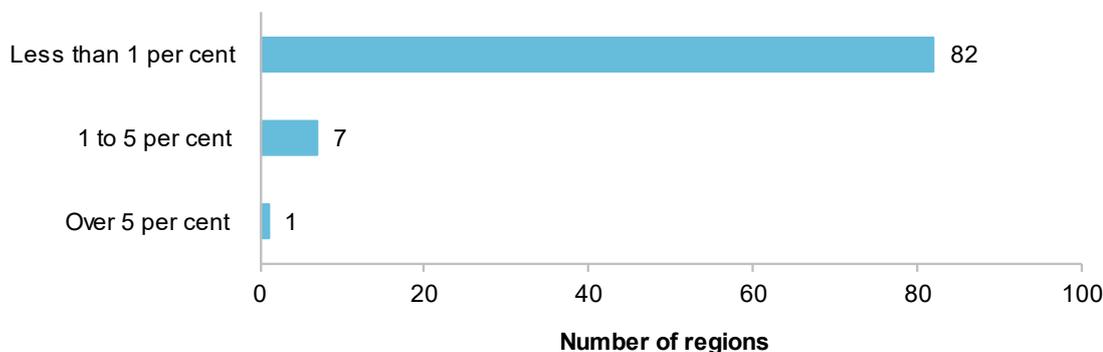
---

<sup>26</sup> As of May 2021, employment in SA4s ranged between about 17 000 and 2.8 million persons, and half of all SA4s had total employment of between about 85 000 and 194 000 persons. Representing labour markets was a key consideration in the delimitation of SA4s (ABS 2016; Labour Market Information Portal 2021).

---

**Figure 5.7 In most regions, employment is not concentrated in the production of vulnerable exports**

Estimated share of market sector employment directly engaged in the production of vulnerable exports<sup>a,b</sup>



<sup>a</sup> 'Migratory offshore' and 'no usual address' SA4s are excluded from the analysis. <sup>b</sup> The methodology used to produce these estimates can be found in appendix E.

Data sources: ABS (*TableBuilder: Census of Population and Housing, 2016*, Cat. no. 2901.0); CEPII (2021).

---

## Some markets adjust quickly, others more slowly

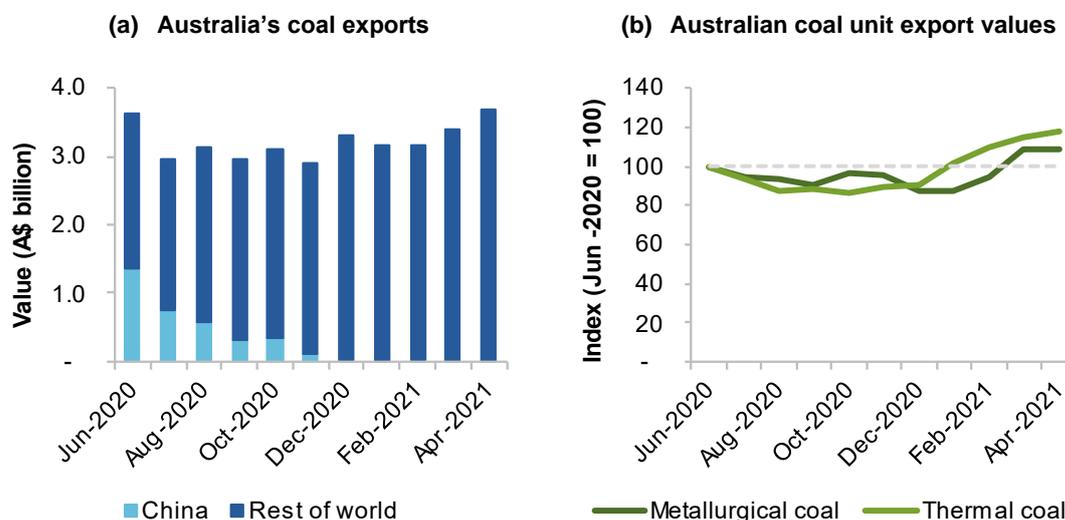
When exports are geographically concentrated, it can be difficult to find alternative export markets if demand is disrupted. If alternative markets are not available, or if alternative markets are small relative to the main/primary market, disruptions tend to reduce prices and the value of Australia's exports significantly.

The finding that coal is not a vulnerable export is consistent with how recent disruptions have played out.<sup>27</sup> Reports emerged in June 2020 of ships having difficulty unloading Australian coal at Chinese ports, and by late 2020 it was clear that China had implemented informal bans on Australian coal imports (Henderson et al. 2020). This decreased prices but 'markets have quickly adjusted to the Chinese trade disruptions on Australian coal' (DISER 2021b, p. 4). Increased exports to other markets have largely offset the decline in exports to China and prices received by Australian exporters are similar to what they were in mid-2020 (figure 5.8).

---

<sup>27</sup> Analysis of the global trade data does suggest that some categories of Australia's coal exports should be regarded as vulnerable, but the global trade data does not adequately capture the distinction between thermal coal (used to produce electricity) and metallurgical coal (used to produce steel). Analysing data that does capture this distinction (DISER 2021b) shows that no destination market accounts for over 50 per cent of Australia's exports of either type of coal.

**Figure 5.8 Coal exports to other markets have largely offset the loss of the Chinese market and prices are at pre-disruption levels**



Data sources: DFAT (2021b); DISER (2021a).

In contrast to what occurred with coal, exporters of timber products — which are identified as vulnerable — have experienced difficulty finding new customers following China banning some Australian timber imports in late 2020, citing biosecurity concerns (ABC/Reuters 2020; Lynch 2021b). Between October 2020 and April 2021 total exports were down by half, although exports to some markets increased during the period. Monthly exports to India, for example, went from around \$0.2 million to nearly \$20 million over this period (DFAT 2021b). In another example, exporters of rock lobsters — which are also identified as vulnerable — appear to have had greater difficulty finding new international markets following China’s import ban in late 2020 (Wood 2021).

The difficulty that exporters may face finding or expanding in alternative export markets is a function of many factors not captured in the Commission’s analysis. For example, the costs of finding new customers will likely be smaller for standardised products like coal than differentiated products like wine (Rajah 2021). The growth of Australia’s wine exports to China in recent years, for example, is partly attributable to years of investment in advertising and education campaigns (Westcott 2021). Businesses have invested in marketing and brand-building activities in other markets in the months following China’s introduction of prohibitive tariffs in late 2020, but such investments can take years to pay off (Evans 2021; Le May 2021).

Similarly, exporters of differentiated or premium products may have greater difficulty expanding into new markets because they likely already target markets with relatively high willingness to pay. This means that selling into new markets may require discounting. In

---

2019, only 1 per cent of the value of Australia’s vulnerable exports were classified as ‘differentiated’ (this included, for example, watches) (CEPII 2021; Rauch 1999).<sup>28</sup>

Adjusting production or marketing to ensure compliance with requirements is another factor that can make switching to new markets costly. (Even if adjustment is not necessary, verifying existing processes to ensure compliance has costs.) Wine exporters looking to begin selling in the United States, for example, would need to ensure they comply with the *Internal Revenue Code*, *Federal Alcohol Administration Act*, *Alcohol Beverage Labeling Act* and *Food, Drug and Cosmetic Act* (Wine Australia 2021).

Adjusting to export demand shocks through expanding domestic sales is another channel for mitigating — but not eliminating — the impact of such shocks.

- In the case of timber, inability to source timber has reportedly been a barrier to some Australian processors growing their operations, so it is possible that the domestic market will absorb at least some of the timber that otherwise would have been exported to China (Herrmann and Green 2020). However, many Australian processors are not set up to use the type of timber previously exported to China. (Packham and Barrett 2021).
- In the case of rock lobsters, product destined for sale in China at about \$100 per kilogram was sold in the domestic market, for \$30; a boon for domestic consumers but a major hit to producer income (Wood 2021). This suggests that domestic demand could not absorb large quantities at the higher prices. Responding to the import ban, some producers expanded production of a cooked product to sell locally and abroad (Harkell 2020).

Although finding new markets is costly and can require price discounts, the total impact of disruptions can easily be overstated. The capacity for adjustment is a feature of a market economy; the role of governments is to minimise impediments that regulation might impose on this capacity for adjustment (chapter 7).

## How vulnerable are services exports?

The filters applied above cannot be applied to services exports because detailed data on global trade in services is unavailable. Instead, the first filter is applied to Australia’s two largest services exports — education-related travel services (education) and other personal travel (tourism) — which make up about 60 per cent of Australia’s services exports. Data on these industries is gathered from a range of public sources.

The only filter that can be used to analyse the vulnerability of services exports is whether Australia is reliant on a single market (filter 1 in table 5.1). If the exporter is reliant on a single market, then it makes the export vulnerable to geopolitical risks and foreign exchange

---

<sup>28</sup> Rauch (1999) identified whether exported products: (1) were traded on organised exchanges, (2) had reference prices quoted in trade publications, or did not satisfy (1) or (2). If neither (1) nor (2) were satisfied, an export was identified as differentiated.

---

risks, for example. The other filters are not relevant because the global markets for education and tourism services are not concentrated.

## Education

Education was Australia's largest services export in 2019-20 and the fourth largest Australian export overall, representing 8.3 per cent of Australia's exports (figure 5.1). International students spent about \$15.6 billion on fees and \$21.7 billion on goods and services, both of which count as export revenue (ABS 2020d).

Higher education is a large part of national income and comprises about 68 per cent of education exports (ABS 2020d). The sector is not defined as vulnerable because no single market accounts for more than 80 per cent of exports. The proportion of international student enrolments from China, the largest source of international students, was 37 per cent in 2019 (DESE 2021), well below the threshold of 80 per cent chosen for deeming vulnerability in goods or services. There are other markets that universities have access to if there is a disruption to enrolments from Chinese students.

## Tourism

Tourism is Australia's second largest services export, accounting for 3.4 per cent of Australia's exports in 2019-20 (figure 5.1). This export is also linked to education as many parents of international students will come to visit their children.

Applying the first filter to the export market shows that the tourism sector is not vulnerable to a disruption in a single market. In 2019, 8.7 million international visitors came to Australia; of these, 15 per cent came from China, 15 per cent from New Zealand, 9 per cent from the United States, 8 per cent from the United Kingdom and the rest from other economies (Tourism Research Australia 2021). These values are all below the 80 per cent cut-off.

This analysis does not take into account the different spending patterns of tourists, but doing so does not change the conclusion. Chinese tourists spend up to three times more than any other tourist, so spending by Chinese tourists represents about 28 per cent of total spending (Tourism Research Australia 2021), which is well below the 80 per cent cut-off.

## Risks to services exports

The Commission's application of the framework to Australian exports has focused on geographic concentration as a source of risk, and both tourism and education were found to be not vulnerable.

The COVID-19 pandemic, however, has highlighted that the main risk to education and tourism export revenue is restrictions on the movement of people, including migration

---

policy, lockdowns, and border closures, which affect demand for services and the ability to supply services. For example, travel restrictions have caused a decline in the number of international students in Australia by about 9 per cent from 2019 to 2020 (AEI 2021), which affects university revenue. The longer borders remain closed, the more this jeopardises university and tourism income. Online services can act as a substitute for some services such as education — some universities use online learning and have discounted online programs to attract and retain international students (Hare 2021).

Understanding the effects of policies on these services requires a deep dive analysis that is beyond the scope of this study.

**FINDING 5.3: AUSTRALIA'S BIGGEST SERVICES EXPORTS ARE NOT VULNERABLE**

Education and tourism services are Australia's biggest services exports. These services are not identified as vulnerable because the main importer makes up less than 40 per cent of the market. However, both education and tourism services are vulnerable to factors that impede the movement of people.

### **5.3 Vulnerable imports used to produce exports**

Some of Australia's exporting industries use vulnerable imports (those identified in chapter 4) in production. Reliance on vulnerable imports makes exporting industries more susceptible to short-term disruption if the supply of those imports were interrupted and if those inputs were critical to production (box 5.1).

**Box 5.1 Disruptions to supply of critical inputs in mining during the COVID-19 pandemic**

The COVID-19 pandemic resulted in disruptions to supplies of critical inputs to the Australia mining industry. For example, underground coal mining in Australia requires the use of P2 and N95 masks and respirators to minimise the risks to health and safety of miners. The global demand shock for face masks and the prioritisation of securing personal protective equipment (PPE) for health industries led to a shortage of 50 000 masks per month in the Australian coal mining industry (Minerals Council of Australia, sub. 14, p. 3). This shortage posed 'immediate risks to the continued operation of some mines (and potentially downstream industries such as coal-fired power stations)' (ACCC 2020a, p. 4). Disruptions to mining operations were avoided by the ACCC granting the mining industry permission to coordinate to source a range of critical inputs, with the flexibility to add to the list of critical inputs as the COVID-19 pandemic unfolded and more critical inputs were identified (Minerals Council of Australia, sub. 14, p. 3).

There are several categories for face masks in the trade data using the Harmonized Tariff Item Statistical Code (HTISC) product classification, none of which are identified as vulnerable to single-source supply in chapter 4.

Chapter 4 identified 292 imported products as vulnerable to supply disruptions. This included many products used as inputs into Australian production, including textile, chemical, wood, metal, machinery and electrical, stone and glass, and mineral products.

This section identifies the extent to which those vulnerable imports are used to produce Australia's top 10 exports.<sup>29</sup> The analysis focuses on Australia's most valuable exports because a disruption to these exports would tend to have larger negative impacts on the Australian community. These exports and the industries that produce them are listed in table 5.2.<sup>30</sup> Input-Output (I-O) industry classifications sometimes group the production of multiple products. For example, beef is one of Australia's main exports but I-O industry classifications group the production of sheep, grains, beef and dairy cattle together.

**Table 5.2 Australia's main export industries**

<i>Grouping</i>	<i>Most valuable exports (rank)</i>	<i>Industry (Input-Output Industry Group)</i>
Iron ore	Iron ores and concentrates (1)	Iron ore mining
Coal	Coal (2)	Coal mining
Oil and gas	Natural gas (3) Crude petroleum (9)	Oil and gas extraction
Education	Education-related travel services (4)	Technical, vocational and tertiary education services (including undergraduate and postgraduate)
Metal ores	Gold (5) Aluminium ores and concentrates (8) Copper ores and concentrates (10)	Non-ferrous metal ore mining
Tourism	Personal travel services (6)	Accommodation Food and beverage services Employment, travel agency and other administrative services
Beef	Beef (fresh, chilled, frozen) (7)	Sheep, grains, beef and dairy cattle Meat and meat product manufacturing

Sources: ABS (*Australian National Accounts: Input-Output Tables, 2016-17, Cat. no. 5209.0.55.001*); DFAT (2021a).

<sup>29</sup> The analysis is equivalent to that in section 4.3 and details of the method are found in appendix C.

<sup>30</sup> Logistics industries (such as wholesale trade, road transport, air and space transport) are excluded from this section. While these industries facilitate trade, inputs into these industries are already analysed in chapter 4.

---

## How reliant are Australia's main export industries on vulnerable imports?

Imports represent a small fraction of the production costs of Australia's main exporting industries (figure 5.9a). In 2016-17, payments to domestically-sourced labour and capital (primary factors) were typically the largest components, with the exception of beef production where inputs of domestically-sourced goods (mostly cattle) represented a higher share of costs.

Most goods inputs were domestically sourced but some industries relied on imported inputs more than others (figure 5.9b). For example, imports represented about 73 per cent of the cost of all goods inputs for education, but under 9 per cent for beef. Industries that use more imported inputs in production are likely to be more susceptible to import supply disruptions.

Most main export industries used imports of fuels; specialised and other machinery and equipment; basic chemical products; accommodation; and some clothing (likely PPE) (based on the broad product groups of the I-O tables). But the types of products that are imported varies by industry. For example:

- beef production used imports of veterinary pharmaceutical and medicine products
- tourism used imports of food products, air and space transport, and travel agency services
- education used imports of professional, scientific, computer and electronic equipment and publishing services (except internet and music publishing).

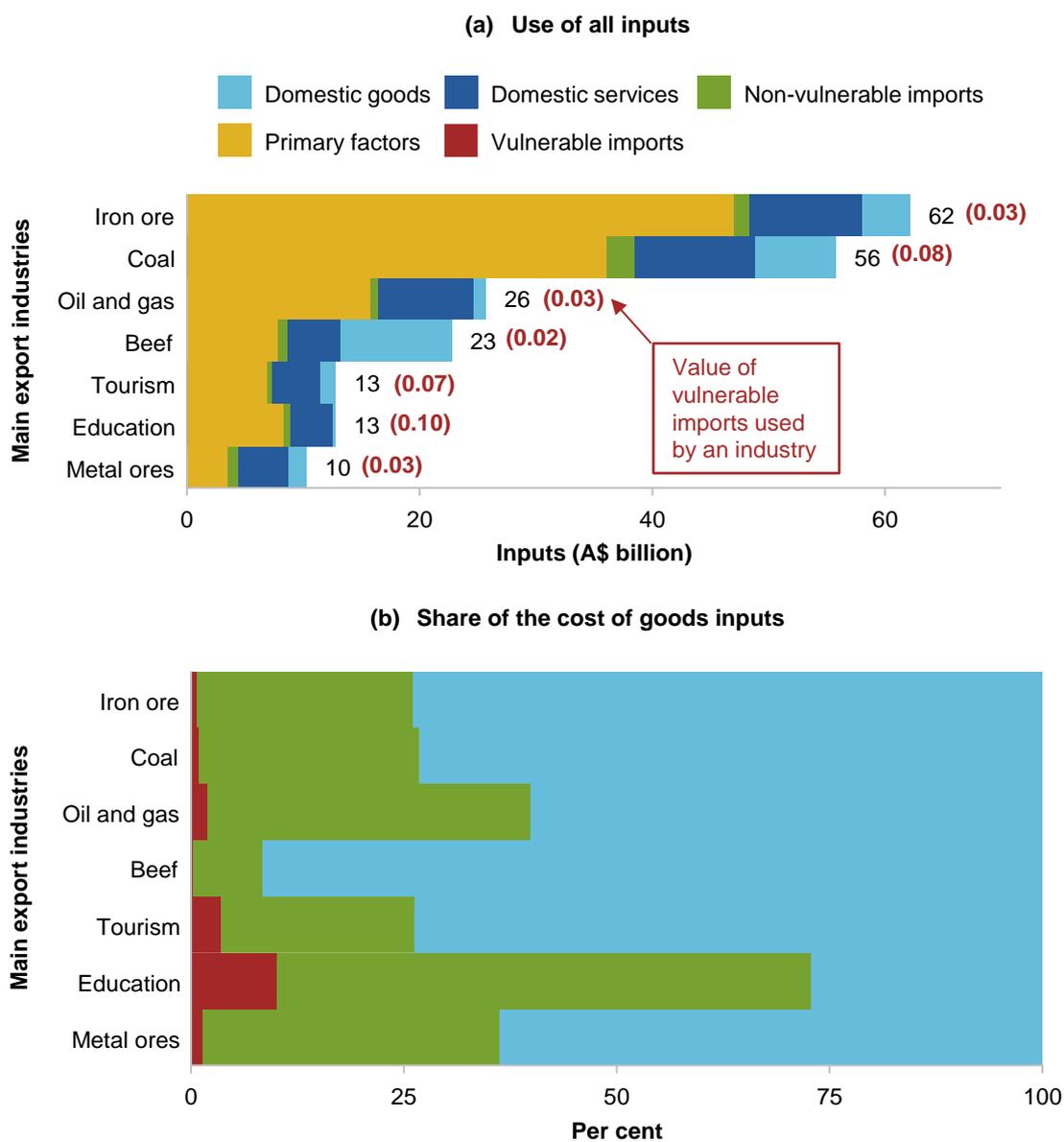
If the vulnerable imports identified in chapter 4 (based on the finely-grained trade data) fall into these larger product groups, then the industries that rely on them may be relatively more exposed to import disruptions and susceptible to supply chain disruptions, particularly if the imported goods are also critical inputs (that is, there are no substitutes).

Vulnerable imports represent a small fraction of the cost of all goods inputs for export industries (figure 5.9b). Education had the largest share at 10 per cent, while beef had the lowest share at less than 0.5 per cent because most of their goods inputs were locally sourced. For iron ore, Australia's largest export, vulnerable imports accounted for less than 1 per cent of the value of all goods inputs.

The finding that vulnerable imports represent a small share of the goods used in main export industries is suggestive evidence that vulnerable imports may not be *critical* to the production of Australia's main exports. However, this evidence is not conclusive because criticality can be independent of value (such as the relatively inexpensive face masks that are critical to underground coal mining, see box 5.1).

**Figure 5.9 Imported inputs form a small part of main export industries' cost structures**

Input use by main export industries, A\$ billions, 2016-17<sup>a,b,c</sup>



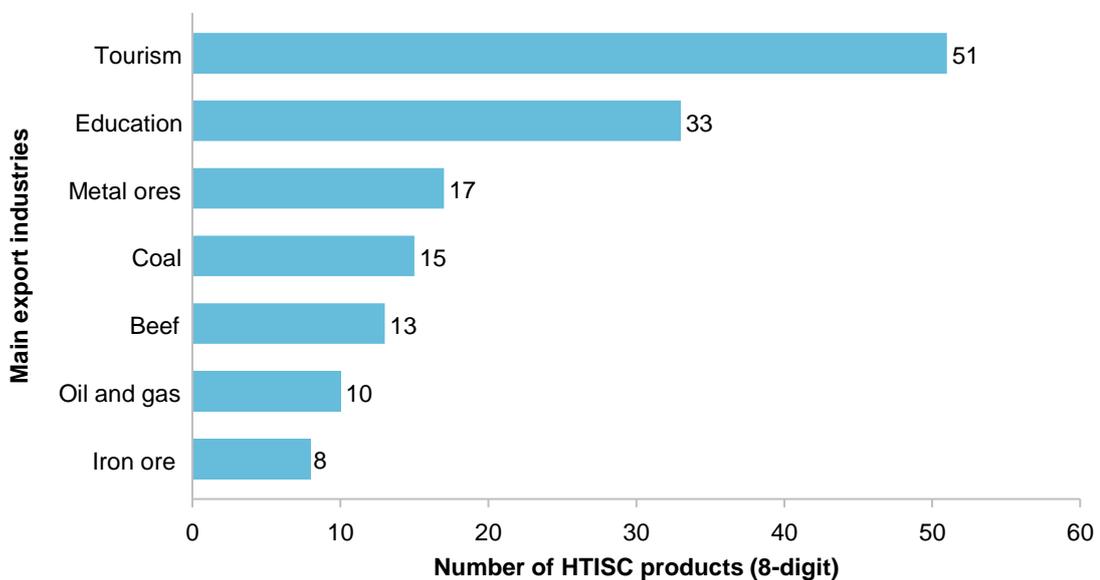
<sup>a</sup> Export part of production only. <sup>b</sup> Primary factors include payments to labour and to owners of capital. <sup>c</sup> Imports include some services as a result of the mapping of import data to I-O industries.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

Australia’s main export industries used 66 vulnerable imports, but import use varied across industries (figure 5.10).<sup>31-32</sup> Tourism and education used a larger number of vulnerable imports than all the other main export industries. Oil and gas extraction and iron ore mining used the least.

Similarly to the results for essential industries (chapter 4), laptops and computer equipment were used in most main export industries and were the highest-value vulnerable import. Some products (such as grinding balls<sup>33</sup>) were used by a handful of industries (such as coal and metal ores mining).

**Figure 5.10 Tourism used the largest number of vulnerable imports**  
Number of vulnerable imports used in main export industries, 2016-17<sup>a</sup>



<sup>a</sup> Products identified as vulnerable if the imports used by an industry were more than A\$1 million.

Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables, 2016-17*, Cat. no. 5209.0.55.001); UN Comtrade (2020).

Many of the vulnerable imports used by Australia’s main export industries are classified as textiles or ‘miscellaneous products’ (table 5.3). The tourism and education sectors are unlikely to cease to function, at least in the short term, without access to new clothing, video

<sup>31</sup> Only 281 of the 292 vulnerable imports identified in chapter 4 could be mapped to product groups in the production data (Input-Output Product Groups).

<sup>32</sup> A minimum value filter of A\$1 million was used to screen out products that otherwise met the criteria for being considered a ‘vulnerable import used by a main export industry’. Very small import values arise for some products as a result of the coarser nature of the mapping of imports and production classification changes over time (as the I–O products are defined at a higher level of aggregation than the imports data).

<sup>33</sup> Although identified as vulnerable, grinding balls are subject to an anti-dumping measure indicating that there is some local supply (ACCC 2018).

games, wrist watches and brooms. This result is likely a function of these two industries producing services, rather than goods, and so imports of vulnerable goods are less likely to be critical. This also suggests that a larger *number* of vulnerable imports used by an industry does not always reflect a greater susceptibility to supply chain disruptions.

The analysis suggests that the main supply chain disruption risks are to the mining of iron ore, coal, and other metal ores which use imports of chemical products, some of which are identified as vulnerable to having a single source of supply. These products point to avenues for further investigation with experts to determine whether any are critical to production.

**Table 5.3 Main export industries use many vulnerable imports of textiles and miscellaneous products**

Number of vulnerable imports used in main export industries, by product type. Products defined at the HS Subheading level (8-digit)

<i>Product type<sup>a</sup></i>	<i>Tourism</i>	<i>Education</i>	<i>Metal ores</i>	<i>Coal</i>	<i>Beef</i>	<i>Oil and gas</i>	<i>Iron ore</i>
Animal and animal products	4	1	0	0	0	0	0
Chemicals and allied industries	0	1	2	1	3	0	1
Foodstuffs	7	1	0	0	1	0	0
Footwear and headgear	2	1	1	1	1	1	0
Machinery and electrical	2	2	4	3	1	2	1
Metals	1	0	2	2	0	1	0
Miscellaneous	14	17	1	1	1	1	0
Raw hides, skins, leathers, furs	1	1	0	0	0	0	0
Stone and glass	1	2	1	1	0	0	1
Textiles	9	5	4	4	3	3	3
Transportation	0	0	2	2	1	2	2
Vegetable products	9	0	0	0	2	0	0
Wood and wood products	1	2	0	0	0	0	0
<b>Total</b>	<b>51</b>	<b>33</b>	<b>17</b>	<b>15</b>	<b>13</b>	<b>10</b>	<b>8</b>

<sup>a</sup> Product types based on an aggregation of the 21 product groups listed in Schedule 3 of the *Customs Tariff Act 1995* (Cwlth) aggregated to 15 groups. No mineral products or plastic and rubbers products were used, so these product types are not listed in the table.

Sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *Australian National Accounts: Input-Output Tables*, 2016-17, Cat. no. 5209.0.55.001); UN *Comtrade* (2020).

**FINDING 5.4: FEW IMPORTS IDENTIFIED AS VULNERABLE ARE LIKELY TO BE CRITICAL TO THE PRODUCTION OF AUSTRALIA'S MAIN EXPORT INDUSTRIES**

Australia's main export industries used 66 vulnerable imports in production, but most of these products are unlikely to be *critical* to production processes. Further, vulnerable imports are a small share of the goods used in production, by value, which is suggestive evidence that they may not be critical to production, but it is not conclusive because criticality can be independent of value. Consultation with industry experts is needed to assess criticality, especially for vulnerable imports of chemical products used in mining.

---

## 6 Supply chain risk management

### Key points

- Supply chain risk management balances the trade-off between the expected costs of a disruption — that is, a potential increase in the cost of purchasing goods and services upstream or a potential loss of revenue downstream — with the opportunity cost of investing in risk management.
- Risk management is costly, much like buying insurance to protect against other types of risks is costly.
- To make an effective decision on the level of risk to manage, firms need to understand the nature of the potential disruption (likelihood, size, etc.), and its potential impact to their supply chains. This is not always straightforward. Supply chains can be long, complex and opaque, and information on a firm's supply chain can be difficult to obtain.
- Biases can affect the decisions of firms to invest in risk management. For example, because of the experience with the COVID-19 pandemic, firms may over invest in strategies that seek to mitigate the risk of a future pandemic, when other risks may be more probable and imminent.
- Firms will employ risk management strategies such that the perceived benefit of their mitigation exceeds the potential costs of a disruption.
  - Key strategies used to prepare for supply chain risks include: no action, stockpiling, supplier or market diversification, contingent contracting, and developing domestic capability.
- Different strategies will perform better under different types of disruptions and contexts. For example, some strategies are not effective at managing downstream risks.
  - Firms will likely have to employ a range of strategies to effectively manage risk.

Firms operate in a world of uncertainty, taking risks in pursuing their objectives. With risks come the possibility of success but also failure, and adverse events can have significant cost implications for firms and the community. This chapter establishes a framework to better understand risk management of a firm's supply chain (section 6.1), and then explores the key elements to assessing and managing supply chain risks, including understanding risks (section 6.2) and identifying how to best manage them (section 6.3).

Identifying who should manage supply chain risks, including the role of government, is covered in chapter 7.

---

## 6.1 A framework for managing risks

### Thinking about risk

Risks of a disruption can be characterised by the probability of an event occurring and its consequences (Ritchie and Brindley 2007, p. 305). There is uncertainty about what, when and where disruptions will occur (for example, they could be geopolitical events, natural disasters or economic crises), as well as their intensity and impact.

The likelihood of some external risks (environmental, geopolitical, and so on) may be difficult to assess accurately, but even low probability risks or those that are difficult to estimate should be managed as they can have severe consequences. If not managed effectively, these disruptions can impact a firm's operations, or have broader market-level implications that threaten the supply of essential goods and services to the community.

The consequences of an event can be viewed as their effect on profit (either through increased costs or lower revenues). An interruption in supply might cause costly delays or force a firm to find another, higher-cost, source of supply. If no supply is available, the interruption is similar to an infinite increase in costs. This conceptualisation also applies to downstream interruptions. Where there is a disruption to a firm's buyers, alternative buyers may only purchase the good at a lower price, lowering a firm's revenue.

Other aspects of supply chain disruptions that affect the cost of a disruption include:

- the **duration** of the event, such as how long the effects may last for
- the **lead time** of the event and how much time a firm has to implement a response before the effects are felt
- the **initial shock** and **contagion** of the shock, which can be considered from both a geographical perspective and an industry perspective. For example, the initial shock of the COVID-19 pandemic was felt by China, then spread to other economies. Likewise, for industries, initially only a few industries were affected (those that relied on production in the Wuhan area) then this spread as the virus spread (McKinsey & Company 2020b, pp. 23–24).

Taken together, the probability of a disruption and its consequences quantify a risk. Firms can then use this information to assess the costs and benefits of various supply chain risk management strategies.

### Managing risks in a supply chain

Risk management can be used to mitigate the costs of disruptions, and better manage their consequences once they occur. Broadly, risk management involves three steps:

- understanding risk — identifying which risks are faced and their likely consequences

- 
- treating risk — making decisions on how to best manage risks, such as reducing exposure to risks through diversification or investing in capacity to recover from a disruption
  - owning risk — determining who is responsible for managing supply chain risks.

Firms can lessen the consequences of disruptions by improving how they anticipate, react to, and recover from them. However, not all risks will be managed. Some risks (or consequences from certain disruptions) will not be managed because they cannot be foreseen. Others will not be managed because the cost of mitigation is too high relative to the potential consequences.

Risk management does not mean that all disruptions identified by a firm can be avoided, but the effects of many can be reduced. Earthquake proofing a building does not mean that it would be completely protected from damage, but will likely reduce the amount of damage that occurs in the event of an earthquake. The initial cost of risk mitigation would be borne regardless of whether an earthquake occurs, but this form of physical insurance would be chosen when it is cheaper than the expected costs of major building repairs if an earthquake occurs and no mitigation activities are undertaken.

There are various stages of building supply chain resilience — from prevention through to recovery (box 6.1). Firms may treat risks across several stages. For example, demand shocks can be treated using a combination of preparedness strategies and response strategies (box 6.2).

### **Trade-offs must be made**

While supply chain disruptions increase costs, managing risks also has costs. People take steps to protect their health, income and assets against risks by buying insurance. Likewise, investing in strategies to manage supply chain risks involves costs — the investment is equivalent to paying insurance premiums. Thus, firms accept higher costs in good times in order to lower costs in the event of a shock.

Resources, such as the time, money or effort needed to understand, manage and deal with risks, have opportunity costs — that is, they cannot be devoted to other uses. These costs are part of all the other costs of supplying goods and services; they contribute to the price of goods and services, and fall eventually to consumers. For example, the costs of diversifying a consumer base arise mainly in the forms of additional marketing costs and foregone income as alternative markets may require some discount to gain a share of the market.

## Box 6.1 Stages of supply chain risk management

Risk management strategies can be thought of in a prevention, preparedness, response and recovery paradigm that is often used in emergency and disaster management. In the context of this study, strategies improve supply chain resilience by:

- preventing a disruption (or lowering the likelihood of a disruption occurring)
- preparing the rest of the supply chain to avoid the costs of a disruption
- improving the speed and effectiveness of the firm's response
- facilitating a firm's recovery from a disruption.

Firms make decisions about investing in each of these stages before a disruption, but naturally some strategies will only come into effect after a disruption has occurred (response and recovery).

Different risks are better treated in different stages. For example, a predictable risk (such as the potential consequences of the United Kingdom withdrawing from the European Union) might best be treated in the prevention stage. However, an unknown, highly uncertain risk (such as a large storm) might be better treated through response and recovery (or in preparatory actions that will help foster a more effective response or recovery after a disruption). A combination of strategies used at different stages is likely to be the most effective approach to managing risks.

The figure below outlines some of the different strategies available to firms.

Prevention	Preparedness	Response	Recovery
Reduce the likelihood of a disruption	Prepare the rest of the supply chain to mitigate costs of the disruption	Improve the speed and effectiveness of the firm's response	Recover from the disruption
<p>Locate factories, suppliers or warehouses in areas that are less prone to disruption</p> <p>Choose suppliers that are less vulnerable to disruption</p> <p>Invest in risk management for critical suppliers</p>	<p>Hold additional buffer stock</p> <p>Have additional capacity among other suppliers</p> <p>Diversify consumer base, supply network and geographic footprint</p> <p>Postpone point of product differentiation</p> <p>Have interoperable component parts</p> <p>Use contingent contracting</p> <p>Take out insurance</p>	<p>Invest in early detection systems</p> <p>Have contingency plans in place ahead of a disruption</p> <p>Have flexible manufacturing processes</p> <p>Adjust prices or use promotions to influence consumer behaviour</p>	<p>Develop post-disruption recovery plans</p>

Sources: Hopp et al. (2012); PC (2014b).

---

## Box 6.2 Managing risk from surges in demand

While supply disruptions can arise from disruptions to suppliers or distributors in a chain, they can also come from fluctuations in global or domestic demand for a good. For example, during the COVID-19 pandemic, supply chains were disrupted by sharp increases in demand for personal protective equipment and other medical products. This was compounded by limitations on expanding supply, such as factory closures or reduced capacity due to health regulations.

Surges in demand have the same effect as sudden declines in supply — shortages occur and prices rise. Firms can prepare for disruptions using certain supply-side risk management strategies (such as stockpiling or having contracts with suppliers that can ramp up production if needed), but they can also respond to disruptions through demand-side strategies. Supply- and demand-side strategies can work together, where the former help to meet demand, and the latter help to smooth or dampen demand.

Where there is a shortage, prices help allocate what supply is available (in addition to incentivising firms to increase supply). The benefit of prices managing the allocation of disrupted supplies is that those who value a good the most (and are able to pay for it) are able to obtain it.

If prices are unable to adjust or become prohibitive, firms and governments can introduce buying limits or other restrictions to manage a shock. Non-price mechanisms are generally used in a crisis for goods that are critical for wellbeing. For example, product purchase limits were used to reduce shortages from panic buying and stockpiling of medicines by hospitals, pharmacies and consumers. Also, limited supplies of COVID-19 testing kits were initially only made available to higher-risk cases.

Firms and governments can also manage demand by providing information, especially where consumers might not be making rational purchasing decisions. For example, in an effort to calm panic buying, governments and supermarket retailers communicated to consumers that there was sufficient capacity to meet demand and there was no need to stockpile groceries.

*Sources:* Knaus and Doherty (2020); Pharmacy Guild of Australia (sub. 16, p. 13); Smeets (2020).

Effective risk management involves purchasing the right amount and type of insurance, taking account of: the benefits of the different strategies; the probability of a disruption; the estimated costs of a disruption; the firm's degree of risk aversion; and the opportunity costs of the resources needed to manage risks.

A key part of making an appropriate trade-off is to identify an acceptable degree of risk aversion — the willingness to bear some risk of loss rather than devoting additional resources to reduce the risk. At some point, people choose to live with some exposure to risk so that they can continue to use their resources in other ways. Where that point is depends on a firm's aversion to risk, the cost of risk management, and the probability and cost of disruptions.

This study focuses on effective risk management from a community perspective — that is, balancing trade-offs and accounting for the consequences of a disruption to the community and society's degree of risk aversion. This means choosing the balance of risk management strategies that maximises community wellbeing over time.

---

While ‘insurance’ is a useful analogy to highlight the costs of risk management strategies, there are some important distinctions between risk management in this study relative to a common insurance product. Many insurance products focus on financial compensation in the event of a disruption and firms can purchase business continuity insurance to protect themselves financially from supply chain risks. This form of insurance does not protect the community from losing access to essential goods or services when a disruption occurs.

For industries that are considered essential because they produce income, the distinction between physical restoration and financial compensation is less important. However, for other industries, it is important to consider risk management strategies that restore access to critical inputs in the event of a disruption. Further, while pooling of risks is commonly used by insurers to manage risks, some firm-level risk management strategies (such as stockpiles or domestic production) do not involve diversification of risk.

Effective risk management is hard to do in practice, because there are a broad range of supply chain risks; supply chains are complex and opaque to assess for risk, and there are many possible strategies to address different types of risks. That said, some principles can help. In particular, risk management strategies are best implemented by those who are close to the risk, have the best information required to manage it, have incentives to do so, and face few impediments.

#### FINDING 6.1: SUPPLY CHAIN RISK MANAGEMENT FRAMEWORK

Supply chain risk management is similar to buying insurance for other types of risk. In effect, a firm pays an insurance premium upfront to invest in strategies to insure itself against potentially large cost increases if a disruption occurs.

## 6.2 Understanding risk

For firms to manage risks effectively, they need to understand their upstream and downstream supply chains and how risks make them vulnerable. Contributors to a supply chain’s vulnerability include lack of flexibility, length and geographic clustering (chapter 2).

Gathering information to better understand risks is not costless. This may be particularly problematic for small firms, who lack scale to benefit from large investments required to better understand the full set of their upstream suppliers or downstream buyers. Survey data indicate that small firms were far less likely to ‘assess and record’ changes in their supply chain as part of their supply chain risk management activities (17 per cent for businesses with 0-4 employees, compared with 42 per cent for businesses with 200 or more employees) (ABS 2017b).

Understanding risks along the entire supply chain can also be difficult. For example, for Dell’s network of over 7000 suppliers (McKinsey & Company 2020b, p. 48), the costs of

---

understanding what each supplier does and what risks they face rises with each additional node. Firms may only have a murky view of their supply chain beyond their first tier suppliers. This can lead to problems when disruptions occur further upstream. For example, in 2007, Menu Foods Corp., a producer of pet food had to recall more than 60 million cans and pouches of dog and cat food following a number of reported deaths. The deaths were linked to contaminated wheat gluten procured from ChemNutra, who, unbeknownst to Menu Foods, had outsourced its production to Xuzhou Anying Biologic Technology Development Co. Ltd (Yang et al. 2009, p. 192).

Similar challenges exist for downstream parts of the supply chain. Firms may only understand the demand of their immediate buyers, rather than the demand of end consumers. For example, global semiconductor shortages in 2021 were partly driven by a sudden demand surge in chips when car sales rebounded, after car manufacturers had earlier cancelled orders of semiconductors in anticipation of falling demand for vehicles. Other users stockpiled and increased their purchases of semiconductors, further exacerbating shortages (appendix B). In this case, had semiconductor manufacturers been able to better anticipate changes in the demand for the products their customers manufacture, they could have managed these downstream disruptions better (King, Wu and Pogkas 2021b; Vakil and Linton 2021).

However, a firm may not need to understand its entire supply chain to effectively manage risks. If each firm in a chain recognises the risk from ‘one level up or down’ and takes appropriate action, then it may be unnecessary for them to understand risks further along a supply chain. For example, had car manufacturers forecast the demand for cars accurately, then semiconductor manufacturers would not have needed to understand final demand for cars to manage their supply chain risks.

Well-designed contracts (with damages, for example) can encourage suppliers and buyers to manage and share information about the risks they face. However, this is not always possible in practice. A firm may not be willing to share information where it is proprietary or would hurt their commercial interests, such as by appearing riskier to prospective purchasers or by revealing who their customers are. This risk was highlighted when Land Rover was unaware of, and therefore unprepared for, the looming bankruptcy of UPFThompson — the sole provider of chassis for their Discovery model (Yang 2009, p. 5).

The likelihood of some external risks (environmental, geopolitical, and so on) are also difficult to assess accurately. Firms operate in an environment of uncertainty, where they have imperfect knowledge of future events, or where it may be impossible or too costly to estimate the probability or consequence of some events occurring. While estimating the likelihood of a specific type of disruption is difficult, firms can still estimate the likelihood of *any* disruption at a particular node, using historical information about the occurrence of events. Firms can also manage uncertainty by making provisions for contingencies where they might have little information.

Finally, cognitive and behavioural biases can affect how people and firms perceive risks. Cognitive biases mean that firms can underprepare for low probability events, and

---

overprepare for events that have occurred recently. During a long period of relative stability, the perceived probability of disruptions declines. This can lead to firms under-investing in risk management strategies.

Cognitive biases also mean that firms can over-estimate the probability of a disruption following the occurrence of an event, leading to firms over-investing in strategies designed to deal with that specific type of disruption (to the detriment of investing in strategies to deal with other types of disruptions). Such biases mean that firms may not always make full use of available information, or may evaluate the information inadequately.

Many firms, especially large ones, have sophisticated governance structures to overcome such biases, such as risk committees and frameworks to systematically assess, plan for, and manage risks. Despite this, there is evidence that firms do not always respond rationally to risk. For example, studies have shown that investments to guard against cyber- and IT-security threats have declined just as these threats have become more frequent and severe (Gaudenzi and Siciliano 2018, p. 87).

The pharmaceutical industry illustrates how different factors can impact an industry's understanding of a single supply chain (box 6.3).

## **How do firms understand supply chain risks?**

As part of their risk management practices, firms gather information on risks facing their supply chains. To better understand risks, firms work collaboratively with suppliers and buyers to understand and review potential risks, and to invest in technology and data analytics to help identify risks further along their supply chain. For example:

- Unilever developed a systematic approach to identify critical suppliers (Unilever 2020)
- Cisco implemented a remote monitoring system and developed good relationships between supply chain planners and vendors to keep it apprised of emerging issues downstream (this allowed it to manage the large drop-off in demand following the dot com bubble burst) (Martha and Subbakrishna 2002)
- GM implemented an information system combining information from suppliers and logistics hubs to monitor incidents (McKinsey & Company 2020b, p. 77).

Experts in supply chain management and procurement have also developed tools and practices to help firms better deal with risks in their supply chains (CIPS, sub. 7; KPMG, sub. 39). For example, the Chartered Institute of Procurement and Supply (sub. 7, pp. 46–48) reports that its members use a suite of risk and resilience frameworks.

---

### Box 6.3      **Pharmaceutical supply chains**

Pharmaceutical manufacturing involves two main stages. First, the production of active pharmaceutical ingredients (APIs), and second, the production of formulations — during which the APIs are transformed into tablets, capsules, creams, etc. (Horner 2020). Once the drug is manufactured, pharmacies buy medication from wholesalers and sell them to consumers (with a mark-up and a dispensing fee). If the drug is ‘scheduled’, the Government reimburses pharmacies under the Pharmaceutical Benefit Scheme.

At the beginning of the COVID-19 pandemic, many raised concerns about Australia’s reliance on imported APIs and other pharmaceutical inputs. Australia imports most of its pharmaceutical goods from Europe and the United States, who rely increasingly on APIs manufactured in India and China (PwC 2020). As of 2017, China produced 40 per cent of APIs globally and India supplied 20 per cent of global exports of generic medicines (UK MHRA 2017, p. 10).

During the COVID-19 pandemic, disruptions to Indian and Chinese production of APIs led to concerns of shortages in Australia (ABC 2020). Panic buying and stockpiling ensued and the Australian Government implemented purchasing limits to ensure equitable access to medicines (PSA 2020, p. 6). Despite concerns, the Australian pharmaceutical supply chain was ‘strong and stood up well to the challenges posed by the COVID-19 pandemic’ (Medicines Australia, sub. 55, p. 3). Many companies already had risk management strategies in place, such as emergency stocks of ingredients, and had manufacturing capacity in multiple locations (Mullin 2020). The Therapeutic Goods Administration also worked with industry through the Medicine Shortages Working Party to manage medicine shortages (TGA 2020b, p. 5). Concerns about supply were resolved when Chinese manufacturing recovered quickly and India removed export bans.

However, a lack of transparency did lead to confusion about whether there were actual shortages of medicines. The Pharmaceutical Society of Australia (2020, p. 6) noted in their submission to the Senate Committee on the COVID-19 pandemic:

While pharmaceutical wholesalers may have been in contact with the Therapeutic Goods Administration about supply issues, [information on shortages and wholesale limits] were often not shared more broadly with practitioners at the coalface, such as pharmacists and doctors.

Shortages of other medicines caused by the COVID-19 pandemic have also been reported, such as some hormone replacement therapies and antidepressants (Ross 2021). However, this does not appear to be out of the ordinary. Medicines Australia noted that ‘medicines shortage events, while perhaps more focused on products prone to hospital and public stockpiling due to [COVID-19], did not increase in Australia in 2020’ (sub. 55, p. 7).

Medicine shortages were common even before the COVID-19 pandemic, affecting patients, doctors and pharmacists (Tan, Moles and Chaar 2016). The combination of intense price competition (especially in the generics market) and a lack of transparency in supply chains hampers the ability of firms to assess accurately (and therefore reward) good quality management and supply chain resilience, which leads to shortages (US FDA 2019).

The pharmaceuticals industry is also highly regulated, making entering the market, or modifying existing facilities to respond to a crisis, a potentially slow process. For example, the Therapeutic Goods Administration took between 61-252 days in 2019-20 to approve major variations to medicines (major variations require evaluation of clinical, pre-clinical or bio-equivalence data). That said, they also expedited approval processes during the COVID-19 pandemic (TGA 2020a, p. 16), and are conducting consultations to investigate further reforms to address medicine shortages, and to build on reforms implemented in 2019 to create a medicines shortages reporting scheme (TGA 2021a).

---

Governments gather similar information for supply chains that they consider vital. For example, the Critical Infrastructure Centre conducts risk assessments to monitor vulnerabilities of key assets to espionage, sabotage and coercion risks, with a specific focus on the high risk areas of telecommunications, electricity, water and ports. Risk assessments are done in consultation with state and territory governments, regulators, and private firms, examining:

- cyber security and physical security
- security audits
- emergency management plans
- redundancies
- offshoring and outsourcing of operations
- existing regulatory regimes and controls (DoHA 2020c).

Technological advances have made it easier for firms to understand their supply chains (box 6.4). Advances in tracking technologies and data analytics have made it easier to predict where and when disruptions might occur. These advances have also made it easier to access real-time information about disruptions, facilitating a quicker response and recovery. For example, consumer goods manufacturer Procter & Gamble has integrated multiple types of real-time data for its suppliers and distributors, including inventory levels, road delays and weather forecasts. It also runs scenarios to identify effective solutions in the event of a disruption (McKinsey & Company 2020b, p. 76).

However, as GS1 Australia (sub. 8, p. 4) indicated, ‘the efficacy of [technological advances] is, often, dependent on data quality, governance frameworks and standards for capturing and delivering value through information’. For example, in the logistics sector, the Digital Container Shipping Association and the Blockchain in Transport Alliance have both developed data standards to facilitate the adoption and use of data and technology across the freight, transportation, logistics and affiliated industries (BiTA 2019; DCSA 2021). Improvements have also been made in data collection and analysis.

---

## Box 6.4 Technological advancements in supply chains

### *The internet of things (IoT)*

IoT enables the tracking of location, weather conditions, environmental status, traffic patterns and more. This allows supply chain managers to monitor assets throughout the logistics journey, track shipments and inventories, and whether anything needs to be remedied. One of the risks and costs associated with the use of IoT is the increased vulnerability of a chain to cyber-attacks.

### *Blockchain*

Blockchain is a distributed ledger technology, in which a record of an asset or transaction is maintained in multiple locations. Records of transactions can be used to track the origin of goods and establish trust in shared supplier information.

### *Artificial Intelligence, machine learning and analytics*

Artificial Intelligence, machine learning and analytics are increasingly used to automate many aspects of supply chain management, including warehouse operations, transport and logistics, and inventory management. These technologies are particularly useful: as supply chains become more complex, as data processing capacity increases, and to the extent that decision-making can be automated.

Source: Stackpole (2020).

---

### FINDING 6.2: UNDERSTANDING SUPPLY CHAIN RISKS

Effective risk management requires firms to invest in understanding their supply chain risks to ensure that the benefits of any investment to mitigate the costs of disruptions is at least matched by their potential effects and costs.

## 6.3 Risk management strategies

While it may not be possible for firms to foresee all potential risks, those that take action to understand their supply chain risks will be in a position to consider how to effectively mitigate their impacts.

This section focusses on risk management strategies that firms use to mitigate the impact of upstream and downstream disruptions. In the typology of risk management strategies (box 6.1), the focus here is on prevention and preparedness strategies that allow firms and economies to respond and recover following a disruption. These strategies complement those that firms use to prepare for a more predictable disruptive event that might affect their supply chain, as well as those used to respond to a disruption once it has occurred.

Some risk management strategies are specific to the risk being treated. For example, stockpiling and domestic production restore supplies when dealing with upstream

---

disruptions but are ineffective in managing a downstream drop in demand in an export market. Further, the performance of each strategy depends on the context and nature of the disruption. In most cases, firms apply multiple strategies to mitigate against potential disruptions. This section outlines the costs and benefits of these strategies.

## **Strategies applying to both upstream and downstream supply chain risks**

### **No action (to mitigate risk)**

‘No action’ can be an effective risk management strategy. This is where firms accept the existing risk, because it would be too costly to mitigate its effects, given a firm’s appetite for risk. For example, McKinsey & Company noted that many firms have accepted the likely impacts from the United Kingdom leaving the European Union (‘Brexit’).

For many companies, the UK market is simply not large enough to dedicate significant resources to prepare for Brexit. They believe that the consequences of Brexit will be short-lived operational issues that will ease within a few weeks or months. ... Other companies are simply ready to accept the risk of longer lead times due to customs, stating that they ‘don’t care; customers will simply have to wait longer and pay a bit more; it affects the entire industry’. (McKinsey & Company 2020a)

Decisions on whether to mitigate risk (and to what extent) rely on firms understanding their risks and their consequences, as well as their capability to respond. Firms operate in an environment of uncertainty, where they have imperfect knowledge of future events. In some cases, it can be impossible or too costly to estimate the probability or consequence of an event occurring. In these situations it is difficult for a firm to undertake effective mitigation at a reasonable cost.

Accepting risk, however, may not be an effective strategy where better information would have predicted large impacts or identified a more cost-effective mitigation strategy.

### **Diversifying clients and suppliers across firms and markets**

Diversifying sources of demand and supply helps improve the reliability of supply chains by spreading risk across many sources. Firms can diversify both their supplier base and their customer base. Suppliers and customers are all exposed to different risks and disruptions, and they respond to them differently. By relying on a larger range of alternatives — not just on the lowest-cost supplier or highest-price purchaser — firms will likely mitigate the cost of disruptions affecting a narrower range of sources. As Australian Grape and Wine Incorporated (2020, p. 5) noted:

Diversification is [an] important aspect of trade and it is clear there is a need for [a] sector to spread its risk and consider a broad range of markets that suit their needs ... We have had clear warnings for some time that relying too heavily on a single market with limited ability to shift is a highly risky strategy for business in the current trade environment which can see countries close

---

or slow trade overnight. A flexible diverse array of market options would prove a more sustainable option.

Diversification helps firms deal with uncertainty. Where risks are difficult to anticipate or the probabilities of disruptions are difficult to estimate, having access to a range of suppliers or purchasers is likely to mitigate the effects of a range of possible outcomes (essentially pooling risks). For example, if there is an unexpected geopolitical event affecting bilateral trade, access to alternative markets as sources of supply or demand could reduce the impact of disruptions in bilateral trade.

The value of a diverse customer base was seen recently where some industries were able to pivot their export base when they faced demand disruptions from China by increasing exports to established markets (chapter 5). For example, Treasury Estates Wines tapped into existing alternative markets to reallocate their premium Penfolds Bin and Icon range from China to other growth markets (Treasury Wine Estates 2020, pp. 1–2). Pivoting quickly in response to changes in their markets was possible because of their preparedness in the form of investments in market analysis, marketing, and knowledge about relevant regulations and logistics to serve the alternative markets.

Not all firms are able to prepare and adapt. The importance of diversifying suppliers was highlighted in 2000, when a fire at a Philips semiconductor plant in the United States disrupted supplies of a crucial component in the production of Nokia and Ericsson mobile phones. Nokia officials noticed a glitch in supply even before Philips told them and acted quickly to find alternative sources across Europe, Asia and the United States. ‘They redesigned chips on the fly, sped up a project to boost production, and flexed the company’s muscle to squeeze more out of other suppliers in a hurry’ (Latour 2001). Ericsson moved more slowly.

Unlike Nokia, [Ericsson] didn’t have other suppliers of the same chips, known as RFCs, for radio frequency chips. In the end, Ericsson came up millions of chips short of what it needed for a key new product. Company officials say they lost at least \$400 million in potential revenue, although an insurance claim against the fire may make up some of it. (Latour 2001)

Diversification is most effective where it creates more alternatives at the nodes where there are few existing alternatives. The effectiveness of diversifying supply is limited when it applies to a ‘diamond-shaped’ chain. This is where:

... a firm uses multiple tier 1 suppliers who in turn use a limited number of tier 2 suppliers, who all use the same upstream source ... From the firm’s point of view, the supply chain may appear to be composed of a diverse set of suppliers, often in different countries. However, the reality is that one firm, or a limited number of firms, provides critical materials to all the suppliers. (Slowinski, Latimer and Mehlman 2013, p. 21)

This reinforces the importance of understanding a network beyond the first tier of suppliers (section 6.2).

The costs of diversifying sources of supply and demand include developing and maintaining commercial relationships across multiple potential firms or markets (including upfront

---

regulatory compliance, packaging and market research costs). Further, where multiple suppliers (or customers) are established before a disruption, firms incur higher average costs than if using the minimum cost provider (or average revenue that is lower than if selling only into the market with the highest returns). Diversification typically forgoes economies of scale in production and in shipping, and thus it can be particularly costly or even prohibitive for small firms. Purchasing or selling larger quantities from/to a single source can also increase a firm's ability to influence another firm's risk management, and to recover from disruptions.

### *Robust supplier and customer relationships*

Having reliable access to multiple sources of supply or demand requires firms to invest in relationships with many other firms. The level of investment in relationship building and related costs will likely depend on an assessment about the reliability of existing supply or demand, and the visibility a firm has over its upstream or downstream supply chains. This will be balanced against the considerable costs of establishing and sustaining these relationships. Greater confidence in existing relationships can also be achieved through contractual obligations.

Toyota's strong relationship with its suppliers has been extensively studied and identified as a source of strength. Its suppliers demonstrate flexibility and commitment because Toyota is committed to retaining and rewarding its suppliers (Nishiguchi and Beaudet 1997). In 1997, a major fire to Toyota's sole supplier of a small but crucial brake part threatened to halt production for several weeks as it only held two to three days' worth of stock. Toyota overcame this disruption by collaborating with over 200 firms in its established network to produce the crucial component (about 70 firms directly producing the part — some producing it for the first time) (Nishiguchi and Beaudet 1997, pp. 1–2; 15). The capabilities Toyota developed within its network also promoted effective and quick collaboration, including the sharing of intellectual property, and human and physical capital across the network (Nishiguchi and Beaudet 1997, p. 2). Strong relationships allowed Toyota and its network to rely on just-in-time production, maintaining only limited inventory of the over 30 000 components used to produce vehicles.

While it may be possible to establish new relationships when a disruption occurs, a crisis makes this more difficult and more costly than if the relationship exists already. For example, during the pandemic, travel restrictions made it difficult to meet with new suppliers. Moreover, firms were unable to inspect products or the supplier to assess quality, and were competing with other firms seeking to repair their own supply chains. Downstream firms may face similar issues in finding alternative markets in the short-term, as GrainGrowers (sub. 33, p. 10) noted:

... building new markets for grain exports requires considerable lead-times and major investments in marketing and technical support. Coupled with planting decisions that may occur up to 18 months before harvest, pivoting to new export markets is costly and resource intensive.

---

There is also a trade-off between fewer, better relationships and more diverse relationships. Fewer, yet longstanding, relationships may be more resilient in the face of disruptions, but they are less diverse (and so might carry more risk). As the Australian Meat Industry Council (2020, p. 7) stated:

[T]rade concentration is often a reflection of the deep and longstanding relationships that industry participants have forged with customers in-market, which demonstrates Australian exporters are long-term, reliable suppliers that consistently deliver a safe, wholesome and quality product, regardless of short-term trade disruptions or price fluctuations.

### *Contingent contracting*

Firms can enter into option contracts to diversify their sources of supply or demand.<sup>34</sup> In their simplest form, these types of contracts specify the price of reserving a quantity of a good that a firm would have the option to purchase and that the supplier would commit to supply. The price of reserved units is higher than the price of committed units under a regular purchasing contract. This means that rather than bearing a higher average cost of supply (from relying on many suppliers), a purchasing firm would only bear additional marginal costs when a disruption occurs (Tomlin 2006, p. 642). For the supplying firm, the option contract price would seek to cover the costs of maintaining contingent capacity to produce additional units when required.

Many governments have entered into advanced purchasing agreements to secure access to vaccines against COVID-19, some of which stipulate an option to buy additional units of a vaccine. For example, the United States signed a supply agreement with Moderna to provide 100 million doses of their vaccine candidate for US\$1.525 billion (which included a US\$300 million incentive payment conditional on Moderna obtaining emergency use authorisation by 31 January 2021). The United States Government also had the option to ‘... purchase up to an additional 400 million doses at a fixed price of US\$1.65 billion per 100 million doses by specified dates in the agreement’ (Moderna, Inc 2020, p. 30).

Another type of agreement prioritises supply, where firms negotiate a right of first refusal at the market price for a certain quantity of stock. The state-owned Japan Oil, Gas and Metals National Corporation and Sojitz Corporation have a priority supply arrangement for rare earth products with the Australian mining company, Lynas Rare Earths, as part of a loan facility established in 2011. The agreement, which was extended for another ten years in 2019, stipulated that along with other priority arrangements:

Lynas shall ensure that in the event of competing demands from the Japanese market and a non-Japanese market for the supply by the Borrower or Lynas Malaysia for [Neodymium and Praseodymium] produced from the [Lynas Advance Material Plant], the Japanese market shall have priority of supply up to 7200 tonnes per year subject to the terms of the Availability

---

<sup>34</sup> While contingent contracting applies to both upstream and downstream supply chains, as a risk management strategy, it is more appropriate for dealing with upstream risks to secure existing supplies. For exporters, contingent contracting presents an opportunity (upside risk) to expand their purchaser base, rather than being an opportunity to secure its existing purchaser base.

---

Agreement and to the extent that Lynas will not have any opportunity loss. (Lynas Corporation Limited 2019, p. 4)

Contingent contracting is particularly common in high-tech industries that face large price fluctuations as demand and technology change rapidly. Hewlett-Packard, for example, has designed a customised option contract for memory chips, where it pays suppliers a premium for the option to buy a fixed quantity of memory devices at a fixed price. It exercises this option if the price increases above the fixed price, but lets the option lapse and buys in the open market when the market price is lower (Fu, Lee and Teo 2010, p. 2).

Contingent contracting requires upstream firms to be flexible to have the capability and capacity to expand or contract their production volumes to meet changing demands. It may also require downstream firms to be flexible to adapt to using critical inputs that may not be exactly the same as those from the primary supplier. These arrangements involve additional costs, for example, requiring changes to machinery to be able to use parts of different dimensions. Firms can reduce these costs by postponing the point of product differentiation (that is, keeping production in a generic form as far down the production line as possible) to ensure they can use different components from other suppliers. Nokia in the example above, reconfigured its generic mobile phone quickly so it could accept a slightly different component from other suppliers in the United States and Japan (Tang 2006, p. 38).

Contingent sourcing also relies on the enforceability of contracts. If the shock is sufficiently disruptive, it may raise other issues that interfere with the normal enforcement of contracts. For example, in early 2021, the European Commission disputed whether AstraZeneca was meeting its contractual ‘Best Reasonable Efforts’ over obligations in manufacturing and delivering the required number of doses of COVID-19 vaccines, and established export controls of vaccines produced in the European Union. AstraZeneca underdelivered on the number of doses it was contracted to produce for the European Union as it dealt with operational issues in some of its EU plants and faced large demand for its vaccines from around the world (Hanke Vela and Heath 2021; O’Connor and Kirton 2021). Other contracts may stipulate force majeure conditions, which recognise that some events might be outside the supplier’s control, and sufficient cause to relieve them from their contractual obligations (such as ‘acts of God’ or ‘government actions or interference’) (Borgese et al. 2020).

## **Strategies applying only to upstream supply chain risks**

### **Stockpiling**

Stockpiling refers to firms holding inventories of goods in storage that can be made available when supply chains are disrupted. Firms optimise their inventories to manage day-to-day disruptions. For example, at its Kooragang Island ammonia plant, Orica maintains stockpiles of ammonium nitrate that it uses primarily to manufacture explosives for mining, which it describes as ‘just-in-time inventory’. That is, it maintains a small stockpile of about 6000 to 12 000 tonnes of ammonium nitrate, while mining operations take about 8000 tonnes from its site every seven to ten days (Orica 2020).

---

Stockpiling in the context of managing larger risks refers to maintaining inventories larger than would otherwise be required under purely cost-minimising, just-in-time practices. Stockpiles can be part of an alternative to just-in-time sourcing that is sometimes referred to as a ‘just-in-case’ approach to production and inventory management. Stockpiles are best suited to address shorter-term interruptions to the supply of critical goods while other sources of supply are found or existing supply chains are restored. For example, some participants highlighted that delays in accessing shipping containers during the COVID-19 pandemic has seen many firms in Tasmania investing in additional warehousing space to hold larger inventories (Department of State Growth (Tas.), sub. 11, p. 2; PoM, sub. 35, p. 5).

The costs of maintaining a stockpile vary depending on the good, but in general includes storage and maintenance costs, such as rotating materials and disposing of expired products. For goods with a relatively short shelf life, stockpiling is either not possible or very expensive. For example, in April 2020, the private Minderoo Foundation secured access to an additional 10 million units of COVID-19 testing kits and pathology equipment on behalf of the Australian Government; about half were imported based on existing testing demands and commercial supply chains, and an option was set up to acquire another 5 million (Thompson 2020). These kits have a shelf life of 12 months, so the slower than expected need for testing in Australia and the availability of a number of other testing kits meant that some of those kits were wasted (Kearsley 2021; Knaus and Smeets 2020). Another type of swab, used for RT-PCR testing (one of the most accurate laboratory methods for detecting, tracking and studying the COVID-19 coronavirus), has a relatively short shelf life of 15-36 months, which also makes them costly to stockpile (Johnson 2020).

There might also be safety considerations that limit the ability of firms to stockpile. The Minerals Council of Australia noted the safety rationale for maintaining small stocks, ‘[t]he design of the supply chain for explosives is to ensure volatile precursors are not stored for long periods of time creating safety risks’ (sub. 14, p. 4).

In order to be effective, a stockpiling strategy relies on firms making good assessments of future vulnerabilities to their supply chains. For example, prior to the COVID-19 pandemic, the National Medical Stockpile (NMS) held very limited stocks of personal protective equipment (PPE). The ANAO noted that pre-pandemic replenishment planning for the NMS ‘set out procurement priorities that were focused on chemical, biological, radiological or nuclear threats and an influenza pandemic and did not address other potential health threats’ (ANAO 2020, p. 8).

Stockpiles provide limited capacity to respond to an unexpected disruption. In effect, a small stockpile provides a small amount of insurance, which might be an effective part of a strategy that relies on a stockpile in the very short term, while other responses are put in place. In the case of the COVID-19 pandemic, the NMS stockpiles could not meet Australia’s needs for PPE beyond the very short term, but NMS managers were able to quickly use their contacts and knowledge of suppliers to source more PPE (box 6.5).

---

### Box 6.5      **The National Medical Stockpile during the pandemic**

The Australian Government National Medical Stockpile (NMS), managed by the Department of Health, provides strategic reserves of pharmaceuticals, vaccines, antidotes and personal protective equipment (PPE) for use during the national response to a public health emergency which could arise from natural causes (risks) or terrorist activities (threats). It is intended to supplement state and territory supplies in a health emergency.

Prior to the COVID-19 pandemic the NMS held a small stock of PPE (12 million P2 masks and 9 million surgical masks). By 30 September 2020, the NMS had significantly increased its purchasing of PPE equipment, including 166 million P2/N95 and 595 million surgical masks, and distributed about 21 and 56 million of these masks respectively. (Previously, approximately 3.5 million P2 masks were distributed during the bushfire emergency in January 2020, and about 2.1 million pieces of PPE were distributed during the 2009 swine flu pandemic.)

Procurement was guided by estimates of expected usage of PPE and other medical products. This was based on assumptions about the rate of spread of the virus, the level of interventions, hospitalisation rates and how products are used. This information changed. The ANAO (2020, p. 58) for example, noted 'an initial estimated demand of 800 million to 1.2 billion surgical masks was reduced in April to less than 200 million due to the status of COVID-19 at that time'.

The quantities held prior to the pandemic needed to be expanded significantly beyond the small initial stockpile to meet expected demands, and the Department of Health (working closely with other government agencies) could act as a bulk purchaser of these essential products and was able to procure supplies during a period of high international demand. The Australian Government had 54 contracts (as at 31 August 2020) to procure PPE, medical equipment and COVID-19 test kits to complement the small stockpile.

At the outset of the COVID-19 pandemic, the NMS was valued at \$123 million. The Australian Government provided about \$3.23 billion to the Department of Health to bolster reserves of PPE and other medical equipment between March and May 2020.

*Sources:* ANAO (2020, pp. 6–7; 58; 61); Department of Health (2020, p. 1); Doggett (2020).

### Domestic capability

Firms may choose to establish their own domestic production for a critical input, or pay a premium for the input to be supplied by another firm in Australia. This partially insulates firms from supply chain disruptions that might affect access to overseas supplies, causing shortages or large (and sometimes prohibitive) increases in costs.

For example, as a result of the COVID-19 pandemic, many telecommunication providers and some banks reassessed their reliance on overseas call centres, located mainly in India and the Philippines, after they were unable to meet customer demand when these centres closed due to lockdowns. Crummy (2020, p. 1) observed that:

In many cases, businesses had to quickly decide whether to replace now-defunct South-East Asian [call] centre operations with another offshore provider or provide additional resources to over-stretched Australian [call] centre teams while concurrently migrating agents to a working-from-home (WFH) scenario, or urgently find a new local [call] centre partner to move customer conversations onshore.

---

Where there is a willingness to pay a premium for locally produced goods and services, there are firms that are willing to enter the market. For example, the COVID-19 pandemic showed some firms pivoted their production to high-demand medical goods and services, where previously they may have found it difficult to overcome higher costs of production. For example, some breweries and distilleries, and manufacturers of other chemical products, pivoted their production to hand sanitiser at the beginning of the COVID-19 pandemic to help meet higher domestic needs. By April 2020, domestic production as a share of Australia's total hand sanitiser supply had grown from 50 per cent to about 70 per cent, with total domestic production capacity increasing from approximately 10 to 54 million litres per year (DISER 2020c, p. 4). Other examples of pivoting include a few clothing and related manufacturers producing face masks and other PPE products.

Several participants to this study highlighted the costs of doing business in Australia as a barrier to domestic production (KPMG, sub. 39, p. 9; Medicines Australia, sub. 55, p. 21). The costs of onshoring include maintaining potentially higher costs of production, due to higher input costs (such as labour and energy) and to foregoing economies of scale. According to Logistics Bureau (2020), production in China results in significant savings:

With significant reductions in labour and capital investment expenditure, production costs can be slashed by some 20 to 40 percent, and for labour-intensive products, up to 50 percent and beyond. The main reason for these savings is the availability of cheaper labour — manufacturing labour costs in China average US\$5.5 per hour against the Australian average of US\$15 per hour.

An added factor is that Chinese companies produce in bulk for global consumer markets and therefore import raw materials, e.g. plastics and resins, in quantities so vast that they attract significant discounts from suppliers.

This does not mean there are no opportunities for firms to onshore to improve resilience in their supply chains. Labour and other costs in some traditional offshore manufacturing centres have increased (including in some sites in China), and technology and automation have reduced labour-intensity and labour costs in many industries. These trends present opportunities for business to recalibrate their production choices. An onshoring strategy does not necessarily involve moving an entire supply chain, but rather assessing the parts of the supply chain that are most vulnerable to disruption, and onshoring those parts that still allow firms to remain competitive.

There are limits, however, to the extent to which onshoring can eliminate risks associated with exposure to global supply chain disruptions. Complete insulation from disruptions is unlikely because most domestic production also relies on some imported inputs.<sup>35</sup> Pfizer (sub. 42, p. 2), for example, noted that their COVID-19 vaccine consists of 280 components from more than 19 economies around the world. Moreover, domestic production facilities and transport networks are themselves vulnerable to onshore risks. Recent natural disasters and state-based health regulations during the COVID-19 crisis slowed and jeopardised the movement of goods around Australia.

---

<sup>35</sup> For example, across the veterinary pharmaceuticals and medicinal production manufacturing sector, every \$100 of domestic output is associated with \$50 of imports (ABS 2020a).

---

Depending on the industry, demand in Australia (and any potential export demand for an Australian-produced good) may be well below what could support a factory of efficient scale domestically. For example, much of the world’s fire retardant is produced by one American factory (appendix B). While Australian demand for fire retardant would be highly variable (depending on how severe the bushfire season was), such geographic spikes in demand will smooth out for a producer in a global market. This applies particularly to many goods and services likely to be identified as essential under the Commission’s proposed framework (chapter 3). For the narrow list of goods that appear to be vulnerable, essential and critical under the framework, it may be the case that these goods cannot be wholly produced locally (such as medicines that require imported components), or that Australia does not have the expertise or scale to produce them well or competitively (such as chemicals), such that Australia could never be truly self-reliant.

## How risk management strategies compare

Some strategies will be more suitable than others depending on the disruptions that firms are likely to face and the nature of the vulnerabilities in their supply chain. For example, while downstream risks can be managed by diversifying markets, there are several options available to manage upstream risks. A combination of strategies will likely be needed to mitigate the costs of supply chain disruptions.

Table 6.1 outlines some of the key elements that upstream risk management strategies can be assessed against, and shows the relative strengths and weaknesses of each. For example:

- the less frequently a disruption is expected to occur, the worse a stockpiling or domestic capability strategy would likely perform relative to other strategies
- contingent contracting with alternative suppliers and supplier diversification share some of the same advantages, except if the more reliable (likely higher cost) suppliers have more limited capacity to expand or contract production. In this scenario, contingent contracting would likely perform worse than a diversification strategy
- the longer the duration of a disruption, the less reliably one would expect stockpiling to perform, relative to other strategies. This was seen, for example, in the performance of the NMS in supplying P2 masks for the 2020 Australian bushfires, relative to the pandemic. In the case of the COVID-19 pandemic there were millions more masks required than were held by the stockpile, and other strategies needed to be deployed.

This table is not exhaustive and does not indicate the magnitude of strength and weakness of each strategy relative to others. But it illustrates how the context of a supply disruption (such as whether it is a natural disaster, logistic failure, or pandemic) influences how risk management strategies compare — and that each strategy will present opportunities or difficulties.

The assessment of whether and how to manage downstream disruptions is likely to be more straightforward than for upstream disruptions as there are fewer choices and the costs are easier to determine. The decision to manage a downstream disruption is based on the cost of

diversifying customers (including the effort to establish new relationships) and the potential benefits of securing more stable demand for a firm’s goods and services.

**Table 6.1 Indicative impact of upstream mitigation strategies**  
Performance of strategy against nature of disruption and supplier<sup>a</sup>

	<i>Do nothing</i>	<i>Stockpiling</i>	<i>Supplier diversification</i>	<i>Contingent contracts</i>	<i>Domestic capability</i>
<b>Nature of disruption</b>					
Infrequent	+	-	+	+	-
Longer duration	-	-	+	+	+
Impact localised domestically <sup>b</sup>	?	+	+	+	-
<b>Nature of disrupted supply</b>					
Less flexible in production	-	+	+	-	-
Goods are more perishable	?	-	?	?	+
Lower reliability of preferred supplier	-	+	+	+	+

<sup>a</sup> + Strategy likely to perform better than other strategies; - Strategy likely to perform worse than other strategies; ? Unclear how the strategy would perform under this characteristic. <sup>b</sup> Localised disruption affecting domestic supplies, rather than localised overseas or global disruptions. <sup>c</sup> Difficult for producers to respond quickly due to obstacles, such as capacity constraints or large investment requirements.

Firms will choose the combination of risk management strategies, such that the benefit of their mitigation activities outweighs the expected costs given the nature of potentially foreseeable disruptions. For example, for many agricultural products, the cost of diversification may be too high compared with no action, as the Department of Agriculture, Water and the Environment noted:

... the price premium for many agricultural products [in China] is so high that it’s led to many agribusinesses making the judgement that the risk [of market concentration] is worth taking. (Joint Standing Committee on Trade and Investment Growth 2020, p. 3)

In the case of Australian iron ore, firms have chosen not to diversify their sales away from China (chapter 5). China is a significant buyer of iron ore worldwide, which lessens the risk of geopolitical disruptions in this market, as the two economies have a vested interest in the efficient functioning of the market for iron ore. This, along with the fact Australia receives a price premium for the iron ore it sells to China, suggests the benefit of diversification might not exceed its costs, and firms accept the risks of potential disruptions.

---

FINDING 6.3: HOW WELL STRATEGIES PERFORM DEPENDS ON THE TYPES OF DISRUPTIONS

Each risk management strategy has costs and, some will perform better under different types of disruptions and contexts. Firms will employ a range of strategies to effectively manage risk, such that the benefits exceed the costs.

---

# 7 The role of government in risk management

## Key points

- Supply chain risks are best managed by those who have direct incentives and the capacity to mitigate against them.
  - Government has responsibility, like any firm, to manage risks in supply chains where they purchase and deliver goods and services directly.
- There may be conditions where government intervention in private sector risk management is justified, such as where the private and public net benefits of risk management diverge. For instance, if disruptions have spillover effects or affect national security.
  - In these cases, government could provide expert information; or take more direct ownership of risk management, such as maintaining government stockpiles, mandating or subsidising private stockpiles, or subsidising domestic production capacity and market diversification activities.
- As a result of the COVID-19 pandemic and trade tensions, governments around the world have taken actions to provide direct support for firms to strengthen their supply chains.
  - The Australian Government has provided considerable funding to build resilience in vulnerable supply chains, through its Modern Manufacturing Strategy, and its Fuel Security Package.
- However, government intervention can impose higher costs on the community if support is not fit for purpose. For example, the costs of maintaining a local capability could significantly outweigh the cost of other risk mitigation strategies. It can also decrease firms' incentives to invest in risk mitigation.
- Even where an in-principle case for government intervention exists, any substantive case needs to demonstrate that the benefits of intervention outweigh the costs.
- Governments should ensure firms do not face unnecessary constraints in how they plan and respond to disruptions. This includes maintaining a respected, rules-based and low-cost trading system, and a responsive regulatory environment.
- The Australian Government's newly formed Office of Supply Chain Resilience could use and further develop the frameworks in this study to regularly review the list of goods and services that are vulnerable to disruptions, and critical to the supply of goods and services that are essential for the wellbeing of Australians.

---

## 7.1 Responsibility for managing supply chain risks

Good risk management allocates risk to the party best able to manage it (OECD 2008, p. 49), where ‘best able’ relates to parties with the incentives and capabilities to reduce, respond to, and deal with residual risk. Supply chain disruptions can result in lost sales, profits and reputational damage, and sometimes closure. Firms thus have strong incentives to manage and respond to risks in their supply chains.

Firms up and down the supply chain can also share in managing risks. For example, a supplier may be reliant on revenue from a particular final producer, which would be an incentive for them to respond to any disruption along the final producer’s supply chain (as happened with suppliers of Toyota and Nokia, which is discussed in chapter 6). Contracts can be used and structured to give suppliers strong incentives for reliability, such as by including damages clauses.

While firms will not always manage supply chain risks effectively — due to unforeseen risks or inadequate preparation or response to a disruption — this does not mean government should take ownership of private sector supply chain risks. Governments make mistakes too. Since government interventions involve: compelling firms to undertake certain activities; taxpayers funding firms’ risk management; or the public bearing certain risks, they need to be justified to ensure the benefits outweigh the costs.

However, governments are directly responsible for managing supply chain risks where they deliver or procure goods and services on the community’s behalf, including public services such as health services or national security. Governments have a direct responsibility in many of the supply chains that would be considered essential — such as water, health, communications, and government services (chapter 3). In doing so, governments, like any firm, invest in risk management strategies (as described in chapter 6).

The rest of this section explores whether there is a case for government involvement in private sector risk management, and the potential for it to crowd out private sector investment.

---

### FINDING 7.1: RESPONSIBILITY FOR MANAGING SUPPLY CHAIN RISKS

Risks are best managed by those who have direct incentives and the capacity to mitigate against them.

Firms are primarily responsible for managing risks in their supply chain. Governments have responsibility, like any firm, to manage risks in supply chains where they purchase and/or deliver goods and services directly, particularly when these are essential goods and services.

---

---

## Where might direct government intervention be justified?

Government intervention could be justified where private firms collectively underinvest in supply chain risk management or might otherwise be unable to effectively respond to disruptions, such that market-level supply of an essential good or service is compromised. This may occur when firms' risk appetite exceeds that of the community, such that residual risk in the market exceeds the amount of risk that the community is willing to accept.

This implies that a socially optimal level of investment in risk management might diverge from what private firms deliver (where the social cost or benefit of mitigation is not aligned with the firm's private cost or benefit). This divergence can come about for several reasons.

- Disruptions could have 'contagion' effects. Even if each firm individually managed a disruption effectively, firms (and the community) may still be exposed to large disruption costs. If firms understood the potential impacts of contagion to their business, they may seek to reach agreements with each other to internalise its effects, or governments may impose such measures. Bank deposit guarantees, for example, partially fulfil this role as a form of insurance to prevent large-scale bank failure that could spread to the banking system, and consequently, the broader economy.
- Consuming certain goods and services during a disruption, such as face masks in a pandemic, can have broader benefits to the community. This could lead to private undervaluation of the benefits of securing supply of such goods and services.
- In some essential industries (such as in utilities or health), regulated prices may not provide sufficient financial incentives for firms to invest in risk management despite their importance to society. For example, pharmaceutical pre-distributors (responsible for storing pharmaceuticals after manufacture in Australia or arrival from overseas before supplying distributors or wholesalers (Pharmacy Guild of Australia, sub. 16, p. 5)) may not stockpile additional amoxicillin to prevent a shortage, as they cannot charge a premium when a shortage occurs.
- Even in markets with unregulated prices, firms may under-invest in risk management. For example:
  - a monopoly will consider the potential loss of profits from a disruption, but the damage to profits would be less than the damage to wellbeing<sup>36</sup>
  - if risks are large but infrequent, firms that do not invest in risk mitigation will gain a cost advantage. In a highly competitive market, firms that make this investment could be driven out — even when firms are able to credibly signal their risk management

---

<sup>36</sup> Firms in a perfectly competitive market will make the socially efficient investment in risk management. However, firms with limited market power may under- or over-invest in risk management. The intuition is derived from Mankiw and Whinston (1986), who showed that an oligopoly market with free entry can lead to excess entry because a new firm does not take into account that it is stealing market share from existing firms. Investing in risk management is equivalent to investing to 'enter' the market in a state in which many firms are disrupted. A firm is insufficiently incentivised to invest in case it might be the only firm operating (the monopoly effect) but has a strong incentive to invest if many firms might be operating (the market-stealing effect). Either effect can dominate.

---

activities, customers might buy from cheaper providers and plan to switch providers when a disruption occurs.

- Information asymmetry or limited information can prevent firms from preparing adequately against certain risks. As noted in chapter 6, understanding supply chain risk requires firms having access to information that allows them to make assessments about the probability and consequences of disruptions. Information gaps mean some risks are difficult to plan for. For example, while a rules-based trading system is meant to facilitate a predictable global trading environment, some policies can be hard to predict, such as when the Italian Government vetoed the shipment of AstraZeneca vaccines to Australia in March 2021 (Leeuwen and Tillett 2021).

Even where regulation or other impediments prevent firms from making adequate investments in risk management, this is not sufficient to warrant government taking ownership of inherently private risks. This could reduce incentives for firms to manage risks that they own and are best placed to manage. Governments may not have the information required to manage the risk (that is held by firms), which makes them less effective at managing risk for any given level of risk appetite. That said, governments might need to redesign any regulations that prevent firms from managing risks at a reasonable cost.

To ensure government intervention is effective, governments need to demonstrate that the expected benefits of government investment in mitigating private sector supply chain risks outweigh the expected costs, and that the intervention is the best solution to the identified problem. A potential assessment framework is outlined in section 7.3.

## **7.2 Role of government in managing supply chain risks**

This section examines the policy levers that governments use to intervene in market-level supply chain risk management.

### **What role could government play in prevention and preparation?**

Helping to better understand risk through the provision of information and expertise

Firms are generally in the best position to understand risks in their supply chains (even if they are unaware of risks in all tiers of their chain). But governments also hold certain expertise and knowledge which makes them well placed to disseminate information that can improve a firm's understanding of risks in their supply chain.

The Australian Government has science and research agencies that can support firms to better understand risks in their supply chain. The Bureau of Meteorology, for example, produces forecasts, warnings, and advice that assists Australians to deal with 'the harsh realities of their natural environment, including drought, floods, fires, storms, tsunami and

---

tropical cyclones’ (BOM 2021). Similarly, the CSIRO has expertise in science and technology, and collaborates with government and industry to make supply chains more resilient (box 7.1).

**Box 7.1 CSIRO work relating to supply chains**

- The CSIRO, supported by industry and state and territory governments, developed the Transport Network Strategic Investment Tool (TraNSIT). TraNSIT is a model that maps millions of vehicle trips across thousands of supply chains between production and domestic and export markets. It has been used to analyse the sensitivity of the road and rail network to natural disasters or other disruptions and their impact on freight access to markets.
- The Australian Department of Agriculture funded work by the CSIRO and academics to investigate how climate change might impact different agrifood supply chains in Australia, and how they can adapt.
- Through the Science and Industry Endowment Fund (supported by the CSIRO), researchers developed a prototype of an automated system for fish species identification, counting, size estimation, colour measurement, and tagging of catch, to provide information to improve traceability along the supply chain.
- The CSIRO has other partnerships with industry to support supply chains via imaging and sensor technologies, autonomous robotics, new materials, and manufacturing processes.

*Sources:* CSIRO (2018, 2020); Lim-Camacho (2016); Science and Industry Endowment Fund (2020).

Several government agencies (such as Austrade, and the departments of Foreign Affairs and Trade, Defence, and Home Affairs) offer trade and international relations expertise and information by leveraging off the Australian Government’s extensive diplomatic, trade and security networks. These agencies gather information on geopolitical and security threats that might affect global supply chains, and identify and establish opportunities for trade links. While firms have access to some of this information through their own networks, governments have greater access and reach to foreign governments and their security agencies. Austrade (sub. 46, p. 2), for example, offers a number of digital and other targeted services to support firms in diversifying their exports, ‘... helping [them] to identify new market and commercial opportunities, finding new partners, and promoting Australian products in those markets to help drive consumer demand’.

As a regulator, governments gather critical information, which can identify risk in specific supply chains. For example, the Therapeutic Goods Administration (TGA) coordinates the national Medicine Shortages Working Party, which comprises key medical peak bodies and organisations, in addition to Department of Health staff.

In Australia, medicines sponsors (companies) are required by law to report current and anticipated shortages of prescription medicines and certain over-the-counter medicines. The TGA publishes shortage notifications for the information of health professionals and consumers. If there are any medicine shortages relating to COVID-19, including information about expected duration and the supply of potential alternative products, details will be published on the TGA web page and also communicated more widely to healthcare professionals. (TGA 2020c)

---

During the COVID-19 pandemic, the Medicine Shortages Working Party met regularly to address challenges specific to the pandemic, such as panic buying and stockpiling (Pharmacy Guild of Australia, sub. 16, pp. 13–14). Several participants saw value in continuing (and expanding) data sharing arrangements between industry and government on essential medicine supplies and shortages, and to improve transparency (Medicines Australia, sub. 55, p. 13; Novartis Pharmaceuticals, sub. 15, p. 2; IIER-Australia, sub. 6, p. 9).

Gathering information and expertise is not costless for governments, and initiatives need to demonstrate a net benefit to the community. Governments can benefit from economies of scale in obtaining expertise and insights, relative to individual firms. They may also have access to information in the course of providing a public good or service, which is of value to the community but would otherwise be under-produced if not delivered by government. It is also important to acknowledge the expertise available to firms from other sources, including from industry peak associations, as well as consultants and professional associations with expertise in procurement and supply management (CIPS, sub. 7).

### Mandating or subsidising investment in risk mitigation

Governments can compel or support firms to invest in risk mitigation to reduce the impacts of supply chain disruptions. In terms of risk management strategies aimed at preventing and preparing for upstream and downstream risks, governments could: compel or subsidise firms to understand and diversify their supply links; require firms in essential industries to hold stockpiles; and/or subsidise local production or onshoring. This sub-section looks at some of the key direct government interventions in risk management and examines some of the impacts of this involvement.

As with the many risk management strategies available to firms, governments have the choice of investing in one strategy or many, depending on the type of risk facing the supply chain. For example, Australia has implemented several policies aimed at securing access to liquid fuels (box 7.2). Japan, facing risks to supplies of rare earths, has also opted for a multi-pronged strategy, involving expanded stockpiling, debt guarantees to manufacturers to secure priority rare earth supplies (chapter 6), and direct investment in prospecting in waters off Japan (Ryall 2018, 2020) (appendix B).

Setting requirements on firms to invest in supply chain risk mitigation raises the question of whether some form of taxpayer subsidy is appropriate, particularly if the additional investment supports a community-wide benefit, rather than purely a private one. This may be relevant, for example, in regulated industries where there is a risk that regulation sets the price (or rate of return) too low to account for the costs of risk management.

---

## Box 7.2      **Securing liquid fuel supplies in Australia**

Liquid fuels were not identified as vulnerable in this report due to the range of suppliers that Australia imports from (box 4.4). This does not mean that Australia is immune from disruption to its supply of critical fuels but that there are likely to be several options available if supplies are disrupted. This was a finding of the *Liquid Fuel Security — Interim report* from the then Department of the Environment and Energy:

Initial findings from testing of disruption scenarios show that the global market is generally robust enough to balance out supply and demand. The global oil price will spike in response to a disruption, and this will be an incentive for companies to bring new supplies of oil to the international market. (DEE 2019, p. 43)

Some participants supported this view and noted the resilience in supply and shipping routes. Moreover, they noted the limits of Australia's ability to be self-sufficient in production given its reliance on imported inputs such as crude oil (BP Australia, sub. 53; SAL, sub. 56). BP Australia (sub. 53, p. 2) noted:

... energy security is often conflated with energy independence by policy makers, resulting in inappropriate market interventions including measures to sustain suboptimal refining capability and inefficient, poorly designed mandatory stockholding obligations. These interventions have the potential to significantly increase costs for industrial customers and consumers, diminish supply optimisation by industry and profoundly distort 'in-country' regional markets. As such, fuel security policy must be well considered and the costs to the economy be fully understood and articulated.

Many participants noted that liquid fuel supplies are a critical input to many essential industries and that Australia relies heavily on imports (Bioenergy Australia, sub. 2; GrainGrowers, sub. 33; GPA, sub. 25; IFCBAA, sub. 41; IIER-Australia, sub. 6; MUA, sub. 38; NFF, sub. 22; Port of Newcastle, sub. 5).

The Australian Government has announced several measures in recent years to secure liquid fuel supplies, including:

- support for Australia's domestic refinery capability. The Australian Government established the Fuel Security Service Payment, which provides refineries with a subsidy to 2030 when their margins fall below a certain rate. Additionally, the Government will provide up to \$302 million for infrastructure upgrades to create jobs and help refiners bring forward their production of better-quality (lower sulphur) fuels by three years.
- a minimum stockholding obligation for industry to hold minimum stocks of key transport fuels. The intention is to increase the minimum level of diesel stocks by 40 per cent by 2024, reflecting the importance of diesel to the economy. Additionally, the Australian Government will provide up to \$200 million in competitive grants over three years to support the construction of an additional 780 megalitres of onshore diesel storage.
- establishing a national oil reserve. The Australian Government purchased \$94 million worth of crude oil to store in the United States for an initial period of 10 years. While this measure helps Australia meet its international treaty obligations to hold 90-days of oil reserves, its role in supporting Australia's physical or strategic reserves is less clear. In addition to geopolitical risks, time delays in shipping and refining the oil in Australia are also a risk.
- improving reporting and transparency in the liquid fuel market by modernising the Government's Petroleum Statistics Information Management System.

Sources: DISER (2020a); GPA, sub. 25, pp. 3–4; Laidlaw (2020, pp. 4–5).

---

### *Promoting better understanding of risk*

While not specifically aimed at protecting firms from disruptions to global supply chains, some regulations require firms to invest in understanding their supply chains. For example, the Australian Government requires firms to report on how they monitor and manage other forms of risks.

- Under the *Modern Slavery Act 2018* (Cwlth), entities with consolidated revenue of at least \$100 million per financial year are required to report annually on the risks of modern slavery in their operations and supply chains, and the steps taken to address those risks.
- Under the *Security of Critical Infrastructure Act 2018* (Cwlth) owners and operators of critical infrastructure assets are required to provide information to the Register of Critical Infrastructure Assets to help the Australian Government work with them to identify and manage the national security risks of espionage, sabotage and coercion.

The TGA has adopted a new standard to allow for a medicine to be tracked as it moves through the supply chain and to align with international supply chain tracing systems. Commencing on 1 January 2023, the standard will apply to medicines that have a machine readable code on their label (for example, a barcode). Not all medicines must contain machine readable codes, but medicines that do must comply with the standard (TGA 2021b).

These requirements likely impose modest compliance burdens on (these mainly large) firms. For example, the Department of Home Affairs (2018b, p. 19) estimated that modern slavery reporting requirements would add annual administrative costs of approximately \$22 000 per reporting entity, but that the benefits in terms of improving business practices likely outweigh these costs. For smaller firms, however, the capacity to invest in processes to better understand supply chain risks would be more limited (chapter 6). Some participants called for government support for smaller firms in the form of financial assistance to subsidise risk assessments (KPMG, sub. 39, p. 10), or to encourage access to digital infrastructure and technology (ACCI, sub. 44, p. 2). Such measures are difficult to justify from a market-level perspective without first assessing any capacity gaps among smaller firms that supply essential goods and services.

In addition to efforts to provide information directly (as discussed earlier), governments can reduce the costs that firms might incur to understand their supply chain risks. For example, governments could promote the use of global data standards to facilitate the exchange of supply chain data between industry and governments. As noted by GS1 Australia (sub. 8, p. 6):

[Global Data Standards are] adopted to ensure that relevant information is provided in a common format which is easily understood and sharable by all parties. As transactions by governments and the private sector become increasingly electronic, it is more important and useful to ensure that systems used by stakeholders are interoperable.

---

### *National or regulated stockpiles*

There are limited circumstances where governments take greater ownership of risk mitigation by maintaining or mandating stockpiles of goods considered essential to the wellbeing of Australians. Examples of Australian Government stockpiles include:

- the National Medical Stockpile managed by the Department of Health, which maintains a national stockpile of Personal Protective Equipment (PPE) and other medical equipment for private medical practitioners and state-run health systems (box 6.5)
- the ‘nine strategic equipment stockpiles of marine pollution response equipment around the Australian coastline’ maintained by the Australian Maritime Safety Authority (AMSA 2018)
- liquid fuel stockpiles, and incentives for industry to store and maintain minimum stockholdings of liquid fuels, as part of its Fuel Security Package (box 7.2).

The main advantage of a central stockpile (relative to directing firms to hold stockpiles) is the ability to coordinate and rapidly direct supplies in the event of an emergency. If not all firms experience shortages at the same time, a central stockpile could be more efficient — stocks would be smaller than if each firm had to maintain its own stockpile, because a pool of resources would be used to accommodate the shortages, similar to pooled insurance. For example, Canadian provinces that used more centralised procurement models to secure and distribute supplies across their health systems responded more effectively to the COVID-19 pandemic relative to those that relied on more decentralised models:

Centralized supply chain management enabled a highly coordinated sourcing strategy, whereby distribution of products across a region or province was prioritized to every health organisation based on need. ... findings suggest that decentralized supply chain management creates a very fragile and highly chaotic environment in which every organization is on their own in managing severe product shortages and distributing the products critically needed for care delivery. (Snowdon, Saunders and Wright 2021, p. 40)

### *Subsidising local production and market diversification*

The Australian Government offers a range of direct subsidies to promote local production and to help domestic producers expand their export markets.

The most prominent example of the former is the \$1.5 billion Modern Manufacturing Strategy, announced as part of the 2020-21 Budget. The Strategy seeks to increase the competitiveness, scalability and resilience of Australia’s manufacturing capability within six National Manufacturing Priorities. While the Strategy has a strong focus on job creation, supply chain resilience is one of its four key pillars (Andrews 2020; DISER 2020e). The Strategy has received funding of \$107.2 million from 1 July 2021 to support eligible projects that can address supply chain vulnerabilities for nominated critical products or inputs (DISER 2020d). The department undertook analysis to identify vulnerabilities in Australia’s supply chains prior to the available grant funding being open to applications, and funding

---

will only be available to subsidise domestic manufacturing capability rather than other risk mitigation approaches (Fredericks 2021, p. 38).

Another example of financial support applying to a particular sector is the Fuel Security Service Payment announced as part of the 2021-22 Budget. This measure, part of the Australian Government's broader Fuel Security Package, seeks to secure critical fuel supplies by subsidising Australia's last two refineries when their margins fall below a certain rate. The measure has been costed up to \$2.047 billion to 2030 (box 7.2).

Australia is not alone in providing direct subsidies to support firms to diversify their sources of production. For example, in 2020 the Japanese and South Korean Governments introduced subsidies to onshore manufacturing and to diversify supply chains (primarily relocating production away from China).

- Japan provided subsidies of US\$2 billion to onshore manufacturing and US\$200 million to expand supply chains to South Asia (Editorial Board, East Asia Forum 2020).
- In South Korea, companies looking to reshore their operations can be eligible for corporate tax subsidies, funding to cover relocation and facility costs, as well as specific incentives for firms that build smart factories or use industrial robots in their reshoring plan (Stangarone 2020).

In February 2021, the US President signed an 'Executive Order on America's Supply Chains', which outlined a process for federal agencies to assess risks to supply chains. As a result of its first review into four critical products (semiconductor manufacturing and advanced packaging; large capacity batteries; critical minerals and materials; and pharmaceuticals and active pharmaceutical ingredients), the United States Government announced plans to bolster domestic production, work with overseas suppliers, and 'combat unfair trade practices' (The White House 2021).

In terms of export market diversification, the Australian Government provides financial support to firms, most notably through the Export Market Development Grants. The Export Market Development Grants program reimburses eligible small and medium-sized aspiring and current exporters for part of the cost of promoting, developing and expanding their presence in overseas markets — including the costs of overseas representatives, marketing consultants, marketing visits, attending trade fairs and other promotional activities. In December 2020, the Australian Government announced the \$42.9 million Agribusiness Expansion Initiative:

... to scale up support to over 2000 agri-food exporters each year through Austrade's existing services. Austrade will also work with industry bodies to deliver targeted advice and trade missions (where possible) to help exporters expand and diversify in existing and new markets. (Austrade, sub. 46, p. 3)

---

### *Direct government intervention has costs*

Direct taxpayer assistance to support private firms invest in risk mitigation can be costly, as noted in section 6.2. But beyond the financial costs, there could be other costs.

- Setting expectations of taxpayer support, and with government acting like an insurer who charges no premiums, can reduce the incentive for business to manage their own risks (i.e. crowding out). For example, drought assistance programs have been found to benefit recipients, but not to help farmers improve their self-reliance, preparedness and climate change management (PC 2009, p. XX).
- Government project financing instruments can distort the allocation of resources, and impose hidden costs on taxpayers, for example through risks of non-repayment of debt and concessional financing subsidies (that extend loans to firms on terms substantially more generous than are available through the market) (PC 2020, p. 20).
- Costs imposed on other sectors of the economy that do not directly benefit from government assistance. For instance, to fund the subsidies, governments must increase taxes and charges, cut back on other spending, or borrow additional funds. Funding provided to a single firm can also discriminate against its competitors (PC 2018, p. 2). Moreover, investment and economic activity could be diverted away from more highly-valued uses and sectors of the economy, due to an artificial increase in rates of return in the sector of the economy that received the industry assistance (PC 2014a, p. 94). This could exacerbate supply chain risks in those industries that miss out on assistance.
- Resources that firms use on rent-seeking behaviour to secure government assistance, rather than focusing on things that they could do themselves to improve the reliability of their supply chains (PC 2014a, p. 94).

These costs do not preclude government intervention, but any case for taxpayer-funded risk mitigation needs to demonstrate how the associated costs are outweighed by the benefits to the public, and that the intervention is the best solution to the identified policy problem (PC 2020, p. 20).

Direct government intervention to ensure the supply of essential goods and services should not be used to support broad industry policy objectives. Government subsidies to establish general manufacturing (or ‘sovereign’) capacity:

- will not always be cost-effective or suitable for mitigating most types of disruptions (for example, for fuels refined domestically when overseas crude supplies are disrupted)
- will likely crowd out more profitable forms of private investment in sovereign capacity
- distorts the efficient allocation of resources across the economy.

As Denton and Bruckard (2020) noted, onshoring policies are likely to undercut competitiveness, raise consumer prices, concentrate risk and make industries ‘more vulnerable to smaller, localised and more frequent shocks like floods, blackouts or social

---

upheaval'. Moreover, it is unclear whether industry subsidies facilitate additional investment. For example, while evaluations of Austrade's tailored export services in 2019 and Export Market Development Grants in 2020 found considerable increases in export activity for firms that accessed these supports, data limitations meant evaluators were not able to fully eliminate 'selection bias' (it is likely that some firms applying for these grants were planning to expand their export activity anyway). Therefore any observed and unobserved factors that affect both a decision to participate in the program and the intended outcomes from the program, which are not able to be captured by the evaluation, are likely to bias the estimated additionality associated with these grants (Fisher 2020, p. 49; Kollmann, Palangkaraya and Webster 2019, p. 25).

Government should also be cautious about intervening in private sector risk mitigation because firms' preparations for, and responses to, disruptions are usually effective. These responses are why most people are completely unaware of the myriad supply chain disruptions that happen every year. As McCloskey (2020) pointed out, 'you can depend on it that business people will think up methods of insurance against future plagues better than government-imposed restrictions on whom you can buy from'. For example, although no system is likely to be foolproof, and disruptions in vaccine production in Europe have occurred (Goenka 2021), Australia's pharmaceutical supply chains were able to take measures to manage disruptions as they arose — box 6.3.

## **What role might government play in response and recovery?**

Ideally, governments anticipate and prepare for future disruptions. The reality however is that it is not possible to anticipate all eventualities, and governments will be required to develop policy responses after a crisis occurs. To help ensure that responses are measured and outcomes focussed, this section outlines guidance on good policy practice.

As noted earlier, if a government is responsible for directly providing or purchasing essential goods or services, then it should manage risks in the supply chain — including responding to disruptions if that supply chain fails. Disruptions may also require new policy priorities for governments to support communities respond to unanticipated cost increases. (Under circumstances where risks have not been effectively mitigated prior to a disruption, the community is likely to bear much of the impact.)

Many facets of the COVID-19 pandemic required rapid action from governments to provide public health services. For example, governments secured PPE supplies to hospitals and government-owned aged care facilities, as well as procuring vaccines, and testing supplies. The Australian Government also decided that, for a premium, it would fund domestic production capacity, in addition to making purchasing arrangements with overseas manufacturers of other vaccines. Having domestic vaccine manufacturing capacity sought to avoid relying on global supply chains, as the Prime Minister noted:

Both [AstraZeneca and Pfizer] have experienced global supply challenges but [Australia is] in a fortunate position as a country because of the decisions that have been taken ... [including] the

---

decision to pay a pay premium for an onshore, secure, sovereign vaccine manufacturing capacity via CSL. (Morrison 2020)

As noted earlier, local vaccine production is not the only measure that can be used to respond to the effects of export bans, spikes in global demand, and other supply disruptions. In fact, it can raise other issues if domestic supply risks are not effectively managed, such as where raw materials are unable to be sourced, or where the vaccine chosen for domestic production proves to be less effective. The latter has played out in Australia, where the distribution of the locally produced AstraZeneca vaccine was no longer recommended for people aged under 60 years of age and required the Australian Government to quickly identify and source alternative vaccine suppliers.

Governments also have an important role in coordinating efforts to effectively respond to major disruptions. Several government agencies established taskforces and initiatives to coordinate responses to supply chain disruptions affecting essential industries during the COVID-19 pandemic — including establishing much closer engagement with industry (box 7.3). The Australian Government also revamped how it worked with state and territory jurisdictions to manage the national response to the COVID-19 pandemic, by establishing a National Cabinet process. Notwithstanding, some participants in this study noted weaknesses in this approach, as jurisdictions failed to reach agreement or implement decisions relating to border closures (ACCI, sub. 44, p. 3; MCA, sub. 14, p. 5), and with associated quarantine requirements for essential workers, such as maritime crews (MIAL, sub. 28, p. 11; Ports Australia, sub. 20, pp. 3–4; SAL, sub. 56, p. 47; MUA, sub. 38, p. 29), which led to increased risks to supply chains.

Regulators also play a key role in helping the community respond to unexpected disruptions. As the Medical Technology Association of Australia noted, the TGA:

... has been a key partner in the government-industry collaboration, providing rapid engagement with the sector and developing an accelerated approvals process. As an example, rapid approval of ventilator design variations allowed Australia to get earlier access to new products on the production line which may have otherwise gone to other countries. In addition to rapid approvals, the TGA took on a heavy workload around preparing and publishing regulatory and non-regulatory advice and guidance to industry. The TGA reports that over 2200 new manufacturers entered the market from February to April this year, all requiring guidance. (MTPConnect 2020, p. 8)

Similarly, the Australian Pesticides and Veterinary Medicines Authority supported holders and manufacturers of veterinary medicines to demonstrate their compliance with Good Manufacturing Practice, while scheduled inspections and audits could not take place due to COVID-19 restrictions.

---

### Box 7.3      **Government coordination in response to the COVID-19 pandemic**

The Department of Industry, Science, Energy and Resources worked with industry and the Department of Health to secure supplies of personal protective equipment to the National Medical Stockpile:

The Government supported local manufacturers by providing grants (such as \$4 million to Shepparton-based company Med-Con to increase its production of face masks), reducing regulatory barriers, facilitating supply chain connections, and purchasing equipment for the [National Medical Stockpile] (such as the contract with a consortium of over 30 companies led by Grey Innovation to supply ventilators). (DISER 2020b, p. 4)

The Department of Industry, Science, Energy and Resources also collaborated with the Advanced Manufacturing Growth Centre to support Australian manufacturers and suppliers of critical medical and protective products. They helped them identify collaboration and market opportunities through the Growth Centre's COVID-19 Manufacturer Response Register.

The Department of Defence provided defence personnel to support domestic manufacturing of medical personal protective equipment under Defence Assistance to the Civil Community arrangements. For example, about a dozen engineering maintenance specialists were deployed to Med-Con Pty Ltd to assist the company's existing staff on production, maintenance and warehousing tasks. The Department's Defence Science and Technology Group helped to design new face shields and worked with South Australian defence industry company Axiom Precision Manufacturing to assist with rapid production.

The Department of Foreign Affairs and Trade established a COVID-19 Coordination Unit, which became the principal point for: coordinating the Department's COVID-19 response; whole-of-government policy coordination on implementing COVID-19 policy responses; and facilitating the delivery of personal protective equipment and other medical imports to Australia.

The National COVID-19 Coordination Commission was established to coordinate advice to the Australian Government on actions to anticipate and mitigate the economic and social effects of the COVID-19 pandemic. It formed a working group to work with manufacturers to ensure supply of essential products, such as personal protective equipment, and solve supply chain issues to keep critical goods flowing to Australian communities.

Several agencies also increased their engagement with industry to resolve issues and to keep supply chains functioning, through for example, the Therapeutic Goods Administration's Medicine Shortages Working Group and the Department of Industry, Science, Energy and Resources' Supply Chain Roundtable.

*Sources:* CHP Australia, sub. 40, p. 2; DISER (2020b, p. 4); DPS (2020); Reynolds and Andrews (2020).

The ACCC also authorised exemptions for competitor firms to collaborate without breaching competition laws, where it determined that the likely benefits to the public outweighed the likely costs. The ACCC received 33 applications linked to the pandemic, which is '... approximately as many authorisation applications as the ACCC receives in a typical year, and most of them arrived in a six-week period from mid-March 2020' (ACCC 2021, p. 1). This included allowing collaboration between:

- the Victorian Department of Health and Human Services, private healthcare providers, and public hospitals and healthcare facilities to maximise healthcare capacity and ensure

---

the state-wide coordination of healthcare services during the pandemic (ACCC 2021, p. 4)

- the Minerals Council of Australia and mining operators to secure a range of critical inputs (including PPE). Importantly, the authorisation had:
  - ... the flexibility to include other inputs that might be identified as critical as the crisis unfolded.
  - ... Industry cooperation in combination with the speed and flexibility of regulators was the key element in ensuring [that] operations were not compromised and [long-term] economic damage to regions, jobs and livelihoods were avoided. (MCA, sub. 14, p. 3)

In making these decisions, governments assess whether the net benefits of policy objectives, such as avoiding collusion or having greater certainty over the quality of regulated goods, are lower than the costs experienced from major disruption. Governments also need to ensure that regulators have sufficient flexibility, and as noted by Consumer Healthcare Products Australia (sub. 40, pp. 4–5), the resources to be able to assess and process the authorisations needed to increase the responsiveness of supply chains.

Governments can also intervene to assist firms respond to disruptions in private sector supply chains. For example, the International Freight Assistance Mechanism was introduced as a temporary measure in April 2020 to partially offset the costs of freight disruptions to high-value exporting firms. The COVID-19 pandemic saw the number of passenger flights drop by more than 90 per cent almost overnight and prices increased by between 3 and 13 times pre-COVID-19 rates (Austrade, sub. 46, p. 6). Funding for the International Freight Assistance Mechanism has increased on four occasions since its establishment, from \$110 million to \$781 million, with funding expected to end in September 2021 (Austrade 2021).

As noted earlier, prolonged financial support runs the risk of crowding out more effective responses by private firms and dulling their incentives for future preparedness. More generally, the costs of government intervention need to be considered. As with natural disaster funding, governments should not create a cycle of under-investing in mitigation and insurance, and over-investing in post-disaster recovery, which reduces incentives for firms to manage risks *ex ante* (PC 2014b, p. 2).

## **Providing an open trading environment is vital**

Governments can facilitate more effective responses to supply chain disruptions by creating a regulatory and policy environment that avoids unnecessary impediments to domestic and international trade. An open trading environment allows firms to deal with operating uncertainties or unanticipated risks in their supply chains, and to adapt their production or supply chains in response to a major disruption at a lower cost. Box 7.4 provides some examples of ways trade barriers can increase supply chain risks and affect response to disruptions.

---

## Box 7.4 Barriers to trade, supply chain risks and risk management

Participants to the study provided examples of how barriers to trade have added to risks in supply chains and affected how firms are able to respond to disruptions.

The Australian Steel Association (sub. 27, pp. 1–2), for example, highlighted how dumping actions affect the availability of alternative sources of steel products for Australian manufacturers, and how uncertainty about the timing of the actions increases uncertainty for manufacturers that require steel as an input.

Many measures, such as product safety or health and biosecurity standards and regulations, were also highlighted by participants as adding compliance costs on firms. As Grain Trade Australia and the Australian Grain Exporters Council (sub. 37, p. 5) noted, regulatory measures:

... are often legitimately imposed by Governments to protect consumers, the environment and producers by ensuring biosecurity, integrity and food safety standards. ... [However, they become] ... a trade barrier when they are not based on risk or science, are used to protect domestic production, or when imposed by different countries, with different standards.

According to Accord (sub. 43, p. 2), their members were restricted from taking certain actions to ease supply chain pressures in 2020, due to ‘existing, complex, Australian rules’, including the:

- Importation of products marketed in an overseas jurisdiction with equivalent regulatory oversight e.g. the [European Union], Canada, [United States] and New Zealand.
- Use of locally manufactured ingredients to replace imported ingredients.
- Consideration of new packaging suppliers as interim measures.

Adopting international standards for the purposes of recognition and interoperability, and in particular to temporarily adjust or relax them to enable contingent supplies, was raised by several submissions (see for example ACCI, sub. 44, p. 3; CIPS, sub. 7, p. 34). In 2021, the Australian Government announced that it will work with Consumer Ministers to develop amendments to the Australian Consumer Law and associated legislation to allow the adoption of trusted overseas product safety standards (Morton 2021).

Regulations can also restrict trade in services. For example, licensing requirements in sectors such as architecture and engineering can prevent foreign companies from practicing in Australia. This can restrict the ability of domestic firms to source specialised skills during a disruption.

## Trade is beneficial for managing and responding to supply chain disruptions

The Australian Government plays a fundamental role in supporting a rules-based global trading system. It signs up to these rules of trade between nations (based on the principles of non-discrimination, transparency and reciprocity) primarily through the World Trade Organisation (WTO).

The system provides predictability and mechanisms to avert or resolve trade disputes and gives all nations and businesses regardless of their size the confidence that success in international trade depends on the merits and competitiveness of the goods and services they provide, not their political clout. It has proven effective in progressively lowering trade barriers, which has been a source of economic growth, lifted living standards and contributed to poverty reduction within and across nations. (PC 2019, p. 38)

---

Having minimal constraints on international trade allows firms to diversify their suppliers and markets in preparation for global supply chain disruptions, and to find alternative sources when a disruption affects a specific location in a firm's supply chain. A strong and reliable trading system is particularly important during a crisis. For example, Co-operative Bulk Handling Ltd (sub. 57, p. 7) noted that the Comprehensive and Progressive Agreement for Trans-Pacific Partnership:

... provided new market access opportunities for Australian grains into Mexico with tariffs on barley being eliminated over five years. ... This new market opportunity is timely given the recent tariffs imposed by China on Australian barley, which resulted in Australia effectively losing access to its largest barley market. Whilst the volume does not compare to that of China, the interest shown by Mexico to purchase high quality malting barley demonstrates the ongoing need to invest in activities to diversify markets for our grain commodities.

The Australian Government supports this rules-based trading system by ensuring markets are open to trade and investment, and that the rules are respected and kept up to date. The Commission has previously identified three areas that could continue to drive this, including: periodically reviewing the design and adequacy of foreign investment screening processes; bolstering government efforts to explain how and why the community benefits from trade liberalisation; and lowering remaining trade barriers (PC 2019, p. 51). For example, the Australian Government co-sponsored the *World Trade Organisation Agreement on Trade Facilitation*, which came into force in February 2017. The Agreement seeks to reduce red tape and the costs of procedures, such as customs and border regulations, licensing and transit formalities, administrative processes and documentation requirements.

The Australian Government can also support the rules-based trading system by working with others to resolve long-standing and escalating challenges facing the WTO. This includes reinvigorating its negotiation function, strengthening compliance with notification procedures, and refreshing the rules to handle issues relating to state-owned enterprises, regulatory co-operation, digital trade and intellectual property, among others.

Agreements under the WTO broadly prohibit the use of export restrictions, unless the member can justify that a measure is required to prevent or relieve critical shortages of foodstuffs or other essential products, or to protect human, animal or plant life and health (WTO 2020a, p. 4).<sup>37</sup> These provisions regulate how the measures can be applied (for example, they cannot be discriminatory), and establish notification and dispute resolution mechanisms.

Notwithstanding these provisions under the WTO agreements, they were not widely respected at the outset of the pandemic. By April 2020, approximately 80 governments had introduced export prohibitions and restrictions to mitigate shortages at the national level of medical supplies (facemasks and shields), pharmaceuticals and medical equipment (ventilators), and other products, such as foodstuffs and toilet paper (WTO 2020a, p. 1). However, G-20 members had lifted approximately 27 per cent of trade restrictions by

---

<sup>37</sup> The *General Agreement on Tariffs and Trade 1994* sets out carve outs and exceptions to the general prohibition to export bans and restrictions under Articles XI:2(a) and XX:b respectively (WTO 2020a, p. 4).

---

October 2020, and 63 per cent of their pandemic-related measures actually facilitated trade (including reducing tariffs and streamlining certification procedures on PPE and other medical equipment necessary to combat the pandemic) (WTO 2020b, pp. 4; 32–33).

The WTO noted that export restrictions are not costless. For example, exporters risk losing out in the long run:

... lower domestic prices will reduce the incentive to produce the good domestically, and the higher foreign price creates an incentive to smuggle it out of the country, both of which may reduce domestic availability of the product. On the other hand, restrictions initiated by one country may end-up triggering a domino effect. If trade does not provide secure, predictable access to essential goods, countries may feel they have to close themselves from imports and pursue domestic production instead, even at much higher prices. Such a scenario would likely result in lower supply and higher prices for much-needed merchandise. The long-term effects could be significant. (WTO 2020a, pp. 1–2)

### Regulations should not unnecessarily impede risk management and response

All levels of government have a role to ensure regulations achieve their intended goals, without unnecessarily impeding risk management and response by firms. Particularly pertinent to regulatory impacts on supply chains, regulation should be:

- outcomes focused, that is, not unduly prescriptive. This gives firms the flexibility to find the best way to comply with regulatory outcomes and adapt their operations, if required, during a disruption
- integrated and consistent with other laws, agreements and international obligations. This is particularly important, for example, to ensure domestic regulations do not impede international trade that could support a more diversified supply chain
- enforceable and embody the minimum incentives needed for effective compliance.

This requires regulators to be resourced and empowered to enforce regulation in a manner that allows them to be responsive to changing circumstances, while ensuring that regulatory outcomes are achieved.

Regulation should be reviewed regularly to ensure it is fit for purpose, and while good regulatory systems should be set up to deal with changing conditions, temporary, ad hoc changes, such as the exemptions to competition policy discussed above, may be required to respond to unexpected disruptions. Such responses can be a good opportunity to review regulatory systems, in line with a ‘stewardship’ approach to regulation.

For example, the *Corporations (Coronavirus Economic Response) Determination (No. 1) 2020* (Cwlth) temporarily allowed companies to execute documents electronically. This had long been sought by stakeholders and the Australian Government has since released an Exposure Draft Bill that would permanently allow the use of electronic signatures (the *Corporations Amendment (Virtual Meetings and Electronic Communications) Bill 2020*).

---

## 7.3 A framework for determining whether government intervention is justified

With hindsight, it is easy to identify actions that governments might have taken to better support firms' preparation for the global supply chain disruptions wrought by the COVID-19 pandemic. But when looking forward, governments should bring a disruption-agnostic and principles-based approach to deciding how they support preparation for, and response to, disruptions to global supply chains that might threaten access to essential goods and services. In line with good policy process, box 7.5 outlines three key principles for government intervention in private sector risk management.

### Box 7.5 Good policy process principles where government intervention is appropriate

- **Transparency:** Governments should inform taxpayers about where and how public funds are being used. Where assistance involves mutual obligation, this should be clear and measurable by all parties.
- **Accountability:** Governments and the recipients of public assistance should both be accountable to the public for their actions. In terms of government accountability, the conditions under which industry assistance measures are established should be clearly articulated upfront, and it should be demonstrated that the benefits to the community from intervention are expected to exceed the costs. Ex post evaluations should also be conducted to ensure that expected benefits are being realised, and if not, whether changes to funding arrangements are required.
- **Long-term sustainability of industry without ongoing funding:** Where industry-specific assistance can be justified — given the presence of a government or other impediment, and the costs and benefits of policy intervention — it should not be regarded as a permanent lifeline. Well-designed assistance measures should seek to provide a sound footing for industries to achieve commercial viability, free of specific government funding or other advantage.

Source: PC (2014a, pp. 83–84).

Moreover, drawing on the principles of supply chain risk management outlined in this chapter, figure 7.1 outlines a framework that governments could use to decide whether and how to intervene in managing supply chain risks. Table 7.1 poses questions that are designed to clarify each step in the framework. (Appendix F provides an illustrative example of how this framework could be applied to identify (and assess) feasible policy options to deal with potential risks to Australia's maritime shipping and ports capacity.) The questions are directed at ensuring the continuity of supply for those goods and services that are essential to Australians' wellbeing.

The first step of the framework begins with understanding the problem. Governments need to identify the good or service that they care about, including whether it is vulnerable, essential and critical (based on the approach outlined in chapter 3).

---

Second, governments need to establish their role, and identify all potential options for intervention. This includes understanding whether firms face impediments to managing risks and whether government is best placed to address those impediments. It is important to clearly identify and articulate the objectives of intervention (that is, what barrier is being addressed) and canvas widely for options that might achieve that objective.

Third, governments need to assess the costs and benefits of intervention against no government action. In this step it is important to consider the market response during a disruption and whether government intervention will crowd out firms' investment in risk management. Governments could decide to intervene if the benefits of intervention outweigh the costs. The final step is to monitor and evaluate the effectiveness of the intervention.

It is also important that government periodically reviews and updates the list of goods and services that are vulnerable to supply chain disruptions and essential for the wellbeing of Australians, as it is likely to change over time. This role could be undertaken by the Office of Supply Chain Resilience, which the Australian Government established in 2021 to monitor vulnerabilities and coordinate whole-of-government responses to ensure access to essential goods (Australian Government 2021, p. 11).

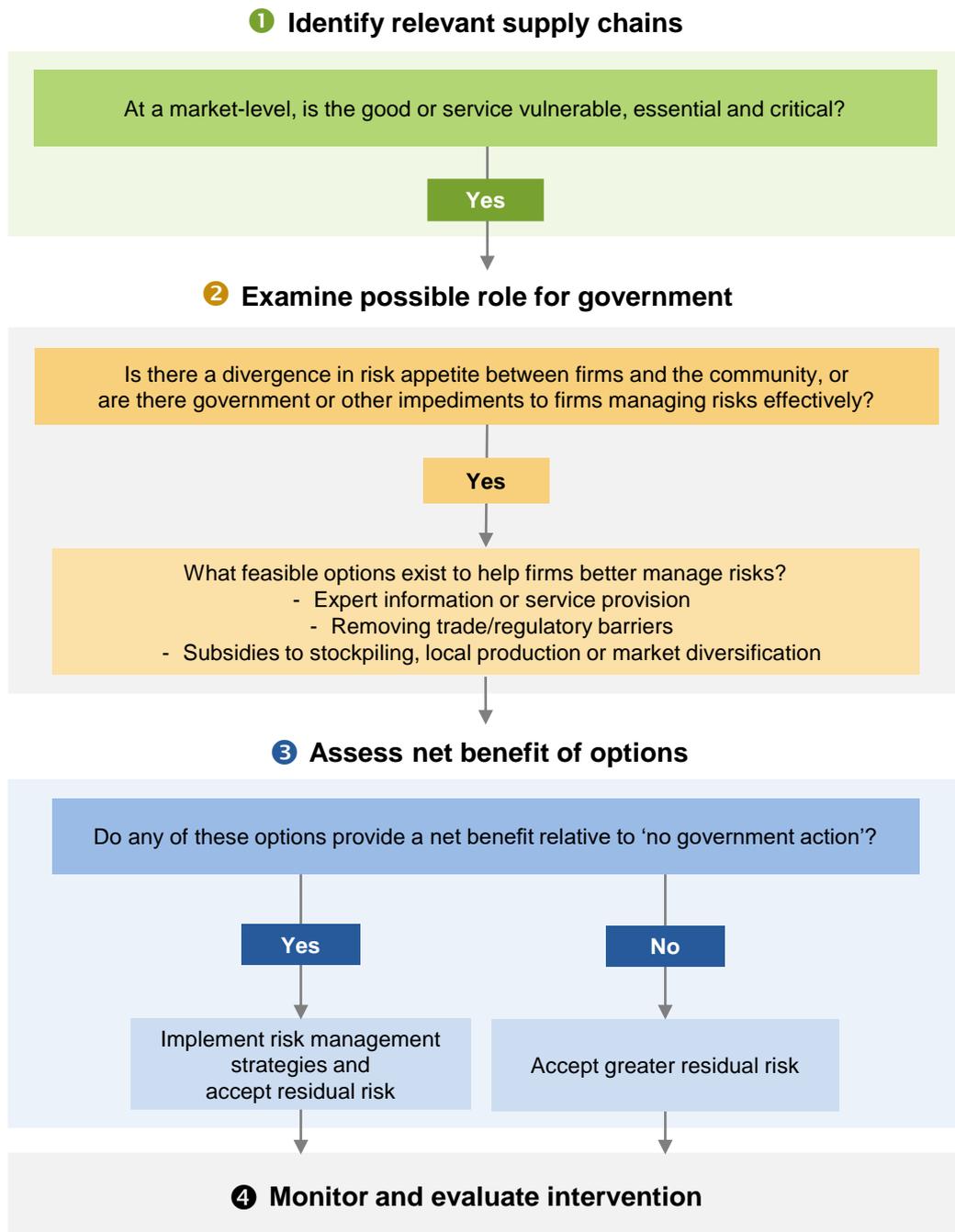
The framework developed in chapter 3 provides a means to repeat such reviews, and preferably they would include expert consultation. This approach is recommended to better understand where vulnerabilities will be visible in data and which data are best suited to identify vulnerable, essential, and critical goods — thus producing the information needed to understand risks and coordinate effective responses.

#### FINDING 7.2: GOVERNMENT INTERVENTION IN PRIVATE SECTOR RISK MANAGEMENT

Government intervention in private sector risk management may be justified when society's tolerance for a residual risk is lower than the residual risk that results from the market and where government or other impediments prevent firms from effectively managing their risks. However, government intervention can crowd out private investment in risk management — the net benefit of any intervention should outweigh the costs.

All levels of government have responsibility for ensuring regulations are fit for purpose, including making temporary changes that let firms adjust to major disruptions. The Australian Government also has responsibility for maintaining and promoting a rules-based international trading system that is respected and kept up to date.

Figure 7.1 A framework for government intervention



**Table 7.1 Questions to ask when considering government intervention**

**Identify relevant supply chains**

- What goods or services are vulnerable? What makes them vulnerable?
  - What disruptions could impact supply of the good or service?
  - What are the characteristics of the good or service?
- Are the goods used in or produced by an essential industry? Why are they essential?
  - For goods used in essential industries, are they critical? (Critical inputs cannot be replaced or designed out.)

**Examine possible role for government**

- Have firms in the supply chain identified and taken ownership of the potential risks? Is risk management across firms consistent with the risk appetite across the community?
- Are there impediments to firms managing risks? These may include:
  - inadequate information on risks
  - risk of contagion that firms do not internalise
  - externalities in consumption, such as the broader community benefits of supplying PPE masks for use during a pandemic
  - inability to price risk (before or after disruption). Could be due to regulation or consumers buying from cheaper non-resilient supply chains in normal times
  - regulatory or trade barriers that prevent firms from implementing diversification strategies.
- What policy options are available to manage market-level supply chain risks? For example:
  - provision of expert information or services
  - removal of trade or regulatory barriers
  - requirements or subsidies for stockpiling, subsidies for local production or for market diversification.

**Assess whether the costs of interventions are justified**

*Do nothing*

- What is the cost of government doing nothing?
  - In response to a disruption, can firms and consumers adapt to use less of the essential good or service, or the critical input to their production? Would standard market allocation mechanisms lead to the critical input being reallocated from non-essential uses to essential uses?

*For each option*

- What are the costs of government providing the service or investment? What are the costs to firms and the community from government intervention?
- Does the government intervention crowd out private investment in risk management?
- Is the policy option fit for purpose for the risk that needs to be managed?
  - For expert information or services: does government have an advantage filling information/expertise gaps that would help firms better manage their supply chain risks? Alternatively, should government require firms to disclose information to increase supply chain transparency?
  - For trade or regulatory barriers: are there alternative regulations that achieve the same policy outcomes but at a lower cost of managing supply chain risks? Can regulatory frameworks adjust to allow firms to respond to supply chain disruptions effectively?
  - For subsidies to stockpiling, local production or market diversification: is the level of investment commensurate with the cost of the risk being managed? Is the timeframe of assistance appropriate? Are there sufficient incentives in place for firms to not need long-term intervention?

---

# A Consultation

The consultation process for this study included:

- four workshops and a number of bilateral meetings with representatives from a range of government agencies (table A.1). The workshops were held on 17 November 2020, 17 December 2020, 2 February 2021, 21 May 2021.
- multilateral and bilateral meetings with industry (table A.2)
- receipt of 59 submissions (table A.3) and two brief comments (available on the Commission’s website).

---

**Table A.1 Government agencies that attended workshops or bilateral meetings**

---

Austrade  
Commonwealth Scientific and Industrial Research Organisation (CSIRO)  
Department of Agriculture, Water and the Environment  
Department of Defence  
Department of Foreign Affairs and Trade  
Department of Health  
Department of Home Affairs  
Department of Industry, Science, Energy and Resources  
Department of Infrastructure, Transport, Regional Development and Communications  
Department of the Prime Minister and Cabinet  
Department of the Treasury  
National COVID-19 Coordination Commission  
Office of National Intelligence  
Reserve Bank of Australia (RBA)  
South Australian Fire and Emergency Services Commission (SAFECOM)<sup>a</sup>

---

<sup>a</sup> Government workshops were only open to Australian Government agencies, as such SAFECOM only participated in a bilateral meeting.

---

---

---

## Table A.2 Multilateral and bilateral meetings with industry

---

Ai Group

Business Council of Australia (BCA) workshop <sup>a</sup>

Australian Chamber of Commerce and Industry (ACCI)

Chartered Institute of Procurement and Supply (CIPS)

Detmold Medical Group

GS1 Australia

Lynas Rare Earths

Medicines Australia

Minerals Council of Australia (MCA)

Shipping Australia Ltd (SAL)

Supply Chain Roundtable<sup>b</sup>

Transport and logistics roundtable<sup>c</sup>

Viatrix

---

<sup>a</sup> The Commission attended a workshop organised by the Business Council of Australia. The workshop was attended by representatives from: Accenture, Adelaide Bank, Amazon, Bendigo Bank, Boston Consulting Group (BCG), BP, Cochlear, H&H Group, Kearny, KPMG, Lendlease and Telstra. <sup>b</sup> The Commission attended a Supply Chain Roundtable organised by the Australian Government Department of Industry, Science, Energy and Resources (DISER). The workshop was attended by representatives from: Accord, Ai Group, the Australian Aluminium Council, the Australian Chamber of Commerce and Industry (ACCI), the Australian Construction Industry Forum (ACIF), the Australian Food and Grocery Council (AFGC), the Australian Small Business and Family Enterprise Ombudsman (ASBFEO), the Business Council of Australia (BCA), the Business Council of Co-operatives and Mutuals (BCCM), Consumer Healthcare Products (CHP) Australia, Chemistry Australia, the Generic and Biosimilar Medicines Association (GBMA), Manufacturing Australia (MA), Master Builders, the Medical Technology Association of Australia (MTAA), Medicines Australia and the Property Council of Australia (PCA). <sup>c</sup> The Commission organised a roundtable with representatives from the transport and logistics sector, including: the Australian Logistics Council (ALC), the Australasian Railway Association (ARA), the Freight Industry Reference Panel, the Freight and Trade Alliance (FTA), the Heavy Vehicle Industry Australia (HVIA), International Forwarders and Customers Brokers Association of Australia (IFCBAA), Maritime Industry Australia Ltd (MIAL) and Ports Australia.

---

---

**Table A.3 Public submissions**

<i>Participant</i>	<i>Submission no.</i>
Richard Billington	1, 4
Bioenergy Australia	2
Muhammad Zaheer Abbas	3
Port of Newcastle	5
Institute for Integrated Economic Research – Australia Limited (IIER-Australia)	6
Chartered Institute of Procurement and Supply (CIPS)	7
GS1 Australia	8
Engineers Australia	9
Water Services Association of Australia (WSAA)	10
Department of State Growth (Tas.)	11
CropLife Australia	12
IBM	13
Minerals Council of Australia (MCA)	14
Novartis Pharmaceuticals	15
Pharmacy Guild of Australia	16
RDA Tasmania (RDAT) and the Tasmanian Logistics Committee	17
Freight and Trade Alliance (FTA) and the Australian Peak Shippers Association (APSA)	18
GeneEthics	19
Ports Australia	20
Imperial Brands Australasia	21
National Farmers Federation (NFF)	22
Victorian Farmers Federation (VFF)	23
Chemistry Australia	24
Grain Producers Australia (GPA)	25
InfraBuild	26
Australian Steel Association (ASA)	27
Maritime Industry Australia Ltd (MIAL)	28
Business Council of Co-operatives and Mutuals (BCCM)	29
Total Laser Cutting Services	30
Export Council of Australia (ECA)	31
Food and Beverage Importers of Australia (FIBA)	32
GrainGrowers	33
Committee for the Hunter	34
Port of Melbourne Operations Pty Ltd (PoM)	35
Be Slavery Free	36
Grain Trade Australia (GTA) and Australian Grain Exporters Council (AGEC)	37
Maritime Union of Australia (MUA)	38
KPMG	39
Consumer Healthcare Products (CHP) Australia	40
International Forwarders and Customs Brokers Association of Australia (IFCBAA)	41
Pfizer	42
Accord	43

(continued next page)

---

**Table A.3** (continued)

<i>Participant</i>	<i>Submission no.</i>
Australian Chamber of Commerce and Industry (ACCI)	44
TyreSafe Australia	45
Australian Trade and Investment Commission (Austrade)	46
Australian Logistics Council (ALC)	47
Business Council of Australia (BCA)	48
Ai Group	49
Australian Rail Track Corporation (ARTC)	50
Master Builders Australia	51
NSW Farmers	52
BP Australia	53
Association of Mining and Exploration Companies (AMEC)	54
Medicines Australia	55
Shipping Australia Ltd (SAL)	56
Co-operative Bulk Handling Limited (CBH)	57
Caravan Industry Association of Australia	58
Victorian Automotive Chamber of Commerce (VACC)	59

---

---

## B Case studies in vulnerability

Chapter 4 and submissions to this study identify products and processes for further investigation to establish whether they might be critical in the supply of goods and services that are essential to Australians' wellbeing. Given the nature of some of these products and processes, this appendix investigates them to provide the reader with some context within which to assess the material in chapters 4 and 5.

The products investigated below include:

- rare earths, because of their critical role in the production of many goods around the world
- integrated circuits and semiconductors as an example of a large market of essential items under pressure from multiple disruptions
- water treatment chemicals, to clarify issues around potential substitutability
- fire retardant, an import used in firefighting and is produced in a single location
- real-time gross settlement (RTGS), a part of the global financial system, which forms one of the more important background processes providing security and liquidity to the world's financial systems and economies.

### Rare earths

Rare earths are a group of 17 elements composed of scandium, yttrium, and the lanthanides<sup>38</sup>, which feature unique catalytic, metallurgical, nuclear, electrical, magnetic, or luminescent properties. Rare earth compounds are critical inputs in a number of essential technologies and industries such as electronics and renewable energy (Dushyantha et al. 2020). They are relatively abundant in the Earth's crust, but cluster in exploitable ore bodies only in limited locations, which earns them the qualifier 'rare' (Haxel, Hendrick and Orris 2002). Trade in rare earths is recorded under HS codes 280530, 284610 and 284690.<sup>39</sup>

Once rare earths are mined, they need to be separated and refined, which can be difficult, polluting and costly. For example, the cracking and leaching process of rare earth processing, which separates the saleable element from its contaminants (some of which are radioactive), leaves residue to be disposed of or stored long after the product has been sold (Law 2019).

---

<sup>38</sup> Lanthanides are 15 metallic chemical elements with atomic numbers 57-71.

<sup>39</sup> Global trade data do not identify the 17 individual rare earth elements separately; determining vulnerability in each would require more detailed data on individual elements.

---

Since the 1990s, industrialised economies that previously mined and refined rare earths have moved production, especially refining, to China (ChinaPower 2020).

Australian imports of rare earths in 2018 were very small<sup>40</sup> and under the Commission's framework (chapters 3 and 4), imports of rare earths are not deemed to be vulnerable. Although Australian imports are small, the critical status of rare earths in the manufacture of essential technologies globally means that a disruption in their supply could affect Australia as an end user of essential electronic equipment. For example, disruptions could affect the supply of laptops, which were identified in chapter 4 as vulnerable (but whose criticality has not yet been verified with experts).

Australian rare earth producer, Lynas Rare Earths, mines neodymium and praseodymium from its Mount Weld mine in Western Australia. The ore is concentrated onsite and shipped to the company's refinery in Malaysia. According to the criteria in chapter 5, these exports appear to be concentrated, but the entire process is vertically integrated within one company. Malaysia exports rare earth compounds mainly to China (46 per cent), Vietnam (30 per cent) and Japan (15 per cent).

According to 2019 trade statistics, the global market for rare earths was not concentrated: as a group, rare earths had a HHI of 1334. Globally, the largest exporter was China (24.9 per cent), followed by Malaysia (from Australian raw materials) (16.6 per cent), and Japan (15.2 per cent).

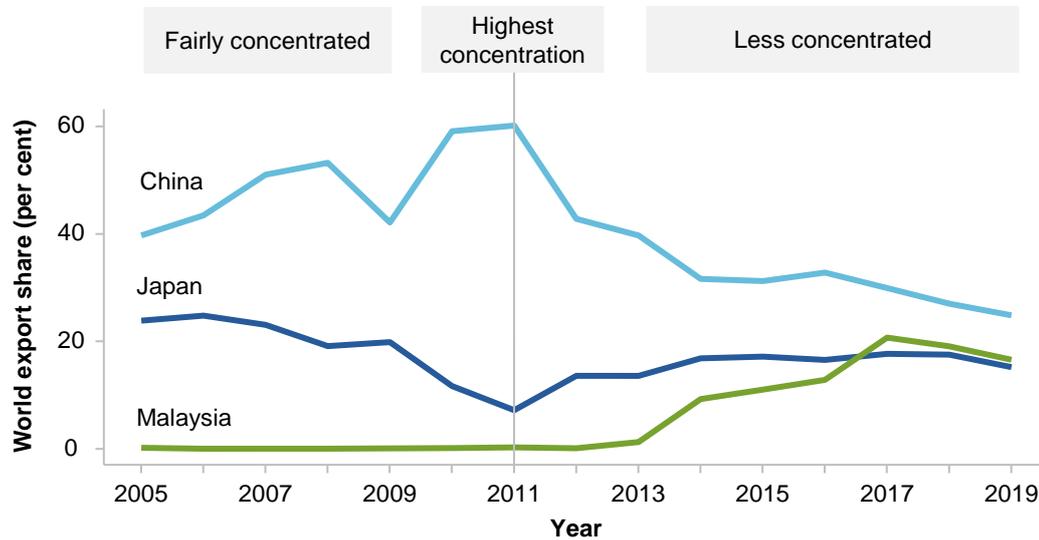
However China's role in the global market for rare earths is more important than the export data suggest: it produces about 90 per cent of global output (Dushyantha et al. 2020). Before 2011, this was reflected in the trade data (figure B.1) but the period since has seen China's export market share drop from a peak of 60 per cent in 2011 to about 25 per cent in 2019, as domestic export quotas were tightened to 'ensure sustainability and curb environmental damage' (Branigan 2010). The perception that China is using its supply dominance as a foreign policy tool, particularly in disputes with Japan (Hui 2021) and the United States (Yu and Sevastopulo 2021) has added some uncertainty to global value chains that rely on these products.

As the main buyer of refined rare earths, Japan has felt the effects of restrictions and uncertainty more than other economies. After 2010 Japan has largely driven the global search for new sources, investing in terrestrial and offshore projects in economies such as Australia, India, Kazakhstan and the United States, and reducing its imports from China (OEC 2019b).

---

<sup>40</sup> Significant differences exist between global trade data sources for rare earths, particularly Australia's contribution to the world market. Analysis presented here is drawn from the BACI database provided by CEPII.

Figure B.1 **Rare earths market concentration has declined following China's export restrictions**



Data source: Observatory of Economic Complexity (2019b).

China is also looking for new sources of supply as it becomes less willing to pay the environmental cost that extraction and refinery processes entail. As its export share has been dropping China's share of rare earth imports has been increasing, to the point that in 2017 it overtook Japan as the world's largest buyer (Schmid 2019, p. 3).

For exports, Australia is well placed to ride the wave of increased demand for rare earths outside China. Japan, for example is building a wider portfolio of suppliers (Hui 2021), which has reduced the share of its imports from China. Lynas Rare Earths has received backing from both Japan and the United States to develop its mining and refining capabilities. The market is still affected by Chinese production quotas which contributes to high prices and makes alternative, higher cost sources economic to exploit (Mancheri et al. 2019).

The United States and Japan, with their governments backing Australian rare earth producers, may still see their domestic consumers buying from the cheapest supplier, which may well be a Chinese supplier should the price be right. Cheaper Chinese rare earths have contributed to the United States (once the world's dominant supplier but with rising costs) exiting the market (Goldman 2014, pp. 153–154). Continued increases in production from China puts downward pressure on prices making it more difficult to develop Australian exports. In 2021, China increased its first half-yearly output quotas by 27 per cent compared to the same period of the previous year (Daly 2021).

---

## Integrated circuits and semiconductors

Integrated circuits (sometimes known as chips or microchips) are a collection of electronic circuits on a piece of semiconductor material. The terms integrated circuit and semiconductor are often used interchangeably. Semiconductors are essential in the running of almost every electronic device and their use is increasing alongside the computerisation of devices. A modern car can have over 3000 chips (Ewing and Boudette 2021).

Chip manufacturing has very high barriers to entry — the work is complicated, the equipment expensive and it can take years to commission a new factory. As such, manufacturing is dominated by three large manufacturers: Taiwan Semiconductor (TSMC), Semiconductor Manufacturing International Corporation (SMIC) in China and Samsung in South Korea.

With a HHI measure of 1399<sup>41</sup> in 2017, the industry producing semiconductors would not be flagged as vulnerable under the Commission’s framework outlined in chapter 3.

Despite not being identified as vulnerable, a combination of factors has led to a global shortage of chips.

- The world experienced shortages since early 2020, brought about by pandemic-related factory shutdowns.
- In December 2020 the US administration restricted SMIC’s ability to buy some US-made inputs. This in turn hampered their ability to supply chips to the world market, causing shortages down the line (particularly in the US auto industry) (Klayman and Nellis 2021). The issue has been exacerbated by stockpiling by Chinese manufacturers in reaction to the US ban on exports of inputs to SMIC (Jeong and Strumpf 2021).
- Larger than expected demand for chip-intensive cars alongside a surge in demand for computers, consoles and gadgets in response to worldwide pandemic-related lockdowns (King, Wu and Pogkas 2021a).
- In February 2021 power outages caused by extreme weather conditions forced the temporary closure of major plants belonging to Samsung, NXP Semiconductors and Infineon Technologies in Texas (Flaherty 2021).
- A severe drought in Taiwan put semiconductor manufacturing there under stress in early to mid 2021 (the production of semiconductors is a series of intricate steps, involving depositing, etching and polishing that requires a large amount of ultra-pure water during each phase). Semiconductor manufacturing is so important to the Taiwanese economy that its supply of water was (in some cases) prioritised over the needs of residents and agriculture (Sui 2021).

---

<sup>41</sup> HHI 1399 in 2017 on HS code 8542. Analysis presented here is drawn from the BACI database provided by CEPII.

---

The shortage in semiconductors is holding up production lines all over the world for products as diverse as home appliances, personal computers and cars.

There exists no short-term fix for the current shortage of semiconductors. Major chip makers are pivoting towards the more profitable chips (for example 5G phones and servers) leaving the lower end market such as those used in computer monitors, speakers and appliances to suffer shortages.

In the longer term, several governments around the world are providing incentives to manufacturers to increase their domestic capabilities. The United States has pledged US\$37 billion to cover the short-term costs of rebuilding and securing America's supply of semiconductors (Mudassir 2021). China, South Korea and Taiwan are making similar investments to increase production.

The issues that have beset the semiconductor industry are varied and not easily addressed. In the end it might just require the pandemic to end and US-China trade relations to normalise before the market can find a new equilibrium.

## **Water treatment chemicals**

A continuous, stable and reliable supply of drinking water is essential. While water itself is sourced locally, making it drinkable involves several chemical inputs whose supply might be vulnerable.

In Australia, drinking water quality is governed by state authorities following national guidelines that outline the chemicals that can be used in the treatment process.

These chemicals are distributed across several HS codes and most chemicals are not vulnerable when the first two chapter 4 filters are applied. In most cases where import concentrations of products are greater than 80 per cent, the HHI for those products show the global market to be competitive (table B.1).

One exception, however, is sodium carbonate<sup>42</sup>, where 93 per cent of Australia's imports are sourced from a dominant world supplier whose market share exceeds 50 per cent. Although the world market appears relatively competitive (HHI 2314), Australia's concentrated buying pattern means the existing supply chain for sodium carbonate is vulnerable.

That said, sodium carbonate is not critical as its role in pH correction appears to be substitutable. In the pH correction process, lime can be used instead of sodium carbonate (Melbourne Water 2020) and is applied by adding either slaked lime or quicklime (NHMRC and NRMMC 2011, pp. 1039, 1044); neither is vulnerable (table B.1). Likewise, sodium

---

<sup>42</sup> The product commonly known as 'sodium carbonate' is referred to as disodium carbonate by the International Union of Pure and Applied Chemistry and in trade classifications.

hydroxide could be substituted for sodium carbonate and is traded in a large, competitive market with imports to Australia also being relatively unconcentrated.

**Table B.1 Water treatment chemicals are not vulnerable**  
Functions and market indexes of selected products used in water treatment

Product	HS code	Use	Concentration of Australian imports (%)	HHI by value <sup>a</sup>	Export share of main global supplier <sup>a</sup>
Aluminium sulphate	283322	Coagulation	91.9	780.5	18.9
Water filtering or purifying machinery or apparatus	842121	Filtration	25.4		
Calcium hypochlorite <sup>b</sup>	282810	Disinfection	73.0		
Potassium permanganate	284161	Disinfection	38.7		
Ammonium sulphate <sup>c</sup>	310221	Disinfection	66.4		
Copper sulphate	283325	Disinfection	40.5		
Parts for lamps (including UV)	853990	Disinfection	35.1		
Includes UV lamps	853949	Disinfection	34.6		
Chlorine	280110	Disinfection	83.7	1 251.3	27.0
Hydrogen peroxide	284700	Disinfection	100.0	1 243.2	23.9
UV or IR apparatus	901820	Disinfection	30.9		
Granulated activated carbon	380210	Disinfection	22.1		
Hydrochloric acid	280610	Disinfection	36.0		
Anhydrous ammonia	281410	Disinfection	69.8		
Sodium carbonate	283620	pH Correction	90.9	2 885.8	50.7
Phosphoric acid <sup>d</sup>	280920	pH Correction	96.3	1 703.5	35.3
Sodium tripolyphosphate	283531	pH Correction	65.7		
Sodium hydroxide	281511	pH Correction	47.9		
Sodium bicarbonate	283630	pH Correction	54.6		
Sulphuric acid	280700	pH Correction	54.7		
Quicklime	252210	pH Correction	36.7		
Slaked lime	252220	pH Correction	41.7		

<sup>a</sup> Calculated for products with import concentration in excess of 80 per cent. <sup>b</sup> Generally used in small systems only. <sup>c</sup> Used in the manufacture of chloramine. <sup>d</sup> For making sodium hexametaphosphate.

Sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished), Melbourne Water (2020); NHMRC and NRMCC (2011), UN Comtrade data.

Water Services Association (sub. 10, p. 3) highlighted the potential vulnerability of chlorine which plays a major role in lowering the disease risk of drinking water. As shown in table B.1, this chemical was identified as being concentrated. However, there are several reasons why the Commission has not identified it as vulnerable.

- Although Australia's main chlorine source is China (73 per cent in 2018), alternative suppliers exist, including Canada (17.1 per cent of world exports), the United States (10.3 per cent) and France (8.1 per cent).

- 
- There exist a number of chemical substitutes for the disinfection process. None of these are perfect substitutes in the short run (requiring expensive equipment and infrastructure alterations), but substitution would be possible in the long run if necessary.
  - Australia is a net exporter of chlorine products, indicating the existence of sizable local production that could be substituted for imports. In 2017 Australia imported around \$1.1 million of chlorine products (HS 280110) while exports were valued at about \$1.4 million.

## Long-term fire retardant

There are two types of fire retardants. Short-term fire retardants are added to water and applied directly to a fire, enhancing the extinguishing property of water itself. These typically take the form of liquids or foams. Long-term fire retardant is usually delivered from the air, mostly by fixed-wing aircraft to create fire breaks. It can be applied to slow or stop the progress of a fire, or as a preventative measure to protect property or infrastructure (DHHS 2017). The Royal Commission into National Natural Disaster Arrangements (2020a):

- reported that long-term fire retardant was used extensively during Australia's 2019-20 bushfire season with large air tankers applying over 24 million tonnes across Australia (p. 210)
- indicated that Australia relies on a single supplier of retardant and acquires enough in advance to cover a 'standard' bushfire season (p. 233)
- suggested that procurement plans (where supply of an essential resource is reliant on international supply chains) match 'anticipated requirements' and if that proved impossible, consideration should be given to domestic production (p. 233).

While demand for retardant during the 2019-20 fire season came under significant pressure, state-based fire authorities were able to adequately supply retardant to fire events in multiple states by sharing equipment, expertise and retardant stockpiles.

The long-term fire retardant referred to in the Royal Commission report is the PHOS-CHeK range, manufactured by Perimeter Solutions in the United States. Perimeter Solutions supplies PHOS-CHeK globally to fire and forestry services and appears to be the only major supplier of long-term fire retardant.

Trade in these products is not recorded under a standalone HTISC category. Given this lack of detail it is difficult to use trade data to assess its vulnerability. That said, sourcing this product from a single firm and plant makes it vulnerable to disruption.

---

## Real-time gross settlement

RTGS systems are the hidden plumbing through which economies operate. By providing almost instantaneous transfer and settlement of large transactions between banks, RTGS provides a level of risk management and liquidity to a financial system.

In Australia RTGS is provided through the Reserve Bank Information and Transfer System (RITS); in 2019-20 RITS handled an average of \$233 billion in transactions every day (RBA 2020b, p. 83). RITS is a designated Systemically Important Payment System (RBA 2019b). This means RITS is the only domestic system with the potential to trigger or transmit systemic disruptions, presenting a significant point of vulnerability for the Australian economy.

Temporary failures in RTGS systems around the world are rare but they could have dire consequences if they lasted more than a few hours.

- The United Kingdom's Clearing House Automated Payment System (CHAPS) went offline for nine hours in October 2014 after software changes caused unexpected issues across the entire system. Upon reinstatement, settlement hours were extended and all transactions were completed within four hours after the usual cut-off (Deloitte LPP 2015, pp. 6, 8). At the time CHAPS settled £252 billion in transfers each day (Deloitte LPP 2015, p. 20).
- A power outage at one RBA data centre shut down RITS for about seven and a half hours in August 2018 (RBA 2019a, p. 5).
- In October 2020 a software defect in a network device is thought to have shut down the European Central Bank's TARGET2 RTGS system for almost 10 hours. At the time of writing an independent review into the incident was ongoing (ECB 2020). TARGET2 settled €672.5 billion in transfers each day in 2020 (ECB 2021).

In all cases no substantive and lasting damage was incurred. An independent review into the CHAPS outage found 51 per cent of housing transactions made that day were delayed, but very little in the way of compensation was sought or paid (Deloitte LPP 2015, p. 8). A similar story could be told for the RITS and TARGET2 outages.

Longer-term disruptions to these systems, however, could be catastrophic. Slowing RTGS transfers between banks can slow down entire economies. Government finances and expenditure can be hit by slowing securities markets and confidence in the health of an economy (SWIFT 2014, p. 9). Given the extent of these consequences, the position of RITS at the heart of the Australian economy makes it an obvious point of vulnerability.

Based on history alone the bulk of any risk to RTGS systems worldwide appears to be from accidental error rather than malicious intent. The three examples cited above all appear to stem from human error or system intervention (by authorised persons) gone awry, and were contained relatively quickly. In this sense, history suggests that systemic stability depends

---

on access to well-trained and qualified technicians, who build robust systems and quickly diagnose problems as they happen.

A targeted attack intent on disabling RTGS infrastructure could have devastating consequences. The RBA's response to the RITS 2018 shutdown and the COVID-19 pandemic have seen new data sites opened and more working from home arrangements for RBA staff (RBA 2020a, pp. 6, 7), which have significantly increased the points of connection with the world outside its system and introduced new vulnerabilities. That said, RTGS systems are typically difficult to attack (SWIFT and BAE Systems 2018, p. 18), and the RBA's cyber security arrangements were declared fit for purpose by the Auditor-General (ANAO 2019, p. 8).



---

## C Technical application of the analytical framework to imports

This appendix provides details on the application of the analytical framework developed in chapter 3 to Australian imports data presented in chapter 4.

- Section C.1 describes how the vulnerability of Australian imports data to supply risks arising from limited sources of supply was assessed.
- Section C.2 describes how Australian production data were used to assess the role that vulnerable imports played in the domestic production of essential goods and services.

The annexes to this appendix provide supporting information about the data sources and the product classifications used.

### C.1 Assessing import vulnerability

The mechanical sorting undertaken in chapter 4 identified Australian imports that were sourced from the main global suppliers in concentrated markets (step 1 of the framework outlined in chapter 3).

This approach considered vulnerability arising from two perspectives:

1. from reliance on existing suppliers and trade flows to provide an indication of *actual* supply risks
2. from *possible* sources of supply to provide an indication of *potential* supply risk.

To illustrate the difference, while Australia may source all its imports of a particular product from a single origin, others may be able to supply the product in the event of a disruption to supply.

The mechanical sorting involved progressively applying three filters to ascertain whether:

1. the main supplier of each product accounts for a large share of Australian imports
2. Australia sources its imports of each product from a concentrated global market
3. Australia sources its imports from the main supplier in a concentrated global market.

The first filter relates to Australian imports, while the second and third filters relate to global markets. Given this, the analysis used two trade data sets — Australian imports data sourced

---

from the Australian Bureau of Statistics (ABS); and the United Nation's *Comtrade* (2020) database of global trade (annex A).<sup>43</sup>

The products that remain after applying all three filters are sourced from the main supplier in a highly concentrated global market with limited, if any, alternative sources of supply in the event of a disruption to existing suppliers. Such products are likely to be more susceptible to disruption than products sourced from more diversified markets.<sup>44</sup>

## Approach used

Assessing import vulnerability involved linking Australian imports and global trade data at the same point in time. Linking trade data raised a series of questions:

1. As trade data come in different levels of product aggregation, what level of product disaggregation is appropriate for analysing supply chain risks?
2. Trade data relate to specific periods of time (such as monthly, and calendar and financial years), what time period is appropriate for the analysis?
3. As some trade is irregular and lumpy (such as imports of civilian aircraft and natural gas drilling platforms), should the analysis focus on a single year or span several years?

## Level of analysis

Trade and economic data are invariably aggregated to some extent (see annex B for details on product classifications). The trade data used in chapter 4 are classified according to the international Harmonized System (HS), or its Australian extension known as the Harmonized Tariff Item Statistical Code (HTISC). The HTISC has five levels of product aggregation, ranging from highly aggregated (known as the 2-digit Chapter) to highly disaggregated (Statistical codes, 10-digit). The number of products imported by Australia in 2016-17 differed by product classification (figure C.1).

Finer levels of product disaggregation enable a closer alignment with the specific products that may give rise to supply chain vulnerability, while higher levels of aggregation group products with broadly similar characteristics to reduce the volume of data. Some very finely grained levels of disaggregation add additional detail that is unnecessary for most purposes (such as differentiating the same product based on its thickness).

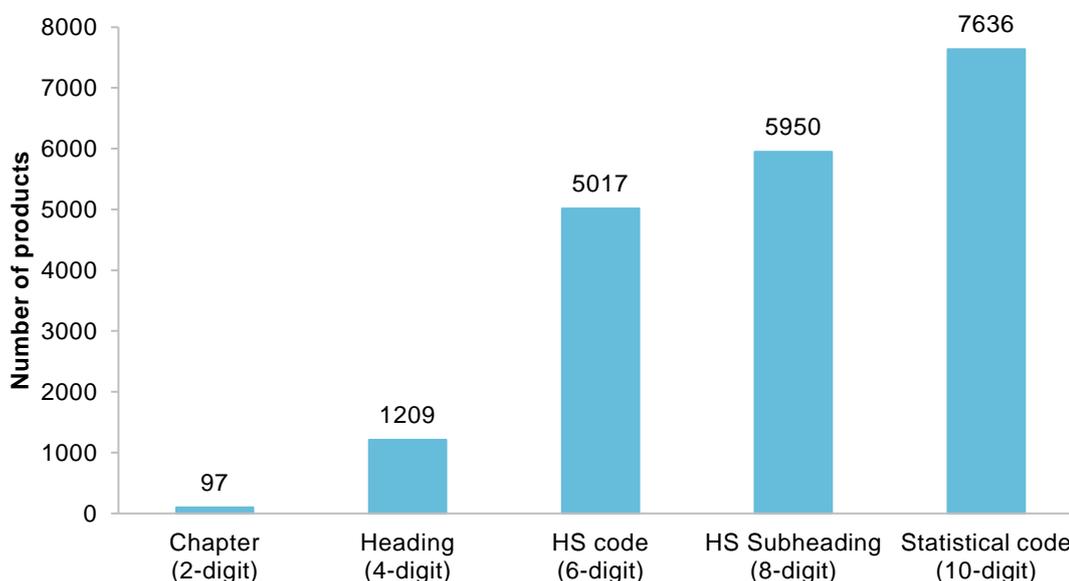
---

<sup>43</sup> The use of global trade data to identify alternative potential suppliers may understate the number of concentrated products, as it implicitly assumes that all sources of potential supply are open to Australia, which may not actually be the case. Australian biosecurity restrictions, for example, prohibit the importation of certain agricultural products from potential suppliers *even if* supplies of these products were available on the world market.

<sup>44</sup> The interest in potential suppliers means that the focus in the global trade analysis is on economies that *export* each product (even though the chapter focuses on Australian imports).

---

Figure C.1 **Number of products by HTISC classification**



*Data source: ABS (Merchandise Imports and Import Clearances, 2020, unpublished).*

---

The level of import concentration varies depending on the coarseness of the product classification used. Import concentrations will be higher for finely grained classifications (those with more digits) than for coarser ones (those with fewer digits), owing to the detailed nature of the product definitions. Fine-grained product classifications are more homogeneous than coarser ones, but may not include products that are effective substitutes. The resulting higher import concentrations may give the impression that some products are vulnerable when substitute products are actually available. On the other hand, coarser classifications may give the false impression that supplies of imports are not concentrated, as concentrated products may be grouped with products that are not. For example, at the 6-digit level many personal protective equipment products are grouped together (most of which are not substitutes) and so are not identified as concentrated, but moving to the 8-digit level reveals individual personal protective equipment products that are concentrated.

There is no right level of aggregation; judgment is needed to balance these two opposing potential sources of bias.

- Analysis of Australian imports used the 8-digit HTISC (known as the HS Subheading level). This level is fine-grained enough to enable potentially vulnerable products to be identified, but not so finely grained that substitute products are classified differently.
- Analysis of global trade data used the 6-digit HS (which is equivalent to the 6-digit HTISC). This is the most disaggregated classification level available in global trade data.

---

## Time period covered

The data used span different time periods:

- the Australian imports data extend from January 2010 to July 2020
- the global trade data extend from 2014 to 2017 (with preliminary data for 2018).

Using multiple years of data raises a set of trade-offs. In theory, it allows for the identification of products that are consistently assessed as vulnerable and might help avoid any bias that arises if a single year of data is not representative of others. However, using multiple years of data raises many practical issues. The main practical issue is changing product classifications which render the data inconsistent over time and which complicate the linking of multiple years of data. The process becomes more challenging when linking across the different product classifications used in trade data and production data.

The time period selected should reflect the current (or most recent) state of affairs. For example, in the past 10 years, Australia's main supplier for a product may have changed, there may be new product technologies that replaced older ones, or the composition of the global trade market may have changed (such as, entries and exits of exporters or changes in the main exporter of a product). Using data that is not timely may result in out of date findings.

The Australian imports data span the beginning of the COVID-19 pandemic which may not reflect a typical year. The pandemic disrupted many trade flows, causing surges in imports of some products (such as personal protective equipment) and a drop in imports of others (such as manufactured products). Therefore, imports data for 2020 would not reflect a typical year or the usual functioning of the Australian economy.

The approach focuses on trade flows in 2016-17, consistent with the latest full year of the global trade data (2017) and the latest year of detailed production data. Given product classifications change over time, using a similar reference year facilitated the linking across multiple data sources (trade and production).

## Thresholds used to for assessing concentration

Measures of concentration were used to ascertain the degree to which a product had a limited source of supply, and was, therefore, identified as vulnerable to disruption.

The trade data capture trade flows at the economy level, not the firm level. Thus, 'supplier' refers to a supplying economy. This also means that measures of concentration may be overstated as many firms within an economy might supply a product. As a result, in terms of our sources of vulnerability, this overstates the lack of flexibility but reflects the level of geographic concentration more accurately.

---

### Australian import data

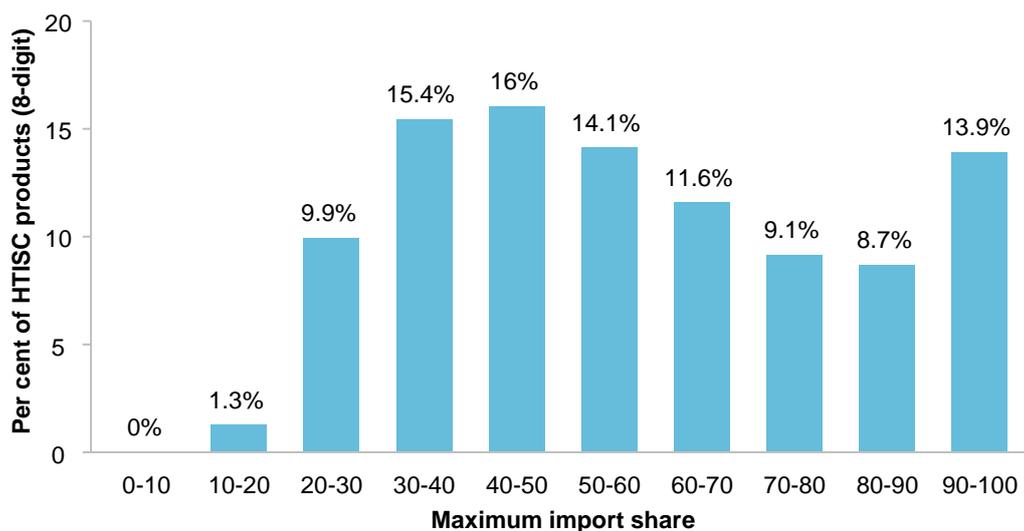
The concentration of imports was determined by assessing:

- the share of imports that each supplier accounted for (referred to as ‘import concentration’)
- the share of imports accounted for by the largest supplier. Shares are based on the *value* of imports.<sup>45</sup>

The share of Australian imports accounted for by the largest supplier varied markedly across products in 2016-17 (figure C.2).

---

Figure C.2 **Distribution of the share of Australian imports accounted for by the largest supplier, 2016-17<sup>a,b</sup>**



<sup>a</sup> There are 5950 8-digit HTISC products. <sup>b</sup> The share of imports from the largest supplier.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

---

Nevertheless, most imported products came from markets with high levels of concentration. Roughly, one-in-seven imported products in 2016-17 (13.9 per cent) came from markets where the main supplier accounted for 90 to 100 per cent of all imports by value. An additional one-in-five products (17.8 per cent) came from markets where the main supplier accounted for 70 to 90 per cent of imports. Indeed, over half of all products came from markets where one economy accounted for more than 50 per cent of imports of that product.

---

<sup>45</sup> The free on board (FOB) value is used because the alternative (the commercial invoice value, insurance costs, and freight, CIF value) includes freight and insurance costs which may distort the measure of concentration.

---

Judgement is required when choosing a threshold to classify an import as ‘concentrated’. The number of concentrated imports identified is sensitive to the threshold selected (see sensitivity analysis below). A threshold of 80 per cent was selected. As with any selected threshold, there might be products with high import concentrations (such as 79 per cent) that will be excluded but may potentially be an input into an essential industry that a policy maker might be concerned about. However, a threshold of 80 per cent provides a more conservative approach than a threshold of 90 per cent (which might appear to be the natural threshold choice given that, in figure C.2, the distribution increases at the 90 per cent threshold).

### *Global trade data*

Concentration in global market supply was assessed in terms of:

- the main exporter’s share of global trade
- the Herfindahl-Hirschman Index (HHI).

Most empirical studies of market concentration calculate market shares based on financial values (such as the value of trade). However, market shares can also be calculated using the quantities traded. The two measures are generally highly correlated, but need not be. Diamonds are an example where a value share may differ materially from a quantity share, given the importance of quality (such as cut, colour, and clarity) in determining value. Differences can also occur for other reasons, such as differences in production concentration implying different unit prices.

The UN *Comtrade* database includes data on trade flows in both value and quantity terms, such that the market share could be calculated using either measure.<sup>46</sup>

Choosing whether to calculate market shares based on quantity or value is not straightforward. If products within a product group are substitutes — even though their price and quality may differ — then quantity-based market shares indicate potential sources of supply are available from another supplier (regardless of the price or quality). However, quantity data is sometimes missing from the global trade data for some products and, therefore, need to be imputed.

The most comprehensive approach to identify all concentrated global markets is to calculate concentration measures using both a value-based market share and a quantity-based market share. The use of both measures errs on the side of caution by flagging the largest set of products for further investigation.

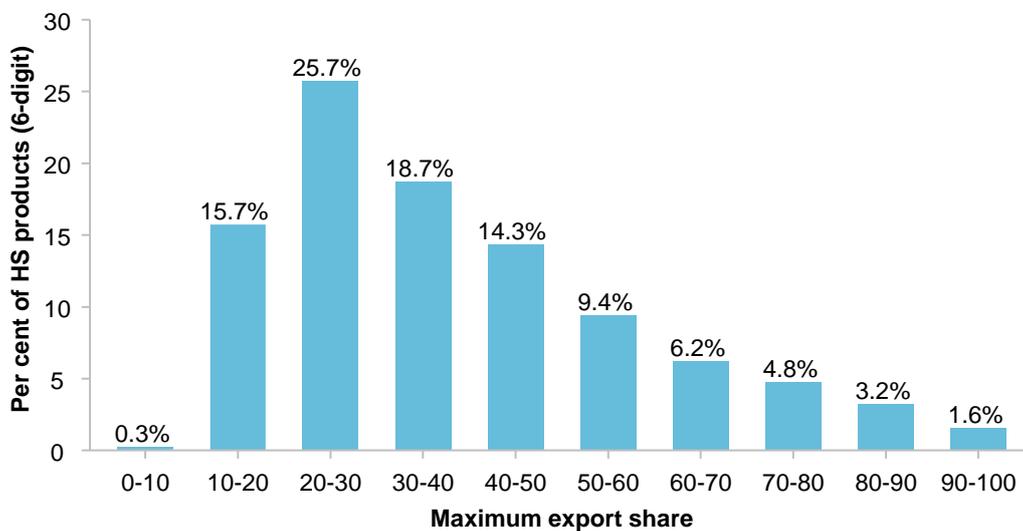
The share of global supply (exports) accounted for by the largest supplier of a product is presented in figure C.3. For only 1.6 per cent of products, the highest share was between 90 and 100 per cent. This means that, although there were other suppliers of the product, one economy accounted for over 90 per cent of global exports — many of the products in this

---

<sup>46</sup> Quantity is reported in net weight in kilograms for most products and the value reported as the FOB value.

range came from either China (20 per cent) or Japan (17 per cent). For a quarter of all products, the highest export share was greater than 50 per cent (that is, one supplier accounted for over half of a product’s global trade). The supply of these products may be vulnerable because of few potential suppliers and the potential to use any market dominance for commercial, security or other purposes (such as when China put quotas on exports of rare earth metals (Shen, Moomy and Eggert 2020, p. 127).

Figure C.3 **Distribution of the share of global exports accounted for by the largest global supplier, 2017<sup>a</sup>**



<sup>a</sup> There are 5204 6-digit HS products.

Data source: UN Comtrade (2020).

The HHI is the most used measure of market concentration. It is popular because it summarises information about both the number of exporters and their respective market shares. It is calculated as the sum of the square of the market shares of each exporter (limited to the largest 50 exporters). The HHI ranges from 0 to 10 000.

In antitrust law in the United States, a HHI between 1500 and 2500, when based on firm market shares, suggests a market is moderately concentrated and above 2500 indicates a market that is highly concentrated (U.S DoJ and FTC 2010). However, as the analysis in chapter 4 is on supplying *economies* rather than on individual *firms* on which the US antitrust law is based, a higher threshold is more appropriate. This is because economies are an aggregation of the firms within them, and this aggregation makes the global market more concentrated.

Given this, a HHI of 3100 (the 75<sup>th</sup> percentile) was used to determine whether a global market is concentrated or not. In instances where the main global supplier has a market share

---

of less than 50 per cent, the use of this threshold captures products where the market contains few suppliers (such that each economy accounts for a large part of the market). These markets also pose risks for supply chains because there are few alternative suppliers. An example of such a market would be one in which the main supplier has a market share of 48 per cent and the remaining two suppliers each have a market share of 26 per cent. Such a market would not be considered concentrated based on the market share of the main supplier, but the resulting HHI of 3656 would indicate that the market is indeed highly concentrated.

### Linking global trade data to Australian imports data

The Australian imports and global trade data were linked at the product level, as the first six digits of the 8-digit HTISC product classification used to classify Australian imports is equivalent to the 6-digit HS product code used in the global trade data.

The World Customs Organization (WCO) revises the HS every five years, which makes linking by product classifications more challenging for the years in which the HS is revised. All of the global trade data use the 4<sup>th</sup> HS revision, which was implemented in 2012. As the Australian HTISC is based on the international HS classification, the Australian classifications also change, such that imports data between 2012 and 2016 use the 4<sup>th</sup> HS revision, but data after 2016 use the 5<sup>th</sup> revision that was implemented in 2017. To link Australian imports data to global trade data, publicly available correspondence files between the 4<sup>th</sup> and 5<sup>th</sup> revision of the HS were used to convert all product classifications to the 4<sup>th</sup> revision. This ensures the linking is accurate and complete.

To ensure consistency with the analysis of Australian imports data, each 8-digit HTISC product was linked to market concentration measures constructed from the global trade data. The implication of this is that the measure of global concentration is measured at a slightly higher product aggregation.

### Sensitivity analysis

Sensitivity testing was undertaken to gauge the robustness of the import vulnerability analysis to:

- the level of product aggregation and concentration threshold selected
- the minimum value needed for a product to be considered potentially vulnerable
- whether imports of all products are likely to be essential
- the representativeness of the focal year 2016-17 in identifying concentrated supply.

### Using a different concentration threshold and level of analysis

The number of imports identified is sensitive to the selection of product classification and the threshold for classifying imports as concentrated (table C.1). The use of coarser

aggregated product classifications (those with fewer digits) results in fewer concentrated imports. Here, the concentration measures are typically lower because they reflect the average concentration for a large group of products — some of which may not be substitutes. For coarser product aggregations, a lower concentration threshold is appropriate. The use of highly disaggregated product classifications (those with more digits) results in many concentrated imports, especially if the threshold is set low. For finer product aggregations, a higher concentration threshold is appropriate.

The analysis presented in chapter 4 aims to strike a balance between the level of analysis (such that substitute products are grouped together) and the concentration threshold (such that limited sources of supply are identified).

**Table C.1 Number of Australian imports identified as concentrated by threshold and product classification, 2016-17**

Products classified using HTISC classification

	<i>2-digit</i> (97 products)	<i>4-digit</i> (1209 products)	<i>6-digit</i> (5017 products)	<i>8-digit</i> (5950 products)	<i>10-digit</i> (7636 products)
90 per cent	0	83	625	826	1 072
80 per cent	1	141	1 051	1 342	1 733
70 per cent	3	239	1 514	1 885	2 442
60 per cent	16	386	2 122	2 573	3 327
50 per cent	24	534	2 805	3 412	4 402

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

### Using different value thresholds

The analysis in chapter 4 included all imports regardless of the values involved. This resulted in many small trade flows being assessed as vulnerable. However, small import values are generally unlikely to cause material consequences for the Australian economy if imports were to be disrupted, irrespective of whether they come from concentrated markets or not.

To test the sensitivity of the results to the absence of any minimum value threshold, the analysis was repeated using four alternative thresholds: A\$400 000, A\$1 million, A\$10 million, and A\$50 million (table C.2).

### Using different sectoral coverage

The analysis in chapter 4 included imports from all sectors of the Australian economy. This resulted in many imports being identified as vulnerable, even though any disruption to their supply is unlikely to cause any significant impact on activities of national significance (such as wrist watches, Christmas decorations, and sparkling wine). These products are unlikely to be essential, even if they are identified as vulnerable.

To test the sensitivity of the results to the inclusion of imports from all sectors, the analysis was repeated excluding those 2-digit HTISC Chapters that are less likely to be critical to national activities (primarily imports of many agricultural items, some foods, and many non-essential consumer-orientated manufacturing products).

Simultaneously imposing a minimum value threshold and restricting the sectoral coverage reduces the number of potentially susceptible imports (table C.2). The restricted sectoral coverage, coupled with a A\$50 million value threshold, reduces the number of products to 35.

These sensitivity tests indicate that the approach taken to defining and assessing import vulnerability has a material impact on the number and type of products identified as vulnerable.

**Table C.2 Sensitivity testing of the number of most concentrated imports, 2016-17**

<i>Minimum value threshold</i>	<i>All HTISC Chapters</i>	<i>Restricted HTISC Chapters<sup>a</sup></i>
0	1 342	550
\$400 000	720	318
\$1 million	594	252
\$10 million	263	105
\$50 million	57	35

<sup>a</sup> Excluding HTISC Chapters 1 to 24, 33, 39 to 71, 92, and 94 to 99.

*Data source: ABS (Merchandise Imports and Import Clearances, 2020, unpublished).*

### Using a different focus year

The analysis in chapter 4 used a single year of imports data to identify products whose supply is concentrated. However, 2016-17 might not be representative of other years, owing to possible year-specific events and changes in suppliers over time.

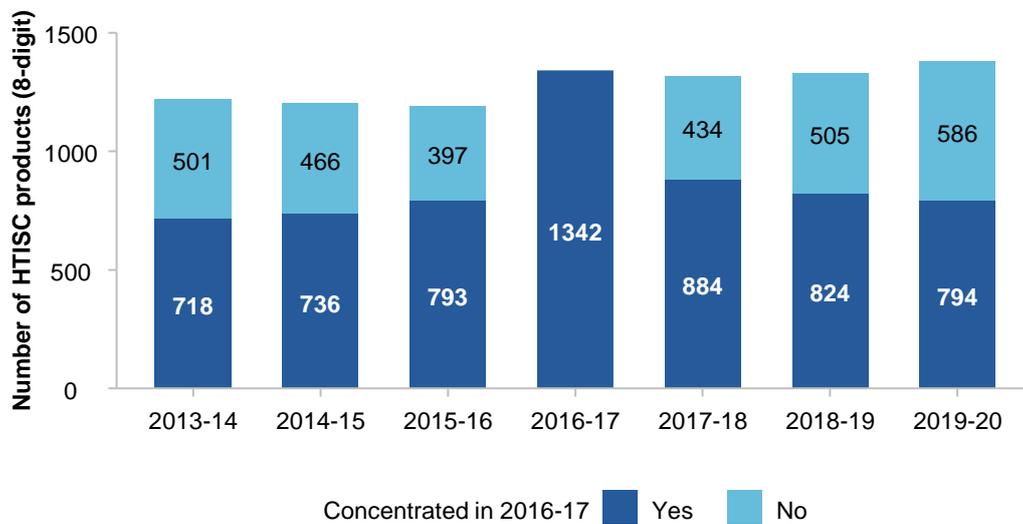
Using multiple years of imports data is complicated by the numerous changes in product classifications for finer disaggregations, which make it difficult to trace imports of individual products over time. A concordance produced by the ABS (Cat. no. 5489.0) was used to attempt to track products over time.

Of the products identified as concentrated in each year, over half were also concentrated in 2016-17 (figure C.4). This suggests that there is some persistence in the concentration in the supply of some products, but there are other products for which the degree of concentration changes over time.

The representativeness of 2016-17 decreases as the distance from the focal year increases. For example, 66 per cent of the concentrated imports identified in 2016-17 are also concentrated in 2017-18, but this decreases to 59 per cent in 2019-20.

Figure C.4 **High degree of persistence in which products are concentrated over time**

Number of concentrated products in each year by whether the product is concentrated in 2016-17



Data sources: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished; *International Merchandise Trade, Australia: Concepts, Sources and Methods*, 2018, Cat. no. 5489.0).

---

## C.2 Assessing essential goods and services

The application of step 2 of the framework involved assessing whether any of the vulnerable imports identified in step 1 are:

1. used as inputs in domestic production by essential industries, and whether the output of these industries are vital for meeting the basic needs of Australians (these imports are indirectly vital, as they form part of the local production of goods and services that meet the basic needs of Australians)
2. vital for directly meeting the basic needs of Australians (these imports are directly consumed by Australian households).

Ascertaining the importance of vulnerable imports in the Australian economy — in terms of both their role in Australian production and their use in meeting the basic needs of Australians — required the linking of Australian imports data with Australian data on the production and consumption of different products.

### The I–O tables

The analysis used Australian production data from the ABS *Input-Output* (I–O) tables for 2016-17 (ABS Cat. no. 5209.0.55.001). A summary of this data is outlined in annex A.

The I–O tables, which are contained in a series of excel spreadsheets, contain the most detailed production and consumption data available for the Australian economy that shows the interlinkages between products and industries in a given reference year (in this case, the financial year 2016-17). The tables cover:

- 114 products classified according to the ‘Input-Output Product Groups’ (IOPG), which are generally listed in the rows
- 114 industries classified according to the ‘Input-Output Industry Groups’ (IOIG), which are generally listed in the columns.

Some additional product information is supplied, with a lag, in the supporting ABS *Input-Output Product Details* according to the more detailed Input-Output Product Classification (ABS Cat. no 5215.0.55.001).<sup>47</sup> Even in its most disaggregated form, the products in the I–O tables are far more aggregated than those in the imports data used.

---

<sup>47</sup> Supplementary I–O tables enable the number of products to be expanded to over 900 (Input-Output Product Classification, IOPC) (the supplementary information does not allow the number of industries to be expanded). These tables were investigated but ultimately not used for the main analysis because the distinction between the use of imports and domestic products was difficult to ascertain, and the use of some products was confidentialised (such as air and water transport which are important for logistics). The difficulty mapping trade data to detailed product data also impeded the analysis of these detailed I–O tables.

The key I–O tables that are relevant to the application of the analytical framework reported in chapter 4 are:

- the ‘use table’, which details the use of each product by each industry and category of final demand (I–O table 2)
- the ‘imports table’, which details the use of each imported product by each industry and category of final demand (I–O table 3).

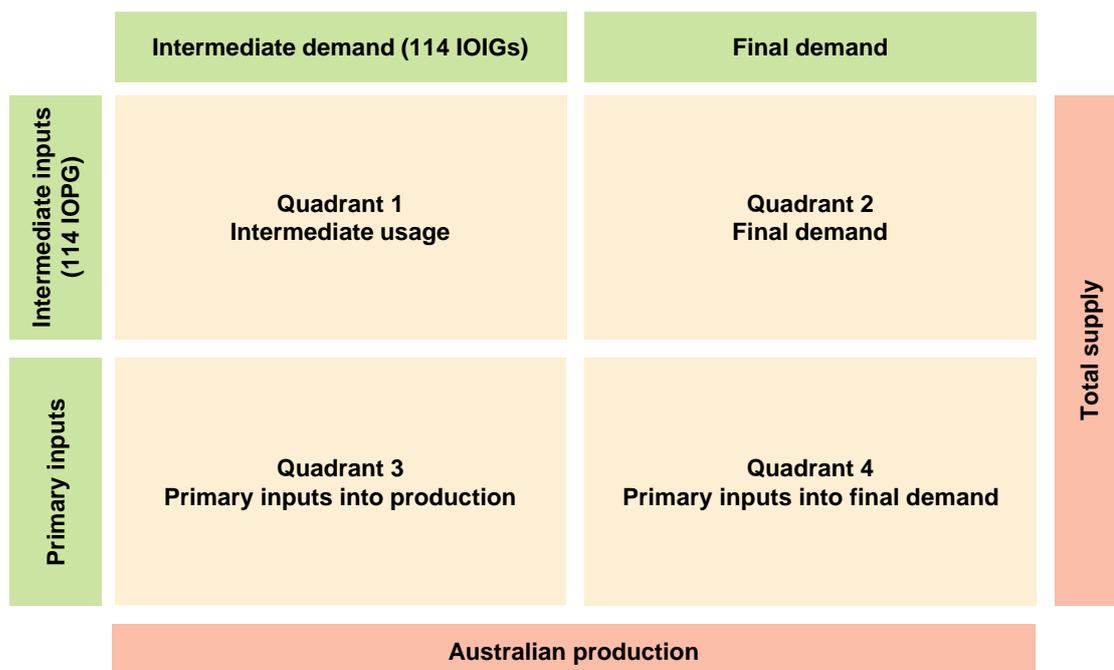
The use of *domestic* products by industries and category of final demand was derived by subtracting the use of imports from total use (that is, quadrants 1 and 2 in the use table *less* quadrants 1 and 2 from the imports table).

The basic structure of each of the key I–O tables is depicted in figure C.5.

- Quadrants 1 and 2 together show the total use of products. This includes the use of products as intermediate inputs into production by industries (quadrant 1) and final demand of households, government, gross fixed capital formation, changes in inventories, and exports (quadrant 2).
- Quadrants 1 and 3 together show the use of primary factors (labour and capital) and taxes used in production of each industry and by each category of final demand.

Quadrants 1 and 3 detail the cost structure of each industry (covering intermediate inputs use, primary factors use, and taxes).

Figure C.5 **Structure of an I–O table spreadsheet**



---

An extended version of the I–O tables was constructed by replacing each product row (IOPG) for total use with two rows — one for domestic use and another for imports (increasing the number of products in quadrants 1 and 2 in figure C.5 from 114 rows to 228). The remainder of the use table was unchanged (quadrants 3 and 4). We call the extended I–O table the ‘supra table’.

The next steps were to classify which products/industries are essential and map the vulnerable imports (HTISC) in the trade data to the products (IOPG) in the supra table.

### **Classifying IOIG/IOPGs as essential**

The narrow definition of essential goods and services outlined in chapter 3 are those that ‘meet the basic needs of Australians’, and include: the provision of water, medicines, communications, energy, defence, health, logistics, transactional banking, and government services.

This conceptualisation of essential goods and services is mapped to the products and industries that produce them in the I–O tables (table C.3).

Essential industries relate to the Australian *production* of essential products by each of the relevant IOIG industries. Essential products relate to the *consumption* (use) of each corresponding IOPG by each industry and category of final demand.

The industry and product labels in the I–O tables are identical, thus giving the appearance that the tables are symmetric. However, the products and industries are conceptually different. Typically, an industry (IOIG) is the largest producer of their corresponding product (IOPG). However, many industries may also produce products that are primary to another industry — this is known as secondary production (shown in the I–O ‘supply table’, table 1).

The approach used here implicitly defines an industry as essential which means that every product that an industry produces is considered essential. However, in practice there may be outputs of an industry that are more essential than others. For example, the ‘Human pharmaceuticals and medicinal product manufacturing’ (IOIG 1801) industry predominately produces human pharmaceuticals and medicines (IOPG 1801) but they also produce some amount of basic chemical manufacturing (IOPG 1803), which may not be as essential in meeting the basic material needs of Australians.

**Table C.3 Mapping of essential goods and services to Australian production data**

<i>Essential good or service</i>	<i>Input-Output Product/Industry Group (IOIG/IOPG)</i>
Banking (1)	Finance (6201)
Health (4)	Human pharmaceutical and medicinal product manufacturing (1801) Veterinary pharmaceutical and medicinal product manufacturing (1802) Health care services (8401) Residential Care and Social Assistance Services (8601)
Water services (1)	Water supply, drainage and drainage services (2801)
Communications (3)	Broadcasting (exc Internet) (5601) Internet service providers, internet publishing and broadcasting, Websearch portals and data processing (5701) Telecommunication services (5801)
Energy (7)	Coal mining (0601) Oil and gas extraction (0701) Petroleum and coal product manufacturing (1701) Electricity generation (2601) Electricity transition, distribution, on selling and electricity market operation (2605) Gas supply (2701)
Logistics (7)	Road transport (4601) Rail transport (4701) Water, pipeline and other transport (4801) Air and space transport (4901) Transport support services and storage (5201) Wholesale trade (3301) Retail trade (3901)
Government (3)	Public administration and regulatory services (7501) Defence (7601) Public order and safety (7701)

---

## Aligning the trade and production data

The ABS does not publish a concordance or mapping from the HTISC classifications used in the trade data to the classifications used in the I-O tables. The absence of such a concordance impedes the analysis of supply chain vulnerability.

To overcome this, the Commission constructed a concordance from the HTISC to the I-O tables. This process is not straightforward, and hampered by widespread changes to the trade and production classifications over time (annex B).

Construction of this concordance involved progressively linking each HTISC product to different classifications that existed over time. The reason for this linking process is that the historical concordance linked HTISC products to the detailed I-O product classification (IOPC) that existed in 2004-05. The subsequent mappings updated the 2004-05 IOPC to, first, 2009-10, and then to 2014-15 using published ABS concordances.<sup>48</sup> The final step involved linking the 2014-15 IOPC to the product and industry groups (IOPG/IOIG) in the I-O tables. Each stage of this linking involved apportioning shares of imports to the relevant classification, such that the final allocation reflected the cumulative effect of the various shares used at each stage.

The imported product rows (IOPGs) in the supra table were replaced with imports from the trade data (HTISC). The amount of the imported product (IOPG) that is vulnerable and non-vulnerable was ascertained by apportioning the CIF (cost, insurance, and freight) values reported in the trade data to each industry's use based on the industry's use of IOPGs. This means that the use of imported products — based on the HTISC trade classification — is approximated based on an industry's use of the broader product group (IOPG) in which the HTISC product belongs. This apportioning method might suggest, for example, that an industry uses sodium carbonate in production when they actually use another specific chemical that forms part of the basic chemicals product group and not sodium carbonate.

The supra table was used to determine whether vulnerable imports:

- are used as inputs into the production of essential industries or
- form part of final demand for essential goods and services.

When assessing inputs into production, a minimum value filter of A\$1 million was used to screen out products that otherwise met the criteria for being considered a 'vulnerable import used by essential industries'. Very small import values arise for some products because of the coarser nature of the mapping of imports and production classification changes over time (as the I-O products are at a higher level of aggregation than the imports data). Given the small values involved, these products are unlikely to constitute critical inputs even if they are used by the industry.

---

<sup>48</sup> The published concordances typically accompany the ABS I-O tables.

---

## Annex A: Data sources

### Australian imports data

The Australian imports data were sourced directly from the ABS.

The Australian Border Force (ABF) collects detailed information on the value of imports for customs purposes. Among other things, this information includes:

- a description of the product imported
- the quantity imported
- the value of the imports
- the economy of origin for the imports
- numerous statistical classifications.

The ABS uses the ABF data as the basis for its merchandise imports statistics. The ABF classifies all imported products according to the HTISC (annex B).

The Commission used existing concordances to link the ABS import data to industry classifications.

### Data confidentiality

The ABS confidentialises imports of certain products, which prevents the products or supplier from being identified in the trade data. For more information on the products that are classified see ABS's International Merchandise Trade: Confidential Commodities List (Cat. no. 5372.0.55.001).

### Data cleaning

The imports data were cleaned to make them suitable for use. First, the monthly data were aggregated to yearly data. Second, goods that were imported into Australia that were re-exported were removed (the ABS refers to these transactions as 're-exports'). Third, imports to Australia from Australia were removed. Finally, transactions that involved negative values (CIF, free on board, or customs value) were removed.

### Global trade data

The global trade data were sourced from United Nation's international trade UN *Comtrade* database (<https://comtrade.un.org/data/>).

UN *Comtrade* is the largest and most comprehensive depository of international trade data. Over 170 reporter economies provide their annual international trade statistics. At the

---

international level, the most detailed product classification available is the 6-digit HS code (annex B). The data collected use the HS revision implemented in January 2012 (also known as the 4<sup>th</sup> revision), and capture each reporting economy's exports of a product to the world (rather than to trading partners). Among other things, this information includes:

- a description of the product
- the exporting economy
- the quantity of the exported product
- the value of the exported product.

Trade data are often messy and incomplete. An alternative global trade dataset was investigated — BACI data<sup>49</sup> ('Base pour l'Analyse du Commerce International': Database for International Trade Analysis) which is built directly from UN *Comtrade* data and includes bilateral trade flows for more than 5000 products and 200 economies. The BACI data are intended to show trade flows between trade partners and so only retain trade observations in which both trading partners are specified (that is, the importer and exporter). In contrast, the UN *Comtrade* data sourced here records an economy's exports of products without specifying its trading partners. This results in some data discrepancies between the databases. The use of BACI data produces similar estimates of market concentration to UN *Comtrade* data, but some differences exist. For example, the HHI (based on quantity) for anthracite coal (HS 270111) is 4842 in UN *Comtrade*, which is highly concentrated, but only 2327 in BACI. The average difference in the HHI across all products is only 340 points.

## Input-Output tables

The Australian production data were sourced from the ABS (Cat. no. 5209.0.55.001). The I–O tables form part of the Australian national accounts, complementing the quarterly and annual series of national income, expenditure and product aggregates. They provide detailed information about the supply and use of products in the Australian economy, and the structure of and inter-relationships between Australian industries. Among other things, this information includes:

- intermediate inputs into production
- final demand
- primary inputs into production
- primary inputs into final demand.

The I–O tables contain information for 114 industry and product groups, which are classified using the IOIG and IOPG (annex B).

---

<sup>49</sup> Publicly available for download: [http://www.cepii.fr/cepii/en/bdd\\_modele/presentation.asp?id=37](http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=37).

---

## Annex B: Classifications

### Harmonized System and Harmonized Tariff Item Statistical Code

The HS is a 6-digit code that is maintained by the WCO. The code is reviewed every five years and updated to ensure it remains relevant given developments in technology and changes in patterns of international trade. There have been five revisions to the HS since the first edition was implemented in January 1988, with the latest revision being implemented by Australia on 1 January 2017. The previous revisions to the HS by the WCO were implemented in Australia in 1996, 2002, 2007, 2012, and 2017. There were minor amendments in 1992. The next revised edition is scheduled for implementation in January 2022. The ABS create non-HS chapters 98 and 99.

Under the HS, each product is assigned to a six-digit product group. The classifications are hierarchical and arranged on a logical basis under specific Chapters (indicated by the first two digits), Headings (indicated by the third and fourth digits) and Subheadings (indicated by the fifth and sixth digits) (table C.4). The HS generally groups commodities according to their degree of manufacture, the material of which they are composed, and by similar generic descriptions. For example, live animals are classified within Chapter 1, animal hides and skins within Chapter 41 and leather footwear within Chapter 64.

---

**Table C.4 An example of the hierarchical structure of the HTISC**

<i>Level</i>	<i>Code</i>	<i>Description</i>
Chapter	61	Articles of apparel and clothing accessories, knitted or crocheted
Heading	61.10	Jerseys, pullovers, cardigans, waistcoats and similar articles, knitted or crocheted
HS code	61.10.30	Jerseys, pullovers, cardigans, waistcoats and similar articles, of man-made fibres, knitted or crocheted
HS subheading	61.10.30.00	Jerseys, pullovers, cardigans, waistcoats & similar articles of man-made fibres, knitted or crocheted
Statistical code	61.10.30.00.53	Women's or girls' jerseys, pullovers, cardigans, waistcoats and similar articles (excl. sweat shirts or the like) of man-made fibres, knitted or crocheted

---

Australia uses an extended version of the HS known as the HTISC to classify its international merchandise trade. The HTISC adds an additional four digits to the international six-digit HS code to give a 10-digit code. Consequently, the first six digits of the HTISC are the same as the first six digits of HS. The Department of Home Affairs adds the seventh and eighth digits to allow the application of different rates of import duty (the inclusion of these two additional digits give subheadings). The ABS adds the ninth and tenth digits for statistical purposes (giving rise to the statistical code) (table C.4).

---

## Broad Economic Classification

The Broad Economic Classification (BEC) was introduced by the United Nations in the early 1970s. The BEC groups commodities according to their main end-use, which align, as far as practicable, with the System of National Accounts (SNA) framework.

The 3-digit BEC classification groups goods into nineteen basic economic categories. Sixteen of these basic categories make up the broad end-use categories: consumption goods, capital goods and intermediate goods. A fourth category (other goods) includes the three remaining basic economic categories, which are difficult to assign to a single main-end use category. These are motor spirit (321), passenger motor cars (51) and goods not elsewhere specified (7). For example, motor spirit and passenger motor cars are used by both industry (as intermediate consumption and capital goods respectively) and households (as consumption goods).

An example of the different levels of aggregation for the BEC codes is presented in table C.5. The 3-digit BEC codes can be linked to the 10-digit HTISC codes.

---

**Table C.5 An example of the hierarchical structure of the BEC**

<i>Level</i>	<i>Code</i>	<i>Description</i>	<i>SNA</i>
Category	1	Food and Beverages	
Sub-category	11	Primary	
Basic category	111	Mainly for industry	Intermediate goods
Basic category	112	Mainly for household consumption	Consumption goods

---

## Australian Input-Output table classifications

### Input-Output Product Classification (IOPC)

The IOPC is a product classification that has been specifically developed for the compilation and application of Australian I–O tables. Because the I–O system describes the production and subsequent use of all goods and services, an I–O product is defined in terms of the characteristic products of industry sectors that produce the product. The IOPC has over 900 individual product items, which are represented by an 8-digit code (these codes are unrelated to the 8-digit HTISC codes).

Additional product information supports the release of each I–O table with a lag (Cat. no. 5215.0.55.001). The additional information enables the number of products to be expanded from 114 IOPG to 900-odd IOPC. There is no additional industry information.

The ABS periodically revises the IOPCs. There have been five versions of the IOPC since 2005. There are publicly available concordance files between these IOPC classifications.

---

The ABS confidentialises production and consumption information for a number of IOPC classifications on confidentiality grounds. Two of these confidentialised products that are particularly pertinent for the analysis of import supply chain vulnerability are air transport and water transport.

#### Input-Output Product Group (IOPG)

Input-Output Product Groups (IOPG) are groups of related IOPCs that are aggregated in the published I–O tables. There were 114 product groups (4-digit codes) in 2016-17.

#### Input-Output Industry Group (IOIG)

Industries in the I–O tables are classified according to Input-Output Industry Groups (IOIG), which are based on the Australian and New Zealand Standard Industrial Classification. There were 114 industry categories (4-digit codes) in 2016-17.

The ABS revises the IOIGs, with three versions since 2005.



---

## D Price elasticities of demand for imports

The last step of the analytical framework proposed in chapter 3 is to identify goods and services that are critical to the functioning of the economy and to the wellbeing of Australians. A good or service is *critical* if it is required for the supply of an essential good or service, that is, it cannot be substituted easily. This appendix tests whether a data-driven approach can be used to determine the criticality of a good. It does this by estimating the price elasticity of demand for selected chemicals that are assessed as vulnerable and essential in chapter 4.

### D.1 What is elasticity of demand and why is it useful?

The price elasticity of demand measures how the quantity demanded of a good changes in response to a change in price (box D.1). For most goods, if the quantity demanded decreases significantly when its price increases, its demand is said to be *elastic*. A demand that is not very responsive to price changes is *inelastic*.

The price elasticity of demand can be interpreted as an indication of the degree to which a good is critical, because it reflects both the necessity of the good and the availability of substitutes. An inelastic demand indicates that users of the product cannot easily substitute away from it and must absorb price increases. For example, if the price of a lifesaving medicine were to increase, most users would still purchase it, and the quantity demanded would not decline much in response to the price increase. However, if the medicine could be substituted, a price increase would likely push users to purchase an alternative, decreasing the quantity demanded for the product whose price increased.

Timeframes affect elasticities. In the short term, the demand for a good such as petrol for vehicles might be inelastic as alternative fuels cannot be used by most vehicles. But in the long term, people can choose between vehicles that use different types of fuels (such as electric, petrol, diesel), which allows them to substitute away from petrol, and makes the demand for petrol more price elastic.

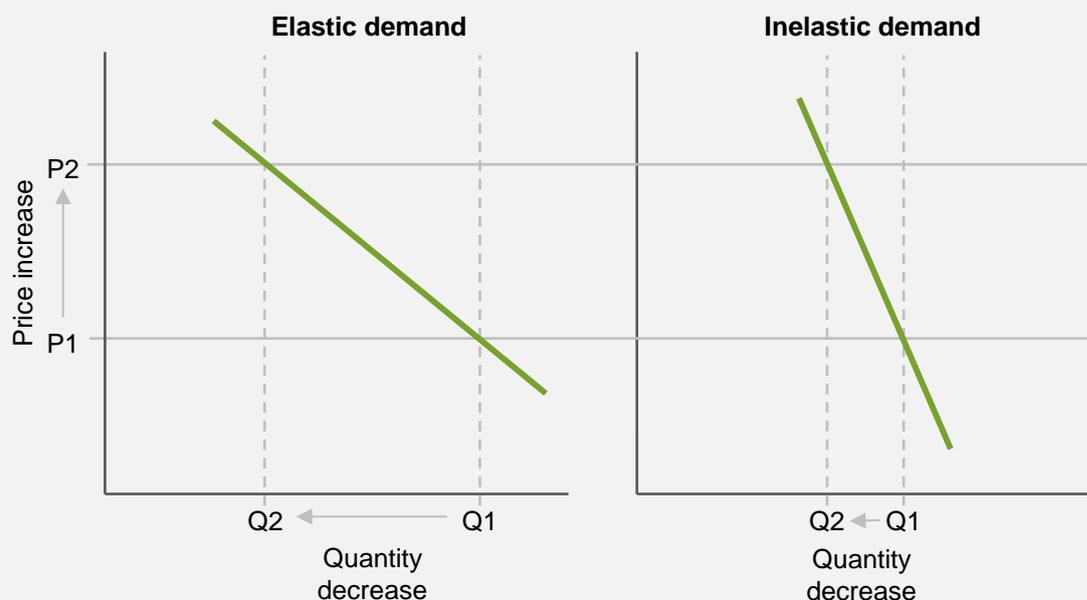
## Box D.1 Elasticities — a primer

An elasticity is an estimate of the effect of a change in one variable from a change in another, related variable. The price elasticity of demand ( $E_p$ ) is expressed as the percentage change in quantity demanded of a good ( $\% \Delta Q$ ), divided by the percentage change in price ( $\% \Delta P$ ) over the same period:

$$E_p = \frac{\% \Delta Q}{\% \Delta P}$$

Because quantity demanded typically declines when price increases, the price elasticity of demand is negative. Demand is considered inelastic if the price elasticity of demand is between zero and negative one — that is, the per cent change in quantity demanded is less than the per cent change in price. Demand is elastic if its elasticity is less than negative one.

As highlighted in the diagram below, an identical price increase can have different effects on the quantity demanded of a product depending on its elasticity — with smaller quantity changes resulting for the product with the more inelastic demand.



## Estimating demand elasticities

The simplest estimate of a price elasticity requires at least two data points with different price and quantity pairs (and other factors affecting the market remaining unchanged).<sup>50</sup> Statistical methods, such as regression techniques, can be used to help isolate the effect of price changes from the effects of other influences on demand — that is, by controlling for observed variables. For example, the demand for peaches might increase with income and decrease with price; including data on income in a regression isolates the effect of changes in income from the effects of price changes.

<sup>50</sup> If a demand is perfectly inelastic, the same quantity is purchased at different prices. That is, quantity demanded is completely unresponsive to price changes.

---

While statistical methods can control for some factors, unobservable factors can affect the accuracy of an estimate. For example, an increase to the price of iron ore is likely to increase its output, which would increase the quantity demanded of key inputs, such as bentonite (used as a binding agent in making iron ore pellets). An increase in the quantity of bentonite demanded due to the increase in the production of iron ore will likely drive higher prices of bentonite, but would not blunt demand, as these higher input prices would be offset by increasing iron ore prices. As a result, we might observe an increase in the price and quantity of bentonite and conclude that the demand for bentonite is *very* inelastic if we fail to take into account the effect of an increase in the price of iron ore on the price and quantity observed in the market for bentonite. Again, if there are data on the price or quantity of iron ore, either variable can be used as a control variable when estimating the demand for bentonite. But in many cases the data required will not be available, which will reduce the quality of estimates, in this case of the price elasticity of demand for bentonite.

To estimate the demand elasticities of vulnerable and essential imports, the challenge is to find a price change that is independent of other factors that affect demand, otherwise estimates may be biased. One potential solution is to assume that Australia is a price taker in the global market and therefore the world price is independent of unobservable factors affecting Australian demand. The logic is that Australia is a small participant in the world market and so changes to Australian demand should *not* affect world prices. For example, if Japan normally imports little iodine, but for some unobserved reason increases its iodine imports significantly, this would cause the world price to increase. But the demand shock in Japan is unlikely to affect the demand for iodine in Australia directly — only indirectly via the increase in the world price. The Australian market's response to the price increase in iodine could then be used to estimate the price elasticity of demand for iodine.

This logic will not always be true; some unobserved factors may affect both Australian demand directly and world prices. For example, if Japan increased its imports of iodine due to a technological advancement that also affected Australia, then the Australian, Japanese and world demand will be directly affected by this technological advancement and world prices would increase. Unobserved factors that influence both the world price and Australian demand directly like this introduce bias into estimates of price elasticities.

In this exercise, we assume that world prices are independent of Australian demand to estimate the price elasticities of vulnerable and essential chemicals. The reasonableness of that assumption would need to be verified in each case.

## **D.2 Estimating elasticities of demand for chemicals**

Using ABS import data (chapter 4 and appendix C), we estimate price elasticities of demand for five chemicals — one of the main categories of essential and vulnerable goods identified in chapter 4. Chemicals are likely to be more homogenous within a category than many other types of vulnerable and essential goods, such as the various clothing categories that include personal protective equipment among many other items. This is important because

differentiated goods each have a different price. If the goods are not homogenous, then the estimates will be affected by changes in the composition of what is imported, rather than changes in prices.

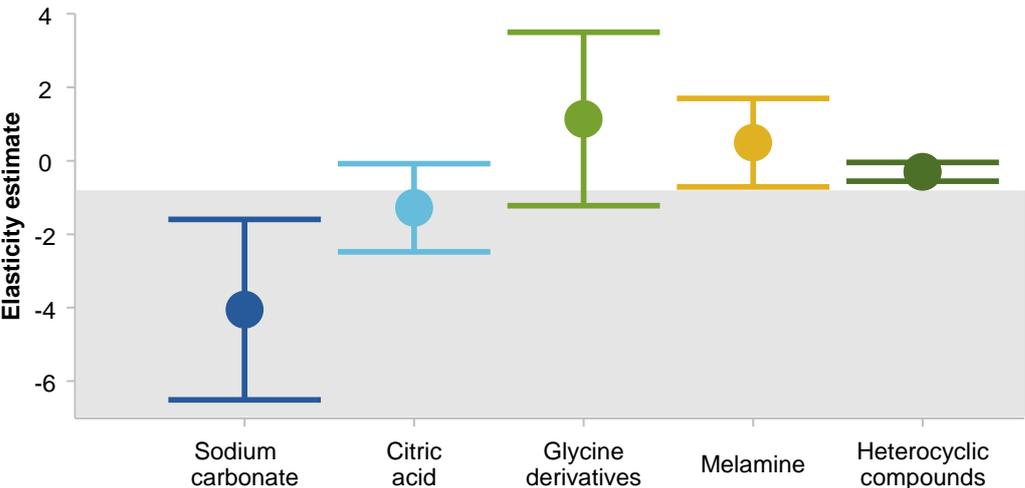
We aggregate the monthly ABS imports data into quarters to estimate elasticities at the 8-digit HTISC level. We derive unit values (prices) by dividing the good's value (including insurance and freight) by its quantity. We then construct a weighted average price using quantity as the weights to create a price variable that reflects the dominant price that the goods are purchased at. As a robustness check we estimated the elasticities using the median price and the results largely do not change.

To estimate the elasticity, we regress the log of the quantity on the log of the weighted average price, including dummy variables for the year and quarter to control for annual and seasonal effects. We do this for five chemicals: sodium carbonate; citric acid; glycine derivatives; melamine; and heterocyclic compounds. The results indicate that:

- the demand for sodium carbonate is highly *elastic*
- results for citric acid are *inconclusive*
- demands for the other chemicals are *inelastic* (figure D.1).

Figure D.1 **Demand for some chemicals is elastic and demand for others is inelastic**

Regression coefficients with 95 per cent confidence intervals<sup>a,b</sup>



<sup>a</sup> Dots represent the coefficient. Whiskers represent the 95 per cent confidence intervals. Tests for statistical significance revealed that the estimate for sodium carbonate is less than negative one at the 5 per cent level of significance; citric acid is not statistically different from negative one; glycine derivatives is greater than negative one at the 10 per cent level; melamine is greater than negative one at the 5 per cent level; and heterocyclic compounds is greater than negative one at the 1 per cent level. <sup>b</sup> Shaded area indicates region with estimates less than negative one (elastic demand).

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

---

## What can this tell us about criticality?

As noted earlier, the estimates of price elasticity of demand can provide an indication of a chemical's criticality. The results of our regression analysis show that the demands for some chemicals are inelastic, which suggests they might be critical inputs.

However, criticality is determined by a chemical's use in a particular industry or production process (box D.2). But the quantity and price data used to estimate the elasticities reflects their uses in a number of different industries. For example, chlorine is imported to treat drinking water, an essential activity, and in swimming pools, which is not deemed essential. It is therefore difficult to make firm conclusions on criticality to certain industries based on these results. More precise data are needed on prices and quantities for the specific products that essential industries require.

The elasticity estimates for the demand for sodium carbonate broadly accord with analysis in appendix B, which indicates that many alternative pH correctors can be used to treat water. But again, regression results are limited by the fact that the water industry accounts for a very small share of sodium carbonate's total use. (This small share means that if the water industry runs out of sodium carbonate, it could be diverted from non-essential uses for at least some time). While the regression results are consistent with findings in appendix B, it cannot be discounted that these results are driven by non-essential uses of sodium carbonate.

Estimating price elasticities of demand is one tool to examine the criticality of goods in the production of essential goods and services, but it cannot replace an expert approach. This analysis indicates that further investigation of how and where chemicals are used is required. More disaggregated data would improve the analysis, but expert advice would be essential to better understand whether substitutes are available and whether a chemical is a critical input into production. Engagement of experts would also help stress test whether the assumptions needed to accurately estimate elasticities hold, and whether the conclusions that are derived from the estimates are valid.

---

## Box D.2 Uses of some vulnerable and essential chemicals

### Sodium carbonate

Sodium carbonate, commonly known as soda ash, is an easily-produced and versatile compound. It is commonly used in the manufacture of glass, detergent, soap, paper and as a food additive. It is also used in water treatment as a pH corrector for the protection of water infrastructure. In 2018, global trade in sodium carbonate was worth US\$3.7 billion, with major suppliers including the United States (40 per cent), Turkey (17 per cent) and China (10 per cent). Australian imports accounted for 1.8 per cent of world trade.

### Citric acid

Citric acid has a number of properties that make it useful in many applications across manufacturing. It is commonly used to give a tart, sour or acidic flavour to manufactured foods and beverages. It is also used as an acidity regulator, a preservative and antimicrobial agent. In 2018, global trade in citric acid was worth US\$1.5 billion, with major suppliers including China (48 per cent) and Austria (16 per cent). Australian imports accounted for 0.7 per cent of world trade.

### Glycine derivatives

Glycine derivatives are amino acids that are used in some medicines and as a pesticide. In 2018, global trade in glycine derivatives (captured within 'organo-inorganic compounds: other than tetramethyl lead, tetraethyl lead, and tributyltin compounds' in the 6-digit HS classification) was worth US\$7.4 billion. Major suppliers include China (41 per cent), the United States (18 per cent) and Germany (12 per cent). Australian imports accounted for 2.2 per cent of world trade.

### Melamine

Melamine is a compound used mainly in the manufacture of plastics, lacquers, adhesives, and insulation. It is also used in paints, textiles and wallpapers due to its fire retardant properties. In 2018, global trade in melamine was worth US\$1.2 billion, with major suppliers including China (42 per cent), Germany (13 per cent) and the Netherlands (12 per cent). Australian imports accounted for 3 per cent of world trade.

### Heterocyclic compounds

Heterocyclic compounds (containing nitrogen hetero-atom(s) only) are primarily used for their herbicidal properties. The herbicide is used on a variety of weeds, such as dandelions, clover, and chickweed. In 2018, global trade in heterocyclic compounds was worth US\$2.6 billion. Major suppliers include China (48 per cent), Germany (10 per cent) and India (6 per cent). Australian imports accounted for 1 per cent of world trade.

*Sources:* Chemical book (2016); CEPII (2021); Observatory of Economic Complexity (2019b).

## Other possible limitations

In addition to the estimates relating to demand for a chemical from many industries, including non-essential industries, there are other limitations that suggest results should be interpreted with caution.

The main regression includes quarterly and yearly dummy variables to control for seasonal and annual effects, but results are sensitive to their inclusion (table D.1). The adjusted

---

R-squared is highest (in most cases) where the dummy variables are included, indicating that the dummy variables have some explanatory power and should be included in the regression. The data show seasonal and annual patterns, consistent with the explanatory power of the dummy variables (figure D.2). For example, imports of heterocyclic compounds tend to dip in the second quarter, and the quantities of sodium carbonate and citric acid seem to grow year-on-year, especially after 2014.

Relevant variables that might be driving demand in Australia could be missing from the regressions. As outlined in the iron ore example above, an increase in the price of an output might raise the prices of inputs and simultaneously increase the quantity demanded of inputs (or dull a decrease in demand for them), biasing an estimate downward. Quarterly and yearly dummy variables control for some of these unobserved factors (such as growth in demand relating to population and economic growth), but there are many other possible influences on demand. For example, there could be technological changes that increase efficiency and could therefore decrease demand. Other technological changes could create new uses for a product, thus increasing demand for it. When unaccounted for in the estimation, these effects can bias estimates.

One potential way to improve on the estimates is to use an instrumental variable — that is, a variable that is correlated with our variable of interest (price), but not with the outcome variable (quantity). The Commission estimated the same equations using exchange rates as an instrumental variable (box D.3). However, the instruments are too weak and produce imprecise estimates.

Finally, elasticity estimates could reflect changes in the import mix, rather than a response to a price change. One way to assess this is by looking at prices of individual transactions. Variation in prices might indicate some heterogeneity in the products recorded. For example, a chemical could be sold in different concentrations, which would be reflected in their prices. While there is clustering around the weighted average price for some chemicals (figure D.3), there is still a lot of variation for what is assumed to be a homogenous group of products — or at least a group whose mix does not change markedly. Changes to the product classifications (HTISC) over time might also affect the import mix (for example, products might be reclassified into other HTISC codes or new codes might be created).

## Summary

Given these limitations, the price elasticities of demand estimated in this appendix should be interpreted with caution. The results show that demand elasticities can give some indication about whether a product is critical to a production process, but data limitations make it difficult to apply the technique across a large number of products and be confident that the technique will accurately identify critical products. These limitations reinforce the need to stress-test both the approach and any conclusions with experts as outlined in the framework (chapter 3).

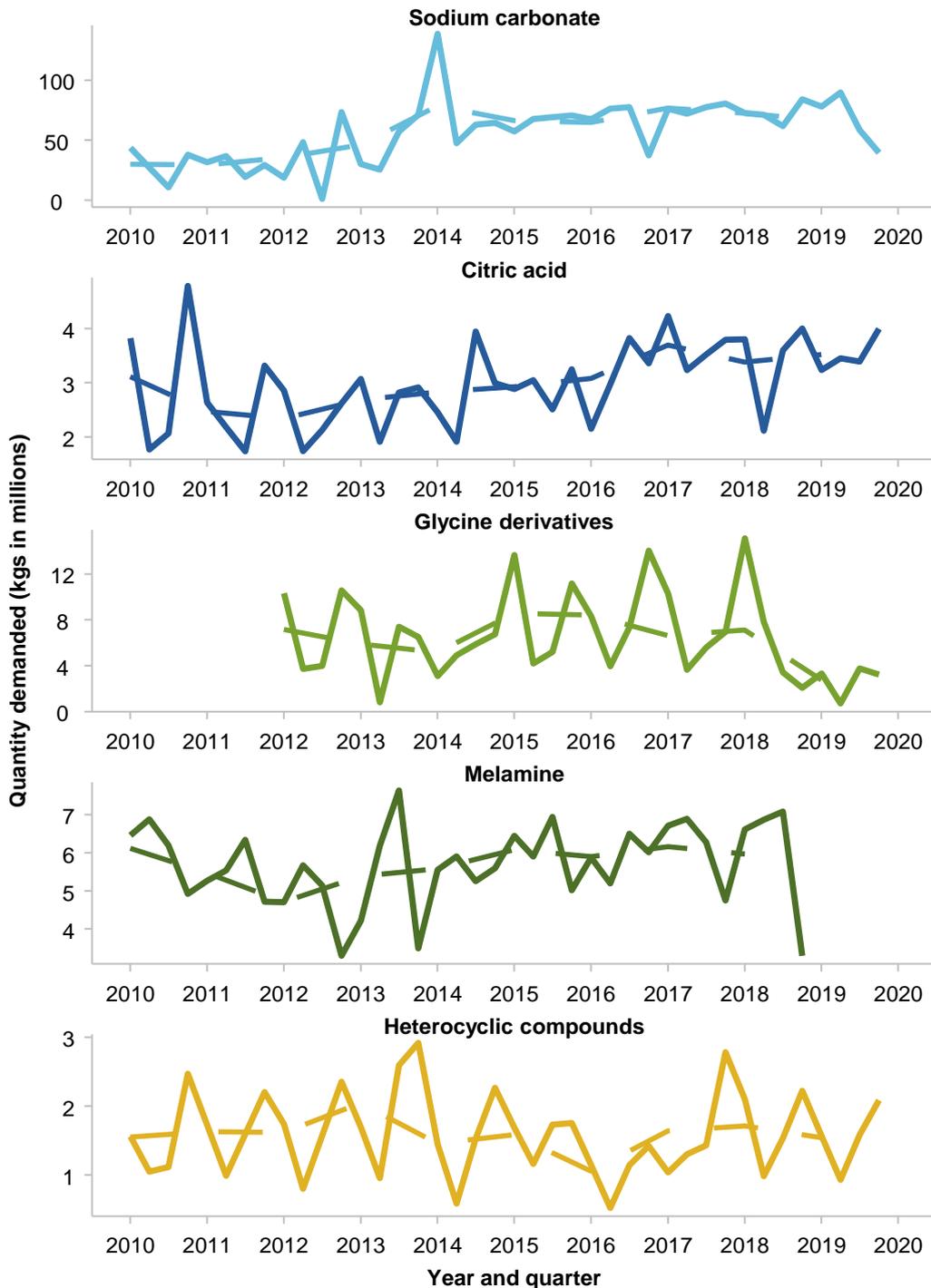
**Table D.1 Regression results<sup>a</sup>**

	<i>No dummies</i>	<i>Year dummies</i>	<i>Quarter dummies</i>	<i>Year and quarter dummies</i>
<b>Sodium carbonate</b>				
Elasticity estimate	0.53	-4.40	0.80	-4.05
Standard error	0.81	1.14	0.82	1.25
Adjusted R-squared	-0.01	0.48	0.00	0.46
N	40	40	40	40
<b>Citric acid</b>				
Elasticity estimate	-0.47	-2.03	-0.10	-1.28
Standard error	0.44	0.60	0.42	0.61
Adjusted R-squared	0.00	0.32	0.18	0.44
N	40	40	40	40
<b>Glycine derivatives</b>				
Elasticity estimate	-0.64	1.68	-0.91	1.14
Standard error	0.79	1.33	0.70	1.20
Adjusted R-squared	-0.01	0.07	0.23	0.34
N	32	32	32	32
<b>Melamine</b>				
Elasticity estimate	0.56	0.29	0.63	0.49
Standard error	0.44	0.82	0.34	0.61
Adjusted R-squared	0.02	-0.10	0.43	0.43
N	36	36	36	36
<b>Heterocyclic compounds</b>				
Elasticity estimate	-0.51	-0.69	-0.15	-0.30
Standard error	0.16	0.18	0.14	0.13
Adjusted R-squared	0.18	0.26	0.65	0.79
N	40	40	40	40

<sup>a</sup> Estimates derived from regressing the log of quantity on the log of price. The estimated coefficient can be interpreted as the elasticity. Each column presents the results from this regression while controlling for different time variables. The first column does not include any control variables. The second column includes a dummy variable for the year. The third column includes dummy variables for quarters. The fourth column includes both year and quarter dummy variables and is the preferred specification.

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

**Figure D.2 Chemicals have annual and quarterly patterns**  
 Kilograms (in millions) imported to Australia, quarterly for 2010 to 2019<sup>a</sup>



<sup>a</sup> The dashed line represents the average quarterly imports for the year.

Data source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).

---

### Box D.3 Estimating price elasticities using instrumental variables

Instrumental variables is a technique used to help control for confounding factors that might bias regression results, in particular endogeneity bias. Endogeneity bias occurs when estimating price elasticities because demand and supply jointly determine market prices and quantities. This means that the explanatory variable (price) is correlated with the error term and this renders ordinary least squares (OLS) regression estimates biased.

The instrumental variables technique involves finding a variable that is correlated with the variable of interest (price), but is not correlated with the outcome variable (quantity). There are two rules that need to hold for an instrumental variable to be valid. In the present case, the instrument:

1. must be *exogenous* (this is known as the exclusion restriction). That is, the instrument has no direct effect on the quantity variable and the instrument is not correlated with any omitted variables. There is no statistical test for exogeneity; instead a theoretical argument needs to be made as to why the instrument is independent from the quantity variable and any omitted variables
2. must be *relevant*. That is, the instrument needs to be a strong predictor of the price. If the instrument is only a weak predictor then estimates are imprecise and biased towards the OLS estimates. There are statistical methods to test the strength of instruments.

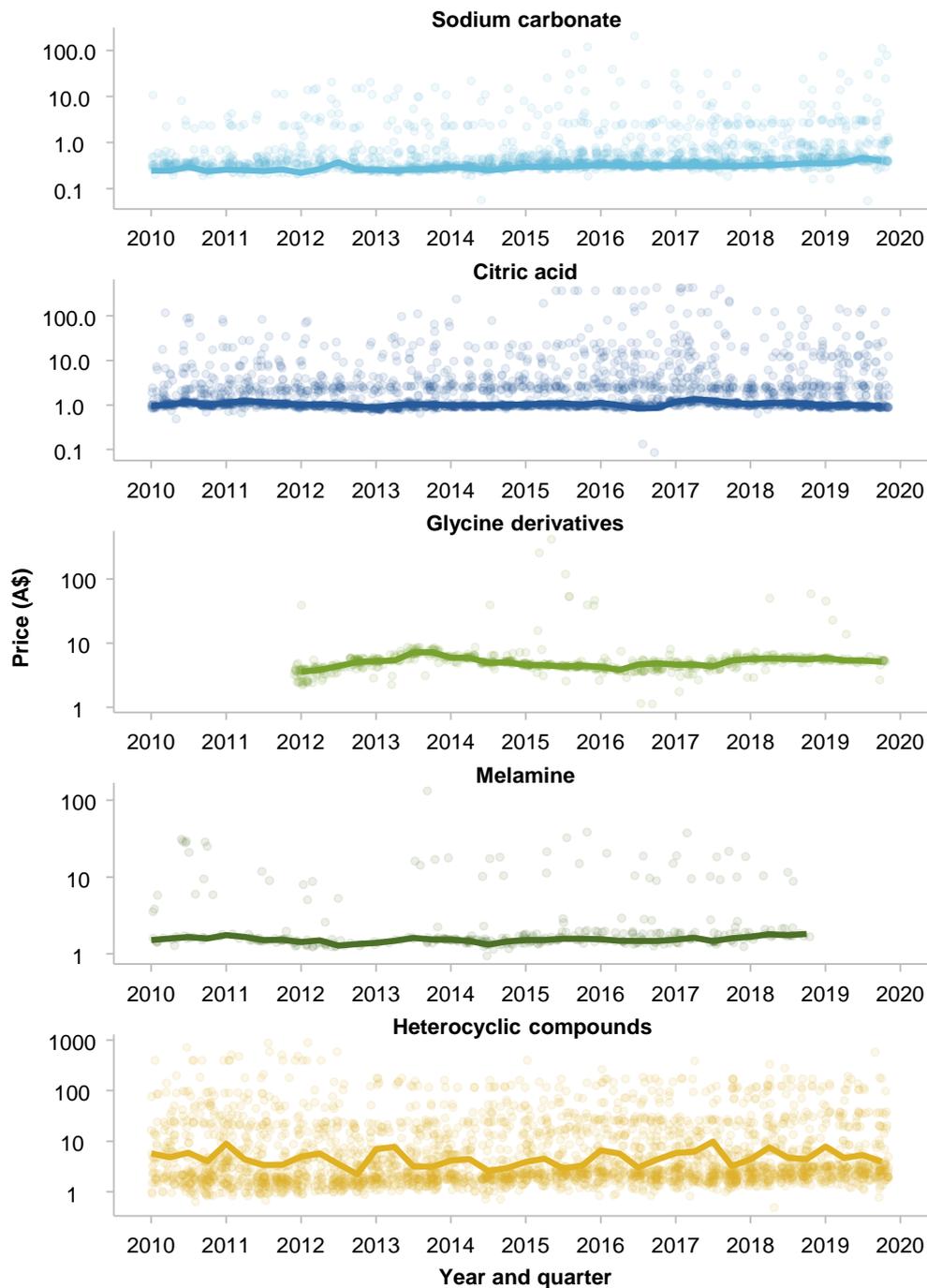
A common instrument used in the trade literature to estimate price elasticities is the exchange rate, as changes to the exchange rate induce price shocks, and are unlikely to affect quantity except through price (Hillberry and Hummels 2013, p. 1239). And outside factors that affect price and quantity of one particular good are unlikely to affect the exchange rate. (A theoretical argument cannot always be made to support this assumption; for example, if we were considering the market for bentonite, discussed earlier, a big jump in world demand for iron ore would affect both price and quantity in the bentonite market; but it would also affect Australia's exchange rate, because iron ore is such a large part of Australian exports. So the exchange rate would not be a valid instrument in the bentonite market.)

The Commission explored the possibility of using instrumental variables estimation, using the trade weighted index and the exchange rates for Chinese Yuan and US dollars as instrumental variables. However, these instruments are *not* sufficiently strong predictors of the prices of the chemicals under consideration and therefore estimates are imprecise and biased towards OLS estimates (Hillberry and Hummels 2013, p. 1233).

Figure D.3

**Prices of chemicals vary**

Jitter plot<sup>a</sup> of prices<sup>b,c</sup> and weighted average price<sup>d</sup> (\$AUD) from 2010 to 2019



<sup>a</sup> Jitter plots slightly perturb each point. <sup>b</sup> Prices are unit values, derived from cost (including insurance and freight, CIF) divided by quantity. <sup>c</sup> Prices presented on a log scale and outliers over \$AUD1000 have been removed for readability. <sup>d</sup> Weighted average price is denoted by the solid line.

Source: ABS (*Merchandise Imports and Import Clearances*, 2020, unpublished).



---

# E Downstream vulnerability of exports

This appendix focuses on the downstream analysis of exports (chapter 5) and provides:

- sensitivity analysis for the identification of vulnerable exports
- methodology for estimating employment related to vulnerable exports.

Appendix C provides information relevant to the analysis of upstream disruption to exports.

## E.1 Sensitivity analysis

The parameter values the Commission has used to identify vulnerable exports are based on judgements. Analysts can choose to vary thresholds when applying the analytical framework used in this report. Care is needed, however, to ensure the assumptions are realistic and defensible. Otherwise, the results will be questionable and compromise the credibility of the analysis and any policy inferences drawn from them. Varying the parameters will naturally change the results. The effects of varying two key parameters are explored here:

- the threshold used in filter 1 (the percentage of the value of Australian exports of a given product going to our biggest destination market)
- the number of years that a product needs to be captured by the first three filters to be classified as vulnerable in filter 4.

Sensitivity analysis was conducted for the parameters used in the second filter (the global market concentration index and the share of imports purchased by the world's biggest importer). Varying those parameters (singly or in conjunction) had minimal effects on the results so the specifics of the sensitivity analysis are not reported here.

### Using different market concentration thresholds in filter 1

A product is captured by filter 1 if, in a given year, 80 per cent or more of the value of its exports go to a single destination market. Using lower thresholds captures more products, and so a greater share of the value of Australia's goods exports (table E.1).

- Moving from a threshold of 80 per cent to 70 per cent results in the largest increase in the *value* of goods exports identified as vulnerable. Excluding iron ore, vulnerable exports increase from 1.9 to 10.5 per cent of the value of goods exports (on average between 2012 and 2019). This is mostly driven by the inclusion of LNG as a vulnerable export — over 70 per cent of Australia's LNG exports went to Japan from 2012 to 2015.

- Moving from a threshold of 70 per cent to 60 per cent results in the largest increase in the *number* of products identified as vulnerable, from 48 to 66 products. The value of these exports is relatively small though — the average value share of vulnerable exports (excluding iron ore) increases from 10.5 to only 11.9 per cent.

**Table E.1 Using different concentration thresholds in filter 1<sup>a</sup>**

<i>Market share threshold</i>	<i>Number of vulnerable exports<sup>b</sup></i>	<i>Value of vulnerable goods exports as a share of all goods exports (2012–19 average)</i>	<i>Value of vulnerable goods exports as a share of all goods exports, excluding iron ore (2012–2019 average)</i>
90 per cent	19	1.1	1.1
80 per cent	35	24.4	1.9
70 per cent	48	33.0	10.5
60 per cent	66	34.4	11.9
50 per cent	81	36.8	14.3

<sup>a</sup> The shaded row corresponds to the results in chapter 5. <sup>b</sup> Products are defined at the Harmonized System (HS) 6-digit level.

Source: CEPII (2021).

## Changing the threshold for the number of years a product must be captured by filters 1-3 to be classified as vulnerable in filter 4

In filter 4, exports are classified as vulnerable if they are captured by the first three filters in *four or more* of the eight years analysed (2012 through 2019, inclusive). This is done to avoid classifying products as vulnerable if they happen to satisfy the threshold criteria simply due to natural year-to-year variations in trade patterns.<sup>51</sup>

The results are sensitive to the number of years selected for filter 4 (table E.2). An increase in the number of years a product is captured by filters 1-3 reduces the number and value of vulnerable exports, while a decrease has the opposite effect.

- Increasing the threshold to *five or more* years reduces the number of products identified as vulnerable from 35 to 29. With this change, iron ore is no longer identified as vulnerable, which is why the share of the value of goods exports that is vulnerable declines significantly. Iron ore ceases to be identified as vulnerable because, while the share of Australia’s exports going to our largest destination market (China) was high throughout the period analysed, it only exceeded the filter 1 threshold (80 per cent) for the four years from 2016 to 2019.
- Decreasing the threshold to *three or more* years increases the number of vulnerable products from 35 to 59. This lower threshold results in LNG being classified as vulnerable because over 80 per cent of Australia’s LNG exports went to Japan from 2012

<sup>51</sup> There are other ways this could be achieved. Products could be classified as vulnerable if, for example, they are captured by the first three filters for the past three years, or in four of the past five years.

to 2014. With this change, the value share of vulnerable exports increases from 24.4 per cent to 33.4 per cent (on average, between 2012 and 2019).

**Table E.2 Changing how many years a good must be captured by filters 1-3 to be classified as vulnerable in filter 4<sup>a</sup>**

<i>To be classified as vulnerable a product must be captured by filters 1-3 for ...</i>	<i>Number of vulnerable exports<sup>b</sup></i>	<i>Value of vulnerable goods exports as a share of all goods exports (2012–19 average)</i>	<i>Value of vulnerable goods exports as a share of all goods exports, excluding iron ore (2012–2019 average)</i>
Five or more years	29	1.8	1.8
Four or more years	35	24.4	1.9
Three or more years	59	33.4	10.9
Two or more years	95	33.6	11.2
One or more years	209	34.5	12.0

<sup>a</sup> The shaded row corresponds to the results in chapter 5. <sup>b</sup> Products are defined at the HS 6-digit level.

Source: CEPII (2021).

## E.2 Methodology for estimating a region’s exposure to vulnerable exports

The impact of disruption to any given export is likely to affect regions across Australia differently, because different industries are more or less concentrated in different regions.

Because data for industry activity are not available at a detailed regional level, the Commission used regional employment data to understand a region’s exposure to disruptions to vulnerable exports. The Commission estimated the proportion of market sector employment that is associated with vulnerable exports in different regions. Only market sector employment is used because it is assumed that non-market sector employment is not directly affected by disruptions to exports in the short term. The non-market sector industries that are excluded from the analysis are Public Administration and Safety, Education and Training, and Health Care and Social Assistance.

The share of employment in a region ( $r$ ) associated with the production of vulnerable exports ( $share\_emp_{r,vuln}$ ) is calculated using the expression:

$$share\_emp_{r,vuln} = \frac{\sum_{i=1}^n (Emp_{i,r} \times share\_exp_i \times share\_vuln_i)}{Emp_r} \quad (1)$$

where:

- $Emp_{i,r}$  denotes industry  $i$ ’s employment in region  $r$ 
  - regions ( $r$ ) are Statistical Area 4 (SA4) regions. As of May 2021, employment in SA4s ranged between 17 000 and 2.8 million persons, and around half of all SA4s

---

had total employment between about 85 000 and 194 000 persons. Representing labour markets was a key consideration in the delimitation of SA4s (ABS 2016; Labour Market Information Portal 2021).

- industries ( $i$ ) are identified with the Australian and New Zealand Standard Industrial Classification (ANZSIC) at the 4-digit level (506 industry aggregates).
- $share\_exp_i$  denotes the share of an industry's output that is exported (since an industry can produce outputs that are both exported and used domestically)
- $share\_vuln_i$  denotes the share of an industry's exports that is identified as vulnerable (since an industry may export many goods, only a few of which may be vulnerable).
- $Emp_r$  denotes market sector employment in region  $r$ .

The numerator of (1) denotes 'vulnerable' employment in a region. This is estimated by multiplying regional employment in each industry ( $Emp_{i,r}$ )<sup>52</sup> by the share of its output that is exported ( $share\_exp_i$ ) and by the share of the industry's exports that are identified as vulnerable ( $share\_vuln_i$ ). Neither of these shares are readily available so the Commission estimated them.

- The share of industry's  $i$ 's output that is exported ( $share\_exp_i$ ) is drawn from ABS Input–Output (I–O) tables, concorded to the ANZSIC classification (ABS 2019). The Commission calculated the share of each product's (Input–Output Product Group) output that is exported and matched the shares to the relevant ANZSIC industries via the concordance.
- The share of industry  $i$ 's exports that are identified as vulnerable ( $share\_vuln_i$ ) is estimated using trade data (CEPII 2021) and a concordance between the Harmonized System (HS) 6-digit product classification and the ANZSIC 4-digit industry classification (ABS 2017a). Using the concordance, we build a basket of goods exports for each ANZSIC industry, providing a total value for each industry's exports. The value of goods identified as vulnerable within each industry is divided by the industry's total exports to estimate the share of an industry's exports that is vulnerable.

The approach outlined above relies on several assumptions, including that:

- the national share of an industry's output that is exported can be used to estimate the regional share of an industry's output that is exported, and
- industry level regional employment shares can be used to estimate the proportion of an industry's national output that is produced in each region.

---

<sup>52</sup> Information on employment by industry and region (place of work) is drawn from the 2016 Census of Population and Housing.

---

## F Maritime shipping and ports capacity

Services from maritime shipping and port operators largely continued to function during the COVID-19 pandemic in Australia (Parliament of Australia 2020c, p. 57; SAL, sub. 56, p. 40). Nevertheless, many participants to this study raised issues with capacity in these sectors as a key risk to their supply chains (box 2.4). While the application of the frameworks in this report has focused on analysing trade data for goods (particularly chapters 4 and 5), transport and logistic services are critical inputs into supplying these goods. Vulnerabilities to disruption in these, along with other services, also need to be carefully assessed and managed to ensure that the supply of essential goods and services in Australia is not compromised.

This appendix illustrates how one might apply the framework for determining whether government intervention is justified (chapter 7), and to identify (and assess) policy options to deal with risks to Australia’s maritime shipping and ports. The analysis below highlights in particular the trade-offs between proposals raised by participants to this study.

### **Are maritime and ports services vulnerable, essential and critical to the economy?**

Services provided by the maritime shipping and ports industries are often included either specifically or within the broad definition of ‘transport’ as essential services (table 3.1 and 3.2).

Further investigation is required to ascertain whether the existing transport of essential goods is particularly vulnerable to disruption, and whether they are substitutable by other transport modes. This requires a closer assessment of the specific services required — for example, bulk carriers, tankers and container ships are all specialised and require different types of infrastructure.

Box 2.4 outlines the areas participants raised that could impact on the capacity of maritime shipping and ports to respond to disruptions. These broadly relate to the factors of vulnerability and criticality that were examined in the goods market in our analysis, such as market concentration of service providers, and the lack of flexibility due to relying on unique infrastructure, critical skills, and other inputs.

Given the scope of this study, this report has not assessed the relative merits of these issues, and the extent to which they make certain shipping and ports services vulnerable to disruption. However, the wide range of issues raised by participants highlights that many

---

factors can affect the resilience of a supply chain. These factors need to be carefully understood and assessed to ensure that the policy response is commensurate with the risk.

## **Is there a role for government in risk management?**

Where vulnerabilities to the supply of maritime shipping and port services are identified, it is then important to determine who is best placed to manage the associated risks (and whether there is a role for government to intervene). As noted in chapter 7, firms directly responsible for providing maritime shipping and ports services would primarily be responsible for managing risks in these supply chains. In Australia, these services are largely provided by private sector firms, with many state or territory governments having privatised their port assets on a long-term lease basis (DIRDC 2018a).<sup>53</sup>

Governments assessing whether to intervene in risk management of private firms need to consider whether market prices reflect the costs of identified risks of disruptions, and whether they incentivise firms to manage them effectively. There may exist barriers that mean risks cannot be effectively internalised by firms.

In some cases, government interventions can impede the ability of markets to manage risk. For example, participants have argued that investment in alternative ports in New South Wales is compromised by provisions in privatisation contracts of key NSW ports. In 2013, the NSW Government committed to compensate the operators of Port Kembla and Port Botany if container traffic at the Port of Newcastle exceeded a specified cap. Under the 2014 privatisation agreement, the new operators of the Port of Newcastle are required to reimburse the NSW Government for any compensation paid to operators of Port Botany and Port Kembla. The ACCC has taken the operators of Port Botany and Port Kembla to the Federal Court alleging that this agreement with the NSW Government had an anti-competitive purpose and effect. According to the Chair of the ACCC (Australian Competition Law 2020):

The compensation and reimbursement provisions effectively mean that the Port of Newcastle would be financially punished for sending or receiving container cargo above a minimal level if Port Botany and Port Kembla have spare capacity. This makes development of a container terminal at the Port of Newcastle uneconomic ... We are taking legal action to remove a barrier to competition in an important market, the supply of port services, which has significant implications for the cost of goods across the economy, not just in New South Wales. The impact of any lessening of competition is ultimately borne by consumers.

It may also be the case that society's tolerance for residual risk is lower than the level of risk that results from the market. For example, the market for liquid fuels may well assess that the availability of suppliers of refined fuels,<sup>54</sup> tankers, and appropriate ports in Australia

---

<sup>53</sup> Where a government agency provides services directly, it is expected to act in the same manner as a private firm would.

<sup>54</sup> As noted in box 4.4, liquid fuels were not identified as vulnerable in this report due to the range of countries that Australia imports from.

---

largely deal with the risks to our domestic supplies (SAL, sub. 56, p. 35); but society may demand greater security through increased stockholdings or domestic refining or shipping capacity (GrainGrowers, sub. 33, p. 7; GPA, sub. 25, p. 2; IIER-Australia, sub. 6, pp. 7–8; IFCBAA, sub. 41, p. 6; MUA, sub. 38, p. 30; Port of Newcastle, sub. 5, p. 5). But greater security comes at a cost, and governments need to weigh up how much society is willing to pay for additional levels of domestic capacity (and whether these would in fact be effective). This is where governments need to carefully consider the various policy interventions they might pursue.

### What feasible policy levers exist to deal with capacity constraints in maritime shipping and ports?

There are many levels of government intervention that could improve the capacity of maritime shipping and port services in Australia to manage risks of supply chain disruptions (table F.1). As noted in chapter 7, the level of risk mitigation by government needs to be justified, proportionate to the level of risk, and be the most effective option at reducing risk. For some risks, multiple interventions may be required.

In the first instance, governments should consider if there are any regulatory or government barriers that reduce the capacity of firms to prepare for or respond to risks. For example, many participants identified that state and territory governments' application of COVID-19 health measures towards maritime crews were not commensurate with the health risks they posed. These decisions added to the cost and capacity constraints of service providers — as well as endangering the physical and mental health of crews that were unable to disembark in Australian ports (MIAL, sub. 28, pp. 11–12; MUA, sub. 38, pp. 28–29; Ports Australia, sub. 20, pp. 3–4; SAL, sub. 56, pp. 48–49). Other participants noted the impact of biosecurity processes in exacerbating delays in maritime shipping (FTA and the APSA, sub. 18, p. 18; RDAT and the Tasmanian Logistics Committee, sub. 17, p. 23). A review in 2020 by the Inspector-General of Biosecurity (2021, p. 4), for example observed that the:

... biosecurity system is not in a strong position to address the diverse and evolving biosecurity risks and business environment expected to prevail in 2021 and through to 2025. This assessment is based on an examination of the systemic problems, including the department's regulatory maturity, its approach to co-regulation, inadequate frontline focus, and the absence of an appropriate funding model.

As a result of this review, the Minister of Agriculture announced measures to achieve biosecurity outcomes in less onerous and risk-based ways, such as thorough increased automation of cargo scanning and documentation processing (Littleproud 2021). Other participants also called for expedited implementation of a single trade window to reduce the complexity of reporting to various agencies (ECA, sub. 31, p. 4; FIBA, sub. 32, p. 3; IFCBAA, sub. 41, p. 5). The purpose of regulation is to manage risks; in reducing substantive compliance costs, governments need to balance the costs with the benefit of a regulation and of the various possible ways in which it might be implemented. Many participants, for example, stressed the importance of biosecurity measures in protecting

Australia’s supply chains from the threat of pests and diseases (GrainGrowers, sub. 33, pp. 10–11; GPA, sub. 25, pp. 8–9; NFF, sub. 22, p. 10).

The next policy lever to consider is whether there is a need for greater information sharing with industry. For example, stakeholders noted the potential for the Australian Government’s freight data hub to drive productivity and service innovation through end-to-end visibility of the supply chain (ARTC, sub. 50, p. 7; PoM; sub. 35, p. 9). Information sharing has costs, including the costs to collect, process, and disseminate the data. It also might reduce the incentives of firms themselves to share data and identify solutions that are best suited to their needs.

**Table F.1 Policy options to address risks to shipping and ports capacity**

<i>Policy option and rationale</i>	<i>Costs of options</i>
<p>Regulatory changes to improve the operation of maritime shipping and port operators, for example, addressing:</p> <ul style="list-style-type: none"> <li>• possible barriers to competition (including across different transport modes)</li> <li>• labour constraints (such as restrictions that affect essential workers’ ability to work during a pandemic)</li> <li>• improved implementation of regulation (for example, more streamlined customs procedures).</li> </ul>	<ul style="list-style-type: none"> <li>• Compliance costs on businesses, and costs to government to implement changes.</li> <li>• Increases risks on the community or lowers firms’ incentives to make investments to manage risks (for example, making investments to boost capacity).</li> </ul>
<p>Improving data sharing between government and industry, and the use of data standards to improve efficiency in logistics and risk management.</p>	<ul style="list-style-type: none"> <li>• Costs for firms and government to implement data standards or data requirements.</li> <li>• Increases costs to firms in complying with data standards or improving data governance.</li> </ul>
<p>Investing in infrastructure or human capital (or incentives for private infrastructure investment) to build additional redundancy into ports and shipping, including considerations of:</p> <ul style="list-style-type: none"> <li>• port location and substitution</li> <li>• ship vessel or container size and type</li> <li>• connection to road and rail infrastructure</li> <li>• technology improvements and automation.</li> </ul>	<ul style="list-style-type: none"> <li>• Costs of investing in deepening port channels, building wharfside infrastructure, and building connections to other transport modes.</li> <li>• Risk of underutilisation and stranded assets.</li> <li>• Reduces incentives for firms to invest in effective risk management (including across different modes).</li> </ul>
<p>Support investment in domestic maritime shipping fleet to build capacity in certain routes, and to protect against nations restricting access to vessels.</p>	<ul style="list-style-type: none"> <li>• Costs of building high redundancy and potential for rent-seeking.</li> <li>• Reduces incentives for firms to invest in effective risk management (including across different modes).</li> <li>• Unlikely to protect from all forms of risk or lead to self-sufficiency across all forms of shipping/container needs. Risk of nations restricting access appears to be highly remote.</li> </ul>

The last set of policies governments could consider is directly investing in risk management by subsidising capacity across Australia’s maritime shipping and ports services. Stakeholders, for example, suggested a potential role for governments to

---

support investment in port infrastructure (Ai Group, sub. 49, attachment 1, p. 4), or in a domestic ‘strategic’ fleet (MIAL, sub. 28, p. 8; MUA, sub. 38, pp. 30 and 32). While these policies would directly increase long-term redundancy in maritime shipping and ports capacity, they are also likely to be significantly costlier than other policy levers. As such, they are likely to be the most distortionary to private sector investment in risk management. For example, a domestic national fleet could discourage carriers from entering the market, and would likely encourage rent-seeking behaviour (such as pressure to provide ongoing financial support or protection from competition).

Whatever the policy lever selected, to ensure government intervention is effective, governments need to demonstrate that the expected benefits of government investing in mitigating private sector supply chain risks outweigh the expected costs. And also that the intervention is the best solution to the identified problem.



---

# References

- ABC (Australian Broadcasting Corporation) 2020, 'Medicine shortage fears as India limits exports amid spreading coronavirus outbreak', *ABC News*, 5 March, <https://www.abc.net.au/news/2020-03-05/fear-of-medicine-shortage-spreads-as-india-limits-exports/12026762> (accessed 29 January 2021).
- ABC/Reuters 2020, 'China suspends Australian timber imports from New South Wales and Western Australia', *ABC News*, 24 December, <https://www.abc.net.au/news/2020-12-24/china-suspends-australian-timber-imports-from-nsw-wa/13013752> (accessed 21 June 2021).
- ABS (Australian Bureau of Statistics) 2016, *Australian Statistical Geography Standard (ASGS): Volume 1 - Main Structure and Greater Capital City Statistical Areas*, July 2016, Cat. no. 1270.0.55.001, Canberra.
- 2017a, *International Merchandise Trade, Australia: Concepts, Sources and Methods*, 2015 - Appendices, Cat. no. 5489.0, Canberra, <https://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5489.0Main+Features12015?OpenDocument> (accessed 21 June 2021).
- 2017b, *Management and Organisation Capabilities of Australian Business 2015-16*, Canberra.
- 2019, *Australian National Accounts: Input-Output Tables*, Cat. no. 5209.0.55.001, Canberra.
- 2020a, *Australian National Accounts: Input-Output Tables, 2017-18 - Table 17*, Cat. no. 5209.0.55.001, Canberra.
- 2020b, *Australian National Accounts: National Income, Expenditure and Product*, Cat. no. 5206.0, Canberra.
- 2020c, *Imports of Personal Protective Equipment (PPE)*, <https://www.abs.gov.au/articles/imports-personal-protective-equipment-ppe> (accessed 28 May 2021).
- 2020d, *International Trade: Supplementary Information, Financial Year, 2019-20*, December, Cat. no. 5368.0.55.003, Canberra.
- ACCC (Australian Competition and Consumer Commission) 2017, *Cattle and Beef Market Study - Final Report*, March, Canberra.
- 2018, *ACCC will not oppose Moly-Cop's proposed acquisition of Donhad*, Media release, 29 March.
- 2019, *Wine Grape Market Study - Final Report*, September, Canberra.
- 2020a, *Interim Authorisation Decision*, <https://www.accc.gov.au/public-registers/authorisations-and-notifications-registers/authorisations-register/minerals-council-of-australia/interim-authorisation-decision> (accessed 27 May 2021).

- 
- 2020b, *Perishable Agricultural Goods Inquiry*, November, Canberra.
- 2021, *COVID-19-Related Authorisations*, April, Canberra.
- AEI (Australian Education International) 2021, *Student Numbers*, Department of Education, Skills and Employment, <https://internationaleducation.gov.au/research/datavisualisations/Pages/Student-number.aspx> (accessed 29 March 2021).
- AIDR (Australian Institute for Disaster Resilience) 2021, *Guidance for Strategic Decisions on Climate and Disaster Risk*, <https://knowledge.aidr.org.au/resources/strategic-disaster-risk-assessment-guidance/> (accessed 3 February 2021).
- AMIC (Australian Meat Industry Council) 2020, *Submission to the Joint Standing Committee on Trade and Investment Growth: Inquiry into Diversifying Australia's Trade and Investment Profile*, Canberra.
- AMSA (Australian Maritime Safety Authority) 2018, *Stockpile Equipment*, <https://www.amsa.gov.au/news-community/newsletters/scene-newsletter-issue-32/stockpile-equipment> (accessed 2 June 2021).
- ANAO (Australian National Audit Office) 2020, *Planning and Governance of COVID-19 Procurements to Increase the National Medical Stockpile*, Auditor-General Report No.22 2020–21, Canberra.
- 2021, *COVID-19*, <https://www.anao.gov.au/work-program/covid-19> (accessed 10 May 2021).
- and Reserve Bank of Australia 2019, *Cyber Resilience of Government Business Enterprises and Corporate Commonwealth Entities*, Australian National Audit Office, Canberra.
- Andrews, K. 2020, *2020-21 Budget - Manufacturing Australia's future*, Media Release, 6 October, Canberra.
- Austrade (Australian Trade and Investment Commission) 2021, *International Freight Assistance Mechanism*, <https://www.austrade.gov.au/news/news/international-freight-assistance-mechanism> (accessed 4 June 2021).
- Australian Competition Law 2020, *ACCC v NSW Ports*, <https://www.australiancompetitionlaw.info/cases/accc-v-nsw-ports> (accessed 25 June 2021).
- Australian Government 2021, *Budget 2021-22: Securing Australia's Recovery: Building a more secure and resilient Australia*, Canberra.
- Australian Grape and Wine Incorporated 2020, *Submission to the Joint Standing Committee on Trade and Investment Growth: Inquiry into Diversifying Australia's Trade and Investment Profile*, Adelaide.
- BBC News 2011, 'Toyota profits plunge after earthquake disruption', *BBC News*, 2 August, <https://www.bbc.com/news/business-14369137> (accessed 21 September 2020).
- Birmingham, S. 2020, 'Australian grains industry conference', speech by Minister for Trade, Tourism and Investment at Australian Grains Industry Conference, Melbourne, 30 July.

- 
- Birtles, B. 2020, 'China claims "quality" problem with Australian coal as \$700 million worth sits idle off ports', *ABC News*, 26 November, <https://www.abc.net.au/news/2020-11-26/china-claims-quality-problem-with-australian-coal/12921354> (accessed 23 March 2021).
- BiTA (Blockchain in Transport Alliance) 2019, *Blockchain in Transport Alliance*, BiTA, <https://www.bitastudio/> (accessed 21 June 2021).
- BOM (Bureau of Meteorology) 2021, *About Us*, <http://www.bom.gov.au/inside/index.shtml?ref=hdr> (accessed 28 January 2021).
- Borgese, A., Newbold, B., Lloyd, K., Scamps-Goodman, A. and Findlay, M. 2020, 'COVID-19: Force majeure and frustration of your contracts', 23 March, <https://www.minterellison.com/articles/covid-19-force-majeure-and-frustration-contract> (accessed 16 February 2021).
- Borys, S. 2020, 'Cyber attacks on Australian businesses on the rise but experts not blaming state actors', *ABC News*, 15 May, <https://www.abc.net.au/news/2020-05-15/cyber-attacks-australian-businesses-increasing-not-state-actors/12253842> (accessed 15 April 2021).
- Branigan, T. 2010, 'Chinese moves to limit mineral supplies sparks struggle over rare earths', *The Guardian*, 25 October, <http://www.theguardian.com/business/2010/oct/25/china-cuts-rare-earth-exports> (accessed 19 February 2021).
- Butler, B. 2020, 'Could China replace Australian iron ore with metal from Africa?', *The Guardian*, 3 December, <https://www.theguardian.com/business/2020/dec/02/could-china-replace-australian-iron-ore-with-metal-from-africa> (accessed 26 March 2021).
- and Davidson, H. 2020, 'China imposes swingeing tariffs on Australian wine in "devastating blow" to exporters', *The Guardian*, 27 November, <https://www.theguardian.com/business/2020/nov/27/china-imposes-swingeing-tariffs-on-australian-wine-in-devastating-blow-to-exporters> (accessed 26 March 2021).
- CEPII (Centre d'Études Prospectives et d'Informations Internationales) 2021, *BACI: International Data Database at the Product Level*, France, [http://www.cepii.fr/cepii/en/bdd\\_modele/presentation.asp?id=37](http://www.cepii.fr/cepii/en/bdd_modele/presentation.asp?id=37) (accessed 1 September 2020).
- Chandra, C. and Kamrani, A. 2004, 'Knowledge management for consumer-focused product design', *Journal of Intelligent Manufacturing*, vol. 14, pp. 557–580.
- ChemicalBook 2016, *Glycine Derivative*, [https://www.chemicalbook.com/ProductCatalog\\_EN/151717.htm](https://www.chemicalbook.com/ProductCatalog_EN/151717.htm) (accessed 15 February 2021).
- ChinaPower 2020, *Does China pose a threat to global rare earth supply chains?*, *ChinaPower Project*, 17 July, <http://chinapower.csis.org/china-rare-earth/> (accessed 12 May 2021).
- Choi, C.Q. 2012, 'Why Iceland volcano's eruption caused so much trouble', 7 February, <https://www.livescience.com/31127-iceland-volcano-ash-plume-trouble.html> (accessed 18 February 2021).
- Christopher, M. 2018, *The Mitigation of Risk in Resilient Supply Chains*, International Transport Forum Discussion Papers, No. 2018/19, OECD Publishing, Paris.

- 
- Clarke, P. 2020, 'Wuhan fiber dominance spells trouble for 5G', 6 April, <https://www.eenewsanalog.com/news/wuhan-fiber-dominance-spells-trouble-5g> (accessed 17 February 2021).
- Conifer, D. 2020, 'China imposes 80pc tariff on Australian barley for next five years amid global push for coronavirus investigation', *ABC News*, 18 May, <https://www.abc.net.au/news/2020-05-18/china-to-impose-tariffs-on-australian-barley/12261108> (accessed 23 March 2021).
- Costello, S. 2020, 'Where is the iPhone made?', 11 September, <https://www.lifewire.com/where-is-the-iphone-made-1999503> (accessed 27 January 2021).
- Critical Infrastructure Centre 2021, *What is the Critical Infrastructure Centre?*, Canberra.
- Crummy, P. 2020, *The Impact of COVID-19 on the Australian Contact Centre Outsourcing Industry*, CPM Australia, Melbourne.
- CSIRO 2018, *Supporting Supply Chains*, <https://www.csiro.au/en/Research/Astronomy/Supporting-supply-chains> (accessed 28 January 2021).
- 2020, *Transport Logistics-TRANSIT*, <https://www.csiro.au/en/Research/LWF/Areas/Landscapes/Transport-logistics-TRANSIT> (accessed 28 January 2021).
- Daly, T. 2021, 'China hikes half-year rare earth output quotas to record level', *Reuters*, 19 February, <https://www.reuters.com/article/us-china-rareearth-idUSKBN2AJ18O> (accessed 12 May 2021).
- DCSA (Digital Container Shipping Association) 2021, *About DCSA*, <https://dcsa.org/about#about-dcsa> (accessed 21 June 2021).
- DEE (Department of the Environment and Energy) 2019, *Liquid Fuels Security Review-Interim Report*, April, Canberra.
- Deloitte LPP 2015, *Independent Review of RTGS Outage on 20 October 2014*, March, London, UK.
- Denton, J. 2020, 'COVID-19: International trade and its ramifications for Australia in a post-COVID global economy', speech by ICC Secretary General at Brookes Oration, Deakin University, 27 August.
- and Bruckard, D. 2020, 'Resilient supply chains can inoculate against vaccine nationalism', 11 October, <https://www.eastasiaforum.org/2020/10/11/resilient-supply-chains-can-inoculate-against-vaccine-nationalism/> (accessed 9 February 2021).
- DESE (Department of Education, Skills and Employment) 2021, *International Student Data 2021*, <https://internationaleducation.gov.au/research/international-student-data/Pages/InternationalStudentData2021.aspx> (accessed 8 June 2021).
- DFAT (Department of Foreign Affairs and Trade) 2020, *Australia's Top 25 Exports, Goods and Services*, Canberra, [https://www.dfat.gov.au/sites/default/files/australias\\_goods\\_and\\_services\\_by\\_top\\_25\\_exports\\_2019.pdf](https://www.dfat.gov.au/sites/default/files/australias_goods_and_services_by_top_25_exports_2019.pdf) (accessed 21 February 2021).
- 2021a, *Australia's Trade in Goods and Services, 2019-20*, Canberra, <https://www.dfat.gov.au/trade/resources/trade-statistics/trade-in-goods-and-services/australias-trade-in-goods-and-services-2019-20> (accessed 29 March 2021).

- 
- 2021b, *Trade Statistical Pivot Tables*, Canberra, <https://www.dfat.gov.au/about-us/publications/trade-statistical-pivot-tables> (accessed 30 March 2021).
- DHHS (Department of Health & Human Services) 2017, *Fire Retardants and Health*, <https://www2.health.vic.gov.au/public-health/environmental-health/environmental-health-in-the-community/fire-retardants-and-health> (accessed 19 February 2021).
- DIRDC (Department of Infrastructure, Regional Development and Cities) 2018a, *Freight and Supply Chains: Ports*, <https://www.infrastructure.gov.au/transport/freight/ports.aspx> (accessed 25 June 2021).
- 2018b, *Inquiry into National Freight and Supply Chain Priorities*, March, Canberra.
- DISER (Department of Industry, Science, Energy and Resources) 2020a, *Australia's Fuel Security Package*, Canberra, <https://www.energy.gov.au/government-priorities/energy-security/australias-fuel-security-package> (accessed 26 January 2021).
- 2020b, *Department of Industry, Science, Energy and Resources Annual Report 2019–20*, October, Canberra.
- 2020c, *Hand Sanitiser in Australia: Market Insights*, October, Canberra, <https://www.industry.gov.au/news-media/hand-sanitiser-in-australia> (accessed 28 January 2021).
- 2020d, *Meeting Our Needs in Times of Crisis, October*, Canberra, <https://www.industry.gov.au/news/meeting-our-needs-in-times-of-crisis> (accessed 29 January 2021).
- 2020e, *Our Modern Manufacturing Strategy*, <https://www.industry.gov.au/data-and-publications/make-it-happen-the-australian-governments-modern-manufacturing-strategy/our-modern-manufacturing-strategy> (accessed 8 February 2021).
- 2021a, *Resources and Energy Quarterly: June 2021*, Canberra.
- 2021b, *Resources and Energy Quarterly: March 2021*, Canberra.
- (Taylor) 2021c, *Locking in Australia's fuel security*, Media release, 17 May, Department of Industry, Science, Energy and Resources.
- Doggett, J. 2020, 'The national medical stockpile – A timely explainer', 10 August, <https://www.croakey.org/the-national-medical-stockpile-an-explainer/> (accessed 28 January 2021).
- DoH (Department of Health) 2020, *Budget 2020-21: Supporting Our Hospitals - COVID-19 National Medical Stockpile*, Fact sheet, Canberra.
- DoHA (Department of Home Affairs) 2015, *Critical Infrastructure Resilience Strategy: Plan*, Canberra.
- 2018a, *Profiling Australian's Vulnerability: The Interconnected Causes and Cascading Effects of Systemic Disaster Risk*, Canberra.
- 2018b, *Regulation Impact Statement: Modern Slavery Reporting Requirements*, Canberra.
- 2020a, *Covid-19 and the Border: Critical Skills and Sectors*, <https://covid19.homeaffairs.gov.au/critical-skills-and-sectors> (accessed 10 September 2020).

- 
- 2020b, *Critical Technology Supply Chain Principles: A Call For Views*, Canberra.
- 2020c, *Security Coordination: Critical Infrastructure Resilience*, <https://www.homeaffairs.gov.au/about-us/our-portfolios/national-security/security-coordination/critical-infrastructure-resilience> (accessed 16 February 2021).
- DPS (Department of Parliamentary Services) 2020, *COVID-19 Australian Government Roles and Responsibilities: An Overview*, Research Paper Series 2019-20, Canberra.
- Dushyantha, N., Batapola, N., Ilankoon, I.M.S.K., Rohitha, S., Premasiri, R., Abeysinghe, B., Ratnayake, N. and Dissanayake, K. 2020, 'The story of rare earth elements (REEs): Occurrences, global distribution, genesis, geology, mineralogy and global production', *Ore Geology Reviews*, vol. 122, art. 103521.
- ECB (European Central Bank) 2020, *ECB announces independent review of payments system outage*, Press release, <https://www.ecb.europa.eu/press/pr/date/2020/html/ecb.pr201116~7b08f0a3c5.en.html> (accessed 10 May 2021).
- 2021, *TARGET2-Securities Annual Report 2020*, April, Germany.
- Editorial Board, East Asia Forum 2020, *Making Supply Chains Great Again*, <https://www.eastasiaforum.org/2020/10/12/making-supply-chains-great-again/> (accessed 9 February 2021).
- Emerson, C. 2020a, 'Protectionism won't make Australia great again', *Australian Financial Review*, 4 May, <https://www.afr.com/policy/economy/protectionism-won-t-make-australia-great-again-20200504-p54pij> (accessed 28 January 2021).
- 2020b, 'Road out leads back to productivity', *Australian Financial Review*, 21 April, <https://www.afr.com/policy/economy/road-out-leads-back-to-productivity-20200420-p54lbe> (accessed 28 January 2021).
- Engineers Australia 2019, *Industry Responses in a Collapse of Global Governance: Workshop Report for Attendees*, February, Melbourne.
- European Commission 2021, *Strategic Dependencies and Capacities*, Commission Staff Working Document, 5 May.
- Evans, S. 2021, 'Wine exports to China crash on tariff hit', *Australian Financial Review*, 29 April, <https://www.afr.com/companies/agriculture/wine-exports-to-china-crash-on-tariff-hit-20210429-p57nc9> (accessed 4 May 2021).
- Ewing, J. and Boudette, N.E. 2021, 'A tiny part's big ripple: Global chip shortage hobbles the auto industry', *The New York Times*, 23 April, <https://www.nytimes.com/2021/04/23/business/auto-semiconductors-general-motors-mercedes.html> (accessed 28 April 2021).
- Fisher, A. 2020, *Review of Financial Assistance to SME Exporters*, A report from Anna Fisher to the Minister for Trade, Tourism and Investment, July.
- Flaherty, N. 2021, 'NXP, Infineon plants hit by power outage in Texas storm', *eeNews Europe*, 17 February, <https://www.eenewseurope.com/news/nxp-infineon-plants-hit-power-outage-texas-storm> (accessed 15 June 2021).
- Fredericks, D. 2021, *Senate Economics Legislation Committee: Estimates*, Hansard, 3 June, Canberra.

- 
- Fu, Q., Lee, C.-Y. and Teo, C.-P. 2010, 'Procurement management using option contracts: Random spot price and the portfolio effect', *IIE Transactions*, vol. 42, no. 11, pp. 793–811.
- GATT 1994, *General Agreement on Tariffs and Trade 1994: Article XXI Security Exceptions*, World Trade Organisation, Geneva, Switzerland.
- Gaudenzi, B. and Siciliano, G. 2018, 'Managing IT and cyber risks in supply chains', in Khojasteh, Y. (ed), *Supply Chain Risk Management: Advanced Tools, Models, and Developments*, Springer, Singapore, pp. 85–96.
- Goenka, A. 2021, 'What is behind the EU's dispute with AstraZeneca over COVID-19 vaccines?', *The Conversation*, 29 January, <https://theconversation.com/what-is-behind-the-eus-dispute-with-astrazeneca-over-covid-19-vaccines-154161> (accessed 12 February 2021).
- Goldman, J.A. 2014, 'The U.S. rare earth industry: Its growth and decline', *Journal of Policy History*, vol. 26, no. 2, pp. 139–166.
- Greber, J. 2020, 'Liveris calls the start of the on-shoring era', *Australian Financial Review*, 9 April, <https://www.afr.com/politics/liveris-calls-the-start-of-the-on-shoring-era-20200408-p54i37> (accessed 7 October 2020).
- Handfield, R. and Graham, G. 2020, 'Coronavirus, tariffs, trade wars and supply chain evolutionary design', *International Journal of Operations and Production Management*, vol. 40, no. 10, pp. 1649–1660.
- Hanke Vela, J. and Heath, R. 2021, 'Brussels blocks vaccine exports in all but name', *Politico*, 7 April, <https://www.politico.eu/article/vaccine-export-block-europe-coronavirus-astrazeneca/> (accessed 17 June 2021).
- Hansell, D. and Rafi, B. 2018, 'Firm-level analysis using the ABS' Business Longitudinal Analysis Data Environment (BLADE)', *Australian Economic Review*, vol. 51, no. 1, pp. 132–138.
- Hare, J. 2021, 'What pandemic? UQ's foreign enrolments peak', *Australian Financial Review*, 19 April, <https://www.afr.com/policy/health-and-education/international-student-enrolments-hit-record-highs-and-staggering-lows-20210415-p57jg8> (accessed 31 May 2021).
- Harkell, L. 2020, 'Aussie rock lobster firm eyes new markets after China road block', *Undercurrent News*, 4 December, <https://www.undercurrentnews.com/2020/12/04/aussie-rock-lobster-firm-eyes-new-pastures-after-china-road-block/> (accessed 4 May 2021).
- Haxel, G., Hendrick, J. and Orris, G. 2002, *Rare Earth Elements - Critical Resources for High Technology*, Fact sheet, <https://pubs.usgs.gov/fs/2002/fs087-02/> (accessed 19 February 2021).
- Henderson, A., Dziedzic, S., Oaten, J. and Patidar, S. 2020, 'China's The Global Times appears to confirm a ban on Australian coal imports amid perilous trade tensions', *ABC News*, 14 December, <https://www.abc.net.au/news/2020-12-14/global-times-reports-australian-coal-exports-blocked-by-china/12983336> (accessed 23 March 2021).

- 
- Herrmann, B. and Green, S. 2020, 'China's ban on Victorian timber exports could mean a boost for Green Triangle's processors', *ABC News*, 13 November, <https://www.abc.net.au/news/2020-11-13/timber-export-ban-boost-for-green-triangle-processors/12880024> (accessed 30 March 2021).
- Hillberry, R. and Hummels, D. 2013, 'Trade Elasticity Parameters for a Computable General Equilibrium Model', in Dixon, P.B. and Jorgenson, D.W. (eds), *Handbook of Computable General Equilibrium Modelling*, vol 1, Elsevier, Oxford, UK, pp. 1213–1269.
- Ho, W., Zheng, T., Yildiz, H. and Talluri, S. 2015, 'Supply chain risk management: A literature review', *International Journal of Operations and Production Management*, vol. 16, no. 53, pp. 5031–5069.
- Hopp, W.J., Iravani, S.M.R. and Liu, Z. 2012, 'Mitigating the impact of disruptions in supply chains', in Gurnani, H., Mehrotra, A. and Saibal, R. (eds), *Supply Chain Disruptions: Theory and Practice of Managing Risk*, Springer, London, UK, pp. 21–49.
- Horner, R. 2020, 'The world needs pharmaceuticals from China and India to beat coronavirus', *The Conversation*, 25 May, <https://theconversation.com/the-world-needs-pharmaceuticals-from-china-and-india-to-beat-coronavirus-138388> (accessed 3 February 2021).
- Hui, M. 2021, 'Japan's global rare earths quest holds lessons for the US and Europe', 23 April, <https://qz.com/1998773/japans-rare-earths-strategy-has-lessons-for-us-europe/> (accessed 26 April 2021).
- Hurst, D. 2020, 'Economic decoupling from China would be "act of national self-sabotage", Labor and Liberal MPs agree', *The Guardian*, 8 December, <https://www.theguardian.com/world/2020/dec/08/economic-decoupling-from-china-would-be-act-of-national-self-sabotage-labor-and-liberal-mps-agree> (accessed 26 March 2021).
- Impullitti, G. and Licandro, O. 2018a, 'Quantifying the gains from trade', 29 April, <https://voxeu.org/article/quantifying-gains-trade> (accessed 18 February 2021).
- and ——— 2018b, 'Trade, firm selection and innovation: the competition channel', *The Economic Journal*, vol. 128, no. 608, pp. 189–229.
- Inspector-General of Biosecurity 2021, *Adequacy of department's operational model to effectively mitigate biosecurity risks in evolving risk and business environments*, Department of Agriculture, Water and the Environment, Canberra.
- Jeong, E.-Y. and Strumpf, D. 2021, 'Why the chip shortage is so hard to overcome', *Wall Street Journal*, 19 April, <https://www.wsj.com/articles/why-the-chip-shortage-is-so-hard-to-overcome-11618844905> (accessed 11 May 2021).
- Johnson, M. 2020, 'Shortage of COVID-19 sample collection tools will be short-lived, suppliers say', *Modern Healthcare*, 22 March, <https://www.modernhealthcare.com/supply-chain/shortage-covid-19-sample-collection-tools-will-be-short-lived-suppliers-say> (accessed 21 January 2021).
- Joint Standing Committee on Trade and Investment Growth 2020, *Official Committee Hansard*. Tuesday, 14 July 2020., Commonwealth of Australia, Canberra.

- 
- Kearsley, J. 2021, “‘Incredible waste of money’”: Two million coronavirus tests to expire this month’, *9news*, 6 May, <https://www.9news.com.au/national/coronavirus-test-kits-government-bought-from-andrew-twiggy-forrest-to-expire-end-of-may/64a287fa-7c8b-4b05-8cca-42abee698213> (accessed 3 May 2021).
- King, I., Wu, D. and Pogkas, D. 2021a, ‘Microchips needed in your car, Playstation and phone are in short supply’, *Bloomberg*, 29 March, <https://www.bloomberg.com/graphics/2021-semiconductors-chips-shortage/> (accessed 28 April 2021).
- , ——— and ——— 2021b, ‘Why is there a chip shortage? Covid-19, surging demand cause semiconductor shortfall’, *Bloomberg*, 28 March, <https://www.bloomberg.com/graphics/2021-semiconductors-chips-shortage/> (accessed 15 April 2021).
- Kito, T., Brintrup, A., New, S. and Reed-Tsochas, F. 2014, *The Structure of the Toyota Supply Network: An Empirical Analysis*, Research Papers, March, 2014–03, Saïd Business School.
- Klayman, B. and Nellis, S. 2021, ‘Trump’s China tech war backfires on automakers as chips run short’, *Reuters*, 15 January, <https://www.reuters.com/business/autos-transportation/trumps-china-tech-war-backfires-automakers-chips-run-short-2021-01-15/> (accessed 28 April 2021).
- Kley, D. van der and Herscovitch, B. 2021, *Protecting Education Exports: Minimising the Damage of China’s Future Economic Coercion*, Policy Options Paper, May, 18, National Security College, Canberra.
- Knaus, C. and Doherty, B. 2020, ‘Global shortage of Covid-19 test kits hits Australia as other nations limit exports’, *The Guardian*, 13 March, <https://www.theguardian.com/australia-news/2020/mar/13/global-shortage-of-covid-19-test-kits-hits-australia-as-other-nations-limit-exports> (accessed 27 April 2021).
- and Smees, B. 2020, ‘Fears millions of Covid-19 testing kits Australia bought from Andrew Forrest could go to waste’, *The Guardian*, 1 July, <https://www.theguardian.com/australia-news/2020/jul/01/fears-millions-of-covid-19-testing-kits-australia-bought-from-andrew-forrest-could-go-to-wasted> (accessed 21 January 2021).
- Kollmann, T., Palangkaraya, A. and Webster, E. 2019, *Impact of Austrade Tailored Services 2012-16, A Report prepared for Australian Trade and Investment Commission*, April, Centre for Transformative Innovation, Swinburne University of Technology, Melbourne.
- Krugman, P., Cooper, R. and Srinivasan, T.N. 1995, ‘Growing world trade: Causes and consequences’, *Brookings Papers on Economic Activity*, pp. 329–377.
- Labour Market Information Portal 2021, *Employment by Industry*, ABS Labour Force Region - SA4 Data, Canberra, <https://lmip.gov.au/default.aspx?LMIP/Downloads/ABSLabourForceRegion> (accessed 7 July 2021).
- Laidlaw, H. 2020, *Liquid Fuel Security: A Quick Guide—May 2020 Update*, Research Paper Series, 8 May, 2019–20, Department of Parliamentary Services, Canberra.
- Latour, A. 2001, ‘A fire in Albuquerque sparks crisis for European cell-phone giants’, *The Wall Street Journal*, 29 January, <https://www.wsj.com/articles/SB980720939804883010> (accessed 21 January 2021).

- 
- Law, Y.-H. 2019, 'Radioactive waste standoff could slash high tech's supply of rare earth elements', *Science*, <https://www.sciencemag.org/news/2019/04/radioactive-waste-standoff-could-slash-high-tech-s-supply-rare-earth-elements> (accessed 22 April 2021).
- Le May, R. 2021, 'Years of struggle ahead for Australian wine producers to replace China as five-year tariff confirmed', *news.com.au*, 29 March, <https://www.news.com.au/finance/business/manufacturing/years-of-struggle-ahead-for-australian-wine-producers-to-replace-china-as-five-year-tariff-confirmed/> (accessed 14 April 2021).
- Leeuwen, H. van and Tillett, A. 2021, 'Italy blocks AstraZeneca vaccine export to Australia', *Australian Financial Review*, 5 March, <https://www.afr.com/politics/federal/italy-blocks-astrazeneca-vaccine-export-to-australia-20210305-p577z4> (accessed 5 June 2021).
- Leigh, A. 2017, *Choosing Openness: A Lowy Institute Paper: Penguin Special: Why global engagement is best for Australia*, Paperback, Penguin.
- Lim-Camacho, L., Crimp, S., Ridoutt, B., Ariyawardana, A., Bonney, L., Lewis, G., Howden, M., Jeanneret, T. and Nelson, R. 2016, *Adaptive Value Chain Approaches: Understanding Adaptation in Food Value Chains*, June, CSIRO, Australia.
- Littleproud, D. 2021, *Biosecurity is Top Priority*, Media Release, 11 February, Canberra.
- Logistics Bureau 2020, *Can Australian Manufacturing be Brought Back Home from China?*, [www.logisticsbureau.com/can-australian-manufacturing-be-brought-back-home-from-china/](http://www.logisticsbureau.com/can-australian-manufacturing-be-brought-back-home-from-china/) (accessed 29 January 2021).
- Lowy Institute 2021, *Covid Performance Index*, <https://interactives.lowyinstitute.org/features/covid-performance/#rankings> (accessed 1 February 2021).
- Lynas Corporation Limited 2019, *Ten Year Extension of JARE Loan Facility*, ASX Announcement, 27 June, Kuantan, Malaysia.
- Lynch, D. 2021a, 'Pandemic aftershocks overwhelm global supply lines', *The Washington Post*, 25 January, <https://www.washingtonpost.com/business/2021/01/24/pandemic-shipping-economy/> (accessed 1 February 2021).
- Lynch, J. 2021b, 'China trade ban paves the way for India as new market for Australian timber', *ABC News*, 1 January, <https://www.abc.net.au/news/2021-01-01/wa-nsw-timber-ban-forces-exporter-to-look-to-india/13024360> (accessed 30 March 2021).
- Mancheri, N.A., Sprecher, B., Bailey, G., Ge, J. and Tukker, A. 2019, 'Effect of Chinese policies on rare earth supply chain resilience', *Resources, Conservation and Recycling*, vol. 142, pp. 101–112.
- Mankiw, N.G. and Whinston, M. 1986, 'Free entry and social inefficiency', *Rand Journal of Economics*, vol. 17, no. 1, pp. 48–58.
- Marsh 2019, *Political Risk Map 2019*, <https://www.marsh.com/au/campaigns/political-risk-map-2019.html> (accessed 1 February 2021).
- 2020, *Political Risk Map 2020: Trade Tensions Threaten Political Stability*, March.
- Martha, J. and Subbakraishna, S. 2002, 'Targeting a just-in-case supply chain for the inevitable next disaster?', *Supply Chain Management Review*, vol. 6, no. 5, pp. 18–23.

- 
- Mawere, M., Mubaya, T., Reisen, M. and van Stam, G. 2016, 'Maslow's theory of human motivation and its deep roots in individualism: Interrogating Maslow's applicability in Africa', *Theory, Knowledge, Development and Politics: What Role for the Academy in the Sustainability of Africa?*, Langaa RPCIG, Bamenda, Cameroon.
- McCloskey, D.N. 2020, *Interview on the Economy and Covid-19 in Brazil*, Interviewed by Francisco de Azeredo for the Brazilian cultural project, May, Porto Alegre, Brazil.
- McKinsey & Company (Alicke and Strigel) 2020a, 'Supply chain risk management is back', 28 January, <https://www.mckinsey.com/business-functions/operations/our-insights/supply-chain-risk-management-is-back#> (accessed 10 September 2020).
- (Lund, Manyika, Woetzel, Bughin, Krishnan, Seong and Muir) 2017, *How CEOs Can Tackle the Challenge of Cybersecurity in the Age of the Internet of Things*, June.
- (Lund, Manyika, Woetzel, Bughin, Krishnan, Seong and Muir) 2019, *Globalization in Transition: The Future of Trade and Value Chains*, January.
- (Lund, Woetzel, Barriball, Krishnan, Alicke, Birshan, George, Smit, Swan, Smit and Swan) 2020b, *Risk, Resilience, and Rebalancing in Global Value Chains*, August.
- (Manyika, Lund, Bughin, Woetzel, Stamenov and Dhingra) 2016, *Digital Globalization: The New Era of Global Flows*, March.
- Melbourne Water 2020, *Drinking Water Treatment*, <https://www.melbournewater.com.au/water-data-and-education/water-facts-and-history/why-melbournes-water-tastes-great/water-treatment> (accessed 16 November 2020).
- Milgrom, P. and Roberts, J. 1992, *Economics, Organization and Management*, 1st edn, Englewood Cliffs.
- Mizen, R. 2020, 'The Australian industries most targeted by hackers', *Australian Financial Review*, 16 September, <https://www.afr.com/politics/federal/the-australian-industries-most-targeted-by-hackers-20200915-p55vq8> (accessed 15 April 2021).
- Moderna, Inc 2020, *United States Securities and Exchange Commission Form 10Q*, Delaware, UK.
- Morrison, S. 2020, *Transcript, 25 January 2021*, Press Conference, Canberra.
- Morton, B. 2021, *Adopting Trusted Overseas Product Safety Standards*, Canberra.
- MTPConnect 2020, *Collaborating in the Public Interest: How Australia's Medical Technology Sector Joined with Government to Fight COVID-19*, Supplementary Report to the MTPConnect COVID-19 Impact Report, June, Australia.
- Mudassir, H. 2021, 'How the world ran out of semiconductors', *The Conversation*, 5 March, <http://theconversation.com/how-the-world-ran-out-of-semiconductors-156532> (accessed 28 April 2021).
- Mullin, R. 2020, 'COVID-19 is reshaping the pharmaceutical supply chain', 27 April, <https://cen.acs.org/business/outsourcing/COVID-19-reshaping-pharmaceutical-supply/98/i16> (accessed 3 February 2021).

- 
- NHMRC and NRMCC (National Health and Medical Research Council and National Resource Management Ministerial Council) 2011, *Australian Drinking Water Guidelines Paper 6 National Water Quality Management Strategy*, Commonwealth of Australia, Canberra.
- Nishiguchi, T. and Beaudet, A. 1997, *Self-Organization and Clustered Control in the Toyota Group: Lessons from the Aisin Fire*, Massachusetts Institute of Technology International Motor Vehicle Program, Tokyo.
- O'Connor, J. and Kirton, D. 2021, 'Vaccine supply row highlights the need to inject certainty into "best efforts" obligations', 5 February, <https://www.williamfry.com/newsandinsights/news-article/2021/02/05/vaccine-supply-row-highlights-the-need-to-inject-certainty-into-best-efforts-obligations> (accessed 16 February 2021).
- OECD (Observatory of Economic Complexity) 2019a, *Crude Petroleum*, <https://oec.world/en/profile/hs92/crude-petroleum> (accessed 27 April 2021).
- 2019b, *Observatory of Economic Complexity*, <https://oec.world/> (accessed 16 February 2021).
- 2019c, *Refined Petroleum*, <https://oec.world/en/profile/hs92/refined-petroleum> (accessed 27 April 2021).
- OECD (Organisation for Economic Co-Operation and Development) 2008, *Public-Private Partnerships: In Pursuit of Risk Sharing and Value for Money*, Paris.
- 2018, *Trade in Value Added*, Paris.
- 2020, 'The face mask global value chain in the COVID-19 outbreak: Evidence and policy lessons', OECD Policy Responses to Coronavirus (COVID-19), Paris.
- OECD-WTO (Organisation for Economic Co-Operation and Development-World Trade Organization) 2021, *OECD Balanced Trade Statistics*, Paris.
- Orica 2020, 'Ammonium Nitrate Q and A', *Community News: Kooragang Island*, no. 3.
- Packham, C. and Barrett, J. 2021, 'Australian timber faces protracted logjam amid China's import freeze', 12 March, <https://www.nasdaq.com/articles/australian-timber-faces-protracted-logjam-amid-chinas-import-freeze-2021-03-11> (accessed 30 March 2021).
- Parliament of Australia 2020a, *Inquiry into Diversifying Australia's Trade and Investment Profile*, [https://www.aph.gov.au/Parliamentary\\_Business/Committees/Joint/Joint\\_Standing\\_Committee\\_on\\_Trade\\_and\\_Investment\\_Growth/DiversifyingTrade](https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Joint_Standing_Committee_on_Trade_and_Investment_Growth/DiversifyingTrade) (accessed 8 April 2021).
- 2020b, *Inquiry into National Security Risks Affecting the Australian Higher Education and Research Sector*, [https://www.aph.gov.au/Parliamentary\\_Business/Committees/Joint/Intelligence\\_and\\_Security/NationalSecurityRisks](https://www.aph.gov.au/Parliamentary_Business/Committees/Joint/Intelligence_and_Security/NationalSecurityRisks) (accessed 26 March 2021).
- 2020c, *Inquiry into the implications of the COVID-19 pandemic for Australia's foreign affairs, defence and trade*, Joint Standing Committee on Foreign Affairs, Defence and Trade, Canberra.
- 2020d, *Senate Select Committee on COVID-19*, [https://www.aph.gov.au/Parliamentary\\_Business/Committees/Senate/COVID-19/COVID19](https://www.aph.gov.au/Parliamentary_Business/Committees/Senate/COVID-19/COVID19) (accessed 5 May 2021).

- 
- PC (Productivity Commission) 2009, *Government Drought Support*, Report no. 46, Canberra.
- 2014a, *Australia's Automotive Manufacturing Industry*, Report no. 70, Canberra.
- 2014b, *Natural Disaster Funding Arrangements - Vol. 1*, Report no. 74, Canberra.
- 2016, *Regulation of Australian Agriculture*, Report no. 79, Canberra.
- 2018, *Trade and Assistance Review 2016-17*, Annual Report Series, Canberra.
- 2019, *Trade and Assistance Review 2017-18*, Annual Report Series, Canberra.
- 2020, *Trade and Assistance Review 2018-19*, Annual Report Series, Canberra.
- Phillips, K. 2014, 'How container shipping changed the world through globalisation', *ABC News*, 20 August, <https://www.abc.net.au/radionational/programs/rearvision/the-big-metal-box-that-changed-the-world/5684586> (accessed 20 February 2021).
- PSA (Pharmaceutical Society of Australia) 2020, *Submission to the Senate Select Committee on Covid-19 Inquiry into the Australian Government's Response to the Covid-19 Pandemic*.
- PwC (Butler and Sorrell) 2020, 'Strengthening Australia's life sciences sector and medical supply chain beyond COVID-19', 23 July, <https://www.pwc.com.au/health/health-matters/strengthening-australias-life-sciences-sector-and-medical-supply-chain-beyond-covid-19.html> (accessed 29 January 2021).
- Rajah, R. 2021, 'Vital trade lessons from China's failed attempt at coercion', *The Australian*, 14 April, <https://www.theaustralian.com.au/commentary/vital-trade-lessons-from-chinas-failed-attempt-at-coercion/> (accessed 14 April 2021).
- Rauch, J. 1999, 'Networks versus markets in international trade', *Journal of International Economics*, vol. 48, no. 1, pp. 7–35.
- RBA (Reserve Bank of Australia) 2019a, *2019 Assessment of the Reserve Bank Information and Transfer System – Material Developments*, <https://www.rba.gov.au/payments-and-infrastructure/rits/self-assessments/2019/material-developments.html> (accessed 6 May 2021).
- 2019b, *Policy Statement on the Supervision and Oversight of Systemically Important Payment Systems*, <https://www.rba.gov.au/payments-and-infrastructure/financial-market-infrastructure/high-value-payments/policy-statement-on-supervision-and-oversight-of-systemically-important-ps.html> (accessed 5 May 2021).
- 2020a, *2020 Assessment of the Reserve Bank Information and Transfer System – Material Developments*, <https://www.rba.gov.au/payments-and-infrastructure/rits/self-assessments/2020/material-developments.html> (accessed 6 May 2021).
- 2020b, *Reserve Bank of Australia Annual Report 2020*, Sydney.
- 2021, *Exchange Rates; Exchange Rates - Daily - 2018 to Current*, Historical Data, [www.rba.gov.au/statistics/historical-data.html#exchange-rates](http://www.rba.gov.au/statistics/historical-data.html#exchange-rates) (accessed 25 May 2021).
- Reynolds, L. and Andrews, K. 2020, *Increasing domestic manufacturing during COVID-19*, Media release, 17 March, Canberra.

- 
- Ritchie, B. and Brindley, C. 2007, 'Supply chain risk management and performance: A guiding framework for future development', *International Journal of Operations and Production Management*, vol. 27, no. 3, pp. 303–322.
- Roberts, B.H. 2018, 'The role of industry clusters in driving innovation and competitiveness of regions', presented at RDA National Forum, Canberra, 16-17 August.
- Rogers, A. 2020, 'Singapore was ready for Covid-19—Other countries, take note', *Wired*, <https://www.wired.com/story/singapore-was-ready-for-covid-19-other-countries-take-note/> (accessed 1 October 2020).
- Ross, A. 2021, 'Health professionals warn Australia is struggling to deal with post-COVID-19 medication shortage', *ABC News*, 19 January, <https://www.abc.net.au/news/2021-01-20/australia-post-coronavirus-medication-shortage/13065076> (accessed 29 January 2021).
- Royal Commission into National Natural Disaster Arrangements 2020a, *Royal Commission into National Natural Disaster Arrangements: Report*, 28 October, Commonwealth of Australia, Canberra.
- 2020b, *Transcript of Proceedings*, Commonwealth of Australia, Canberra.
- Russon, M.-A. 2021, 'The cost of the Suez Canal blockage', *BBC News*, 29 March, <https://www.bbc.com/news/business-56559073> (accessed 29 April 2021).
- Ryall, J. 2018, 'Discovery of rare earth minerals off Japan coast secures 780 years of industrial demand: study', *South China Morning Post*, 12 April, <https://www.scmp.com/news/asia/east-asia/article/2141445/discovery-rare-earth-minerals-japan-coast-secures-780-years> (accessed 10 February 2021).
- 2020, 'Japan moves to secure rare earths to reduce dependence on China', *South China Morning Post*, 17 August, <https://www.scmp.com/week-asia/politics/article/3097672/japan-moves-secure-rare-earths-reduce-dependence-china> (accessed 10 February 2021).
- Sanchanta, M. 2011, 'Chemical reaction: iPod is short key material', *The Wall Street Journal*, 29 March, <https://www.wsj.com/articles/SB10001424052748704471904576228390400576486> (accessed 15 October 2020).
- Saunders, I. 2020, 'Recalibrating international trade in the COVID-19 age', Australian National University, Canberra, 29 April, <https://law.anu.edu.au/research/essay/covid-19-and-international-law/recalibrating-international-trade-covid-19-age> (accessed 21 January 2021).
- Schmid, M. 2019, 'Mitigating supply risks through involvement in rare earth projects: Japan's strategies and what the US can learn', *Resources Policy*, vol. 63, art. 101457.
- Science and Industry Endowment Fund 2020, *Boat to Plate*, <https://sief.org.au/nicta-gift/future-national-ict-industry-platform-program/digital-mission-supply-chain-integrity/boat-to-plate/> (accessed 15 February 2021).
- SCM World 2016, *Future of Supply Chain 2016*, November, London, UK.
- 2017, *Future of Supply Chain 2017*, October, London, UK.
- Shen, Y., Moomy, R. and Eggert, R.G. 2020, 'China's public policies toward rare earths, 1975–2018', *Mineral Economics*, vol. 33, pp. 127–151.

- 
- Slowinski, G., Latimer, D. and Mehlman, S. 2013, 'Research-on-research: dealing with shortages of critical materials', *Research Technology Management*, vol. 56, pp. 18–24.
- Smee, B. 2020, 'Scott Morrison calls for calm as coronavirus prompts panic buying at supermarkets', *The Guardian*, 2 March, <https://www.theguardian.com/world/2020/mar/03/scott-morrison-calls-for-calm-as-coronavirus-prompts-panic-buying-at-supermarkets> (accessed 27 April 2021).
- Snowdon, A., Saunders, M. and Wright, A. 2021, 'Key characteristics of a fragile healthcare supply chain: Learning from a pandemic', *Healthcare Quarterly*, vol. 24, no. 1, pp. 36–43.
- Stackpole, B. 2020, '5 supply chain technologies that deliver competitive advantage', 14 February, <https://mitsloan.mit.edu/ideas-made-to-matter/5-supply-chain-technologies-deliver-competitive-advantage> (accessed 29 January 2021).
- Stanford, J. 2020, *A Fair Share for Australian Manufacturing: Manufacturing Renewal for the Post-COVID Economy*, July, The Centre for Future Work at the Australia Institute, Canberra.
- Stangarone, T. 2020, 'South Korea's struggle to bring manufacturing home', *The Diplomat*, 14 September, <https://thediplomat.com/2020/09/south-koreas-struggle-to-bring-manufacturing-home/> (accessed 7 June 2021).
- Statista 2020, *Taiwan's Share in the Global Semiconductor Market in 2013 and 2017, by Operation*, <https://www.statista.com/statistics/1037531/taiwan-global-semiconductor-market-share-by-operation/> (accessed 22 February 2021).
- Stecke, K.E. and Kumar, S. 2009, 'Sources of supply chain disruptions, factors that breed vulnerability, and mitigating strategies', *Journal of Marketing Channels*, vol. 16, no. 3, pp. 193–226.
- Sui, C. 2021, *Why the world should pay attention to Taiwan's drought*, BBC News, <https://www.bbc.com/news/world-asia-56798308> (accessed 2 July 2021).
- Sullivan, K. 2020a, 'China's ban on Australian beef costing hundreds of millions and putting people out of work', *ABC News*, 9 December, <https://www.abc.net.au/news/2020-12-09/china-bans-cost-meat-industry-hundreds-of-millions/12961538> (accessed 23 March 2021).
- 2020b, 'China's list of sanctions and tariffs on Australian trade is growing. Here's what has been hit so far', *ABC News*, 17 December, <https://www.abc.net.au/news/2020-12-17/australian-trade-tension-sanctions-china-growing-commodities/12984218> (accessed 23 March 2021).
- and Barbour, L. 2020, 'Australian cotton the latest casualty in trade tensions with China', *ABC News*, 19 October, <https://www.abc.net.au/news/2020-10-16/china-disrupts-australian-cotton-trade/12771114> (accessed 23 March 2021).
- , Dziedzic, S. and Birtles, B. 2020, 'Fears more trade bans to come as China halts imports of Australian timber, lobsters, barley', *ABC News*, 3 November, <https://www.abc.net.au/news/2020-11-03/china-broadens-trade-war-against-australian-imports/12841142> (accessed 23 March 2021).
-

- 
- and Gunders, J. 2020, ‘Red-meat processors have beef sales to China suspended as trade barriers escalate’, *ABC News*, 12 May, <https://www.abc.net.au/news/rural/2020-05-12/china-trade-escalation-as-beef-farmers-are-targeted/12237468> (accessed 30 June).
- SWIFT 2014, *Reducing Risk and Increasing Resilience in RTGS Payment Systems*, May, Belgium.
- and BAE Systems 2018, *The Evolving Advanced Cyber Threat to Financial Markets*, Belgium and UK.
- Tan, Y.X.T., Moles, R.J. and Char, B.B. 2016, ‘Medicine shortages in Australia: Causes, impact and management strategies in the community setting’, *International Journal of Clinical Pharmacy*, vol. 38, pp. 1133–1141.
- Tang, C. 2006, ‘Robust strategies for mitigating supply chain disruptions’, *International Journal of Logistics: Research and Applications*, vol. 9, no. 1, pp. 33–45.
- TGA (Therapeutic Goods Administration) 2020a, *Annual Performance Statistics Report 2019-20*, Canberra.
- 2020b, *Regulator Performance Framework Self-assessment report July 2019 to June 2020*, Canberra.
- 2020c, *TGA response to coronavirus (COVID-19)*, Media release, August.
- 2021a, *Building a More Robust Medicine Supply: Proposals to Help Prevent, Mitigate and Manage Medicine Shortages*, Canberra.
- 2021b, *Explanatory Statement - Therapeutic Goods Act 1989: Therapeutic Goods Administration (Medicines - Standard for Serialisation and Data Matrix Codes) (TGO 106) Order 2021*, 25 March, Canberra.
- The Economist 2020, ‘What’s the worst that could happen? The world should think better about catastrophic and existential risks’, *The Economist*, 25 June, <https://www.economist.com/briefing/2020/06/25/the-world-should-think-better-about-catastrophic-and-existential-risks> (accessed 23 September 2020).
- The White House 2021, *Biden-Harris Administration Announces Supply Chain Disruptions Task Force to Address Short-Term Supply Chain Discontinuities*, Fact sheet, 8 June, Washington, DC.
- Thompson, B. 2020, ‘Twiggy’s \$212m virus bill is paid off and saving lives’, *Australian Financial Review*, 21 August, <https://www.afr.com/politics/twiggy-s-212m-virus-bill-is-paid-off-and-saving-lives-20200821-p55nvn> (accessed 3 June 2021).
- Timmer, M.P., Erumban, A.A., Los, B., Stehrer, R. and Vries, G.J. de 2014, ‘Slicing up global value chains’, *Journal of Economic Perspectives*, vol. 28, no. 2, pp. 99–118.
- Tomlin, B. 2006, ‘On the value of mitigation and contingency strategies for managing supply chain disruption risks’, *Management Science*, vol. 52, no. 5, pp. 639–657.
- Tomy, R.E. 2020, *Short-Term Cash Flow Shocks and R&D Investment: Evidence from the 1999 Taiwan Earthquake*, 6 October, SSRN.

- 
- Tourism Research Australia 2021, *International Visitor Survey Results December 2020*, [www.tra.gov.au/data-and-research/reports/international-visitor-survey-results-december-2020/international-visitor-survey-results-december-2020](http://www.tra.gov.au/data-and-research/reports/international-visitor-survey-results-december-2020/international-visitor-survey-results-december-2020) (accessed 31 March 2021).
- Treasury Wine Estates 2020, *Provisional measure to be implemented on Australian wine imports into China*, ASX Announcement, 30 November, Melbourne.
- UK MHRA (UK Medicines and Healthcare products Regulatory Agency) 2017, *Medicines and Healthcare Products Regulatory Agency International Strategy*, UK Government.
- UN ESCAP (UN Economic and Social Commission for Asia and the Pacific) 2020, *COVID-19 and its Impact on Shipping and Port Sector in Asia and the Pacific*, Technical Note, 30 September.
- UN (United Nations) 2020, *UN Comtrade Database*, <http://comtrade.un.org/> (accessed 10 September 2020).
- Unilever 2020, *Unilever's Supply Chain*, May.
- U.S DoJ and FTC (US Department of Justice and Federal Trade Commission) 2010, *Horizontal Merger Guidelines*, <https://www.justice.gov/atr/horizontal-merger-guidelines-08192010> (accessed 19 January 2021).
- US FDA (US Food and Drug Administration) 2019, *Drug Shortages: Root Causes and Potential Solutions*, US.
- Vakil, B. and Linton, T. 2021, 'Why we're in the midst of a global semiconductor shortage', *Harvard Business Review*, 26 February, <https://hbr.org/2021/02/why-were-in-the-midst-of-a-global-semiconductor-shortage> (accessed 15 April 2021).
- WBCSD (World Business Council for Sustainable Development) 2015, *Building Resilience in Global Supply Chains*, December.
- WEF (World Economic Forum) 2020, *The Global Risks Report 2020*, Insight Report, 15 January, 15th Edition, Switzerland.
- Westcott, B. 2021, 'How China is devastating Australia's billion-dollar wine industry', *CNN Business*, 18 February, <https://edition.cnn.com/2021/02/16/business/australia-china-wine-tariffs-dst-intl-hnk/index.html> (accessed 14 April 2021).
- Wine Australia 2021, *Export Market Guide - United States*, <https://www.wineaustralia.com/selling/by-market/export-market-guide-united-states> (accessed 4 May 2020).
- WITS (World Integrated Trade Solution) 2021, *Australia Trade Statistics*, <https://wits.worldbank.org/CountryProfile/en/AUS#> (accessed 19 February 2021).
- Wood, R. 2021, 'Fears for future of rock lobster fishing industry as China ban bites', *9news*, 25 February, <https://www.9news.com.au/national/china-trade-sanctions-bans-hitting-australian-rock-lobster-industry> (accessed 14 April 2021).
- WTO (World Trade Organisation) 2020a, *Export Prohibitions and Restrictions*, Information note, 23 April, Geneva, Switzerland.

- 
- (World Trade Organisation) 2020b, *Report on G20 Trade Measures (Mid-May 2020 to Mid-October 2020)*, Geneva, Switzerland.
- Yang, B., Aydin, G., Babich, V. and Beil, D.R. 2009, ‘Supply disruptions, asymmetric information and a backup production option’, *Management Science*, vol. 55, no. 2, pp. 192–209.
- Yang, Z. 2009, *Supply Risks and Asymmetric Information*, PhD Dissertation, University of Michigan.
- Yu, S. and Sevastopulo, D. 2021, ‘China targets rare earth export curbs to hobble US defence’, *Australian Financial Review*, 16 February, <https://www.afr.com/world/asia/china-targets-rare-earth-export-curbs-to-hobble-us-defence-20210216-p5732h> (accessed 26 April 2021).
- Zsidisin, G.A. and Ritchie, B. 2009, ‘Supply Chain Risk Management – Developments, Issues and Challenges’, *Supply Chain Risk: A Handbook of Assessment, Management, and Performance*, Springer.