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The Australian Multi-Factor Productivity Growth Illusion

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Abstract

Over the past decade, Australian multi-factor productivity growth has been predominantly negative, often leading to the view that there is a 'productivity problem'. It is shown that it is not a useful measure and is thus misleading. Exploratory econometric investigations suggest that economies of scale are the primary drivers of productivity growth. However, more research needs to be undertaken to understand the determinants of these economies of scale before any new policy to promote productivity growth is designed. There needs to be greater understanding of the underlying process of innovation that gives rise to economies of both scale and scope.

1. Introduction

There is a prevailing view in media commentaries that Australia's productivity growth is poor by international standards. This is usually based upon multi-factor productivity growth (MFPG) estimates produced by the Productivity Commission (PC) and the Australian Bureau of Statistics (ABS). The MFPG is the calculated residual growth once the contributions of labour and capital inputs are taken into account. Estimated MFPG has been negative in most years since 2002. This has resulted in discussions concerning appropriate policies aimed at increasing productivity. A few years ago, there were pleas for a stronger and better-targeted innovation policy (Cutler 2008) to address this perceived problem and these did lead to policy changes in 2009. However, more recently, there have been calls from the business community for cuts in the wages of low-income employees to address the productivity problem. However, it is not at all clear what this has to do with stimulating productivity growth because lower wages discourage the shift from labour to the services of capital goods, which embody technical innovation and thus raise productivity.

The notion that there is a problem with productivity is something of a puzzle because average labour productivity growth from 2011 to 2013 reached a rate not seen since the 1990s. A further puzzle lies in the estimates of capital productivity growth, as reported by the PC (2013). They have been negative for a decade, with the level of measured capital productivity in 2013 about 20 per cent lower than it was back in 1990. Commentators have pointed to two possible explanations of these puzzles. First, it has been argued that large capital investments, mainly in the mining sector, have taken a long time to have their full effect on gross domestic

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product (GDP). However, the decline in capital productivity, as reported by the PC, was occurring well before the mining investment boom gathered pace. Second, some have argued that there has been a widespread failure by management to invest in and use capital goods effectively (Bloom et al. 2012). This is related to a broader argument that Australia has been relatively poor at innovation, in comparison with other Organisation for Economic Co-operation and Development (OECD) countries (Cutler 2008) and that this is reflected in the observation of negative MFPG. But how realistic is it to suppose that, over the past decade, Australians have been both bad at investing in capital goods and so bad at innovating that MFPG has been negative? This all seems counterintuitive in an economy with one of the OECD's strongest growth records and the absence of a recession for 22 years.

Can we really draw any inferences, as does Parham (2013), from the estimates of MFPG produced by the ABS and employed by the PC in its regular *Productivity Updates*? The PC fully acknowledges that there are problems with the methodology that is applied (see PC 2013).[1] However, this does not prevent it from publishing estimates of MFPG, not only for GDP but also for 16 different industries. Since these estimates set the scene for national discussions concerning policies to stimulate productivity, it is very important to establish that they are robust.

The goals of this article are straightforward: (i) the validity of the ABS/PC methodology is assessed; (ii) using a very simple approach, evidence is provided that supports the hypothesis that Australia has been enjoying economies of scale, rather than MFPG as measured; and (iii) conclusions are drawn concerning the implications of these findings for policy-making.

2. Estimates of Multi-Factor Productivity Growth: Where Do They Come From?

Both the ABS and the PC use estimates of MFPG that are a product of 'growth accounting'. This is explained clearly in PC (2013). What is not made clear is the set of very restrictive assumptions that are made to obtain such estimates. The methodology used can be traced back to Solow (1957) and builds upon the notion that an aggregate production function exists that includes capital and labour inputs. The production function posited by the ABS contains the net capital stock as a proxy for the flow of capital services and labour hours as a proxy for the flow of labour services. Importantly, this aggregate production function is assumed to be of the Cobb–Douglas form, with all firms profit-maximising and in perfect competition. This means that factors of production are paid the 'value of their marginal products' which, in turn, means that the exponents on capital and labour in the aggregate production function must sum to one (see ABS 2007). These assumptions, plus some very unrealistic ones concerning the aggregation of inputs and outputs from micro to macro, enable the observed profit and wage shares of GDP to be equated with the exponents on the capital stock and labour hours; that is, the values of their marginal factor products, respectively, in a Cobb–Douglas specification of the following form:

$$Y_t = Ae^{\lambda T}.K_t^{\alpha}.L_t^{1-\alpha}.u_t \tag{1}$$

where Y_t is GDP in period t, K_t is the capital stock in period t, L_t is total labour hours in period t, T is time and u_t is the unexplained residual period t.

In each time period, $Ae^{\lambda T}.\underline{u_t}$ is measured as an accounting residual, defined here as B_t:

$$Y_t = B_t.K_t^{\alpha}.L_t^{1-\alpha} \tag{2}$$

Re-expressing in rates of growth:

$$dlnY_t = dlnB_t + \alpha dlnK_t + (1-\alpha)dlnL_t \tag{3}$$

where d denotes a first difference and ln denotes a natural logarithm. If α and $(1-\alpha)$ are assumed to be equal to aggregate profit and wage shares, respectively, then it is elementary to calculate $dlnB_t$, which is MFPG in any year.

In reality, none of the restrictive assumptions made hold, especially when we are dealing with the long periods over which economic growth is studied. However, it is commonly argued that the methodology provides a useful approximation. This reflects an 'instrumentalist' perspective on methodology: useful theory need not be realistic if the goal is prediction rather than explanation. Indeed, there is no 'explanation' involved in the estimation of MFPG as a residual in a growth accounting exercise. But, the resultant empirical estimates are not used for prediction either, so it is not clear what the purpose is of the exercise. Prediction would require that time series modelling be undertaken, but neither the ABS (2007) nor the PC (2013) offers econometric evidence, using historical data, that supports the restrictive Cobb–Douglas growth model applied.

It is clear that the calculation of MFPG depends heavily upon the three central assumptions: constant returns to scale; the presence of perfect competition; and tractable aggregation from microeconomic production theory to macroeconomic production function.[2] The fundamental nature of these unrealistic assumptions tends to be understated and loosely discussed. For example, on page 5 of PC (2013), it is asserted that some of MFPG can be attributed to 'economies of scale'. But, this does not make sense. It is well known that economies of scale imply that the exponents on capital and labour must sum to greater than one but, in growth accounting, they are constrained to sum to one. So, if there are, indeed, economies of scale but a constant-return-to-scale Cobb–Douglas production function is assumed in order to use factor income shares, then the estimates of MFPG must, by definition, be incorrect.[3]

Indeed, negative estimates of MFPG from about 2002 on, reported in, for example, PC (2013), are likely to be in error because they imply that technical innovations, plus a range of other forms of innovation over the past decade, have had *negative* impacts on economic growth. This is very hard to believe. Furthermore, the observed large fall in 'capital productivity' is also counterintuitive. It may well be true that some gestation lags in capital investments in the natural resources sector have been factors in lowering it but, as noted above, the decline occurred before the mining investment boom. Typically, new capital goods are increasingly productive, as new variants come on the market over time. Also, they generally replace old capital goods that are less productive. So, falling capital productivity implies that there has been serious mismanagement of physical capital in productive organisations. This seems very unlikely, despite apocryphal tales about firms buying computers and not knowing what to do with them! It is much more likely that there is a fundamental error in the methodology used to derive productivity growth estimates. This we can examine quite simply.

3. A Simple Test of the Validity of Multi-Factor Productivity Growth Estimates

On page 4 of PC (2013), the standard Solow–Swan growth model, with factor shares of GDP replacing Cobb–Douglas exponents, is specified as in equation (2) above. In each year, the growth accounting identity is used to calculate MFPG. However, the exact calculations made by the PC and ABS are not provided. However, a good example of how it is done is provided in DCITA (2005), in which two sets of estimates of multi-factor productivity for the period 1965–2004 are provided: those of the ABS (MFPG) and those constructed by Erwin Diewert and Denis Lawrence (total factor productivity growth, TFPG). Measures of the capital stock and labour hours used are also provided.

Now, with this complete dataset, we can estimate equation (2) econometrically if we add an error term. Since an aggregate Cobb–Douglas production function was used in the DCITA (2005) study to compute TFPG in each year, the sum of the estimated coefficients on K and L should be close to unity and that on the DCITA estimate of TFPG should also be close to unity. Of course, an exact identity will not exist because the accounting exercise applied yields different coefficients for α and $(1-\alpha)$ in each year. Econometric estimation using time series data can discover average values of these coefficients, with variations consigned to the statistical error term, as is usual in regression

Table 1 Testing Diewert and Lawrence Estimates of Total Factor Productivity Growth (TFPG)

Variable	*Coefficient*	*Standard error*	t-*statistic*	*Probability*
$dlnK_t$	0.271	0.002	108.59	0.000
$dlnL_t$	0.729	0.004	199.79	0.295
$TFPG_t$	0.998	0.002	412.99	0.000
R^2	0.999	Mean dependent variable		0.037
Adjusted R^2	0.999	Standard dependent variable		0.025
Durbin–Watson statistic	0.886			

Notes: Sample (adjusted): 1966–2004 (39 observations). Dependent variable: $dlnY_t$.

analysis. Since it is presumed in such exercises that technical progress is 'Hicks-neutral', there must be no embodied technical change in capital or labour that shifts these coefficients.

It is clear from Table 1 that we are, indeed, dealing with an identity in each year, with the estimated coefficients on the growth in the capital stock and labour hours summing to unity and the coefficient on TFPG also unity over the whole period. It is not a perfect fit because of accounting variations of α and $(1-\alpha)$ in each year.

Now, it is claimed in DCITA (2005) that the estimates of TFPG provided are an improvement on the prior MFPG estimates made by the ABS. To see how much difference this makes, MFPG is substituted for TFPG in our regression of equation (2). We can see in Table 2 that this substitution results in the complete collapse of the estimated relationship. This implies that there is no correspondence between these estimates, both drawn from growth accounting exercises. Indeed, when TFPG and MFPG are regressed on each other, the R^2-value is only 0.036.

The total lack of correspondence of these two measures of MFPG calls into question their usefulness in understanding productivity growth starting with accounting identities and strong assumptions concerning the Cobb–Douglas form of the aggregate production function and the existence of perfect competition. Interestingly, the growth of the capital stock remains significant but introducing a constant, as should be done when the R^2-value is negative, removes all its statistical significance. Only the constant, which indicates the existence of a time trend in levels, is significant and the R^2-value is only 0.043.

In publications by the PC, in general discourse in the media and amongst policymakers, MFPG is viewed as a solid and reliable indicator of productivity growth. The simple regression results presented here suggest that estimates of MFPG, using standard growth accounting methods, may be problematic and thus it would be inadvisable to base policies upon them without further research.

4. Are There Really Constant Returns to Scale?

In PC (2013), it is suggested that economies of scale may play a role in determining economic growth but, as pointed out above, the growth accounting method used cannot identify them.

Table 2 Testing Australian Bureau of Statistics Estimates of Multi-Factor Productivity Growth (MFPG)

Variable	*Coefficient*	*Standard error*	t-*statistic*	*Probability*
$dlnK_t$	0.862	0.148	5.83	0.000
$dlnL_t$	0.173	0.234	0.74	0.465
$MFPG_t$	–0.102	0.199	–0.51	0.610
R^2	–0.069	Mean dependent variable		0.037
Adjusted R^2	–0.129	Standard dependent variable		0.025
Durbin–Watson statistic	2.166			

Notes: Sample (adjusted): 1966–2004 (39 observations). Dependent variable: $dlnY_t$.

Diewert and Fox (2008) addressed this issue in context of the United States and found strong evidence that economies of scale are much more important than MFPG. In other words, constant returns to scale were found not to be in evidence so the assumption of perfect competition could not be supported. With regard to the latter, they presumed that imperfect competition with mark-up pricing existed, which was much more realistic.

Without departing very far from equation (2), we can begin to explore, in a preliminary way, if Australia might be similar. If increasing returns to scale exist then, in equation (2), the estimated coefficients on the growth of labour hours and the capital stock should sum to greater than unity, but Table 2 seems to suggest that there is very little to discuss in this regard when estimating in growth rates. However, it is possible that the very low correlation observed stems from measurement problems. In this regard, there has been an ongoing debate concerning the most appropriate measure of GDP growth to use in econometric research. Snooks (1994) argued that the available ABS estimates, such as those used in the DCITA (2005) study, are incomplete, particularly when we go further back in history, because of the omission of components of production and consumption flows that are not explicitly valued in monetary terms.[4] Such measurement errors can have a particularly marked effect on growth data, so it is useful to construct a sample of GDP data using data of Snooks (1994) up to 1990 and data of ABS for the remaining 14 years, when the measurement errors are likely to be less of a problem.

In Table 3 we can see that, when equation (1) is estimated in growth form, without restricting the exponents to adding up to one, this alternative measure of GDP growth ($dlnY_s$) can be explained by both labour hours' growth and growth in the capital stock, which are significant at the 5 per cent and 10 per cent levels, respectively. It is striking that, with the estimated coefficients on the growth in K and the growth in $\boldsymbol{L}$ summing to 1.48, there is support for the hypothesis that economies of scale are present. The λ term is insignificant, so there is no sign of a statistically significant MFPG effect, although this cannot be ruled out given that the residual errors are serially correlated.

There are two potential problems with the specification estimated in Table 3. First, concerns have already been expressed about using an aggregate measure of the capital stock as a proxy for the flow of capital services. It can be argued that a better proxy for the flow of capital services is the flow of total energy consumed (E) in the economy.[5] Second, the specification is static. It has been widely acknowledged that there is a significant ongoing delay before the full impact of capital investment is felt on economic growth. This is less likely in the case of increases in labour hours but training and learning from experience, particularly using new kinds of capital goods, do take time. A simple way of allowing for delay is to add two lagged explanatory variables in each case and then engage in 'general-to-specific' estimation to obtain a parsimonious representation. The results of these respecifications are reported in Table 4.

This is a much stronger result, with growth in energy consumption entering with a 2-year delay.[6] This is consistent with historical

Table 3 Estimates of Cobb–Douglas Production Function, Growth Form

Variable	*Coefficient*	*Standard error*	t-*statistic*	*Probability*
λ	–0.002	0.017	–0.14	0.892
$dlnK_t$	0.774	0.440	1.76	0.087
$dlnL_t$	0.707	0.263	2.70	0.011
R^2	0.254	Mean dependent variable		0.039
Adjusted R^2	0.212	Standard dependent variable		0.033
F-statistic	6.128	Durbin–Watson statistic		1.171

Notes: Sample (adjusted): 1966–2004 (39 observations). Dependent variable: $dlnY_{st}$.

Table 4 Estimates of Cobb–Douglas Production Function with Energy as Input

Variable	*Coefficient*	*Standard error*	t-*statistic*	*Probability*
λ	0.002	0.010	0.24	0.814
$dlnE_{t-2}$	0.724	0.245	2.96	0.006
$dlnL_t$	0.893	0.242	3.69	0.001
R^2	0.375	Mean dependent variable		0.038
Adjusted R^2	0.339	Standard dependent variable		0.034
F-statistic	10.222	Durbin–Watson statistic		1.002

Notes: Sample (adjusted): 1968–2004 (37 observations). Dependent variable: $dlnY_{st}$.

experience in, for example, the mining sector where increases in capital services, applied in the course of capital investment projects, do not yield their full output growth benefits immediately.[7] Again, strong economies of scale are recorded, with the estimated coefficients on energy consumption and labour hours' growth summing to 1.62. There is no indication of any MFPG effect but, again, there is evidence that serial correlation is present.

Serial correlation can be indicative of slow adjustment when an exogenous shock moves GDP from one equilibrium state to another. This can be captured by a simple partial adjustment model, whereby a lagged dependent variable is added to the growth equation estimated in Table 4. The results are presented in Table 5.[8] Because of the presence of a lagged dependent variable, the Breusch–Godfrey Serial Correlation Test was applied and no evidence of serial correlation was found.

We can see from Figure 1 that the model fits well and the coefficients were found to be very stable when estimated recursively. After allowing for full adjustment, the sum of the estimated coefficients on the growth in energy consumption and labour hours is 1.5. So, once again, the evidence supports the hypothesis that strong economies of scale are present. There is no evidence that MFPG exists: the constant is insignificant and there is support for the hypothesis that the residual errors are random.

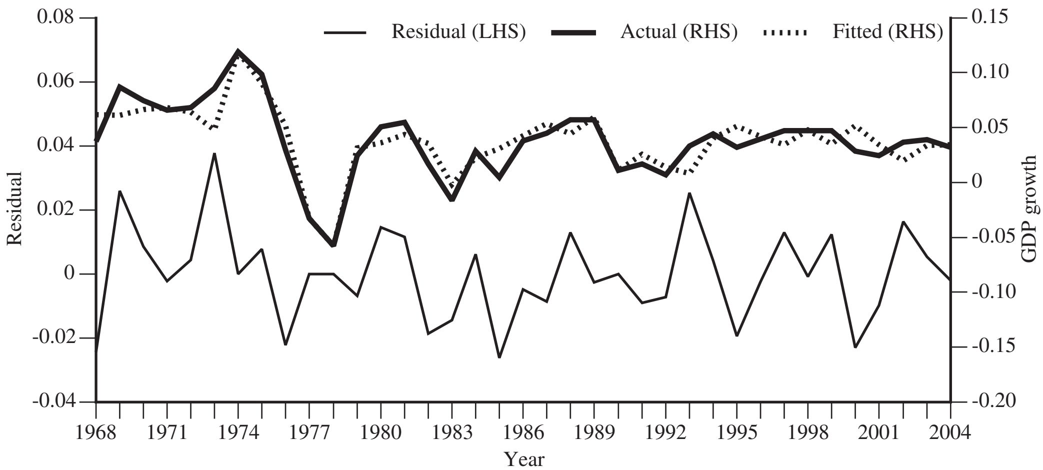
So, this evidence suggests that MFPG, as defined by the ABS and the PC, was not the driver of Australian economic growth from 1965 to 2004. This is in line with the findings of Diewert and Fox (2008) for the United States. So, although much more detailed research is clearly required, it has been quite easy to produce evidence that economies of scale are important in determining Australia's economic growth.[9] In any growing economy that has an

Table 5 Estimates of Cobb–Douglas Production Function, Dynamic Form

Variable	*Coefficient*	*Standard error*	t-*statistic*	*Probability*
$c\lambda$	0.006	0.007	0.99	0.329
$dlnE_{t-2}$	0.441	0.152	2.91	0.007
$dlnL_t$	0.606	0.158	3.84	0.000
$dlnY_{st-1}$	0.309	0.091	3.38	0.002
D1974	0.049	0.017	2.85	0.080
D1977	–0.055	0.017	–3.22	0.003
D1978	–0.064	0.018	–3.60	0.001
D1990	–0.049	0.017	–2.91	0.080
R^2	0.811	Mean dependent variable		0.038
Adjusted R^2	0.766	Standard dependent variable		0.034
F-statistic	17.814	Durbin–Watson statistic		2.128
Breusch–Godfrey Serial Correlation LM Test				
F-statistic	1.319	Probability $F(2,27)$		0.284
Observation × R^2	3.293	Probability $\chi^2(2)$		0.193

Notes: Sample (adjusted): 1968–2004 (37 observations). Dependent variable: $dlnY_{st}$.

Figure 1 Actual-to-Predicted Plots (for Table 5)



imperfectly competitive industrial structure, we should expect to observe increasing returns to scale. However, there is no attempt here to explain why economies of scale exist.

5. Conclusions

There has been much recent discussion of Australia's supposed poor productivity performance, based upon estimates of MFPG. It has been argued here that such estimates are invalid. The evidence suggests that, instead, economies of scale are likely to have been driving Australian economic growth. All three of the simple econometric exercises conducted here suggest that 1 per cent increases in the flow of capital services and labour services result in about a 1.5 per cent increase in GDP.

So, it could be argued that, in contrast to the rather bleak conclusions drawn from MFPG estimates, relatively high rates of labour productivity growth in recent years have been made possible by well-managed investments in capital goods, accompanied by a workforce that has been able to up-skill to take advantage of the capabilities of new capital goods; in particular, computers of all kinds that have enabled massive increases in network connections in the economic system and consequent scale advantages. This has resulted in increases in both wages and profits, with a secular shift in the share of GDP towards the latter. Recently, and outside the period we have been looking at here, this has all occurred in the face of a very high Australian dollar. Also, of course, it is the pressure imposed by the high currency that has led to pleas by some industrial groups for government to enact policies that lower wage costs, purportedly to raise productivity. Yielding to such pressure would be a serious mistake since it would encourage increases in labour intensity in production and provide a disincentive to innovate through capital investment strategies (Dodgson et al. 2011).

From a policy perspective, an economy enjoying economies of scale must be treated differently to one where it is presumed that disembodied Hicksian technical progress is the dominant driver of economic growth. Economies of scale arise because, as inputs of capital and labour increase, there are parallel increases in the quality of products, while unit costs often fall significantly as production volumes and sales increase. It is necessary to view economic growth as the outcome of a developmental process that involves parallel increases in organisation and complexity (Hausmann and Hidalgo 2011). As scale increases, the network structure of the economy expands and the range of goods and services provided increases. This increase in diversity leads to increases in value added across the whole economy. This is particularly true in the service sector, where variety has increased massively as the size of the sector has grown. Much of this 'qualitative' productivity growth is not adequately measured and thus is not fully reflected in MFPG calculations. This is acknowledged in PC (2014, p. 38), even in manufacturing. In relation to small-scale bakeries, it is noted that 'the higher quality … may not be fully reflected in the measures of real value added growth for the subsector, given the challenges in measuring quality'.

Although the findings here are robust, there is no attempt to explain the actual determinants of the economies of scale that have been observed at the aggregate level. Therefore, these findings should be viewed as providing a stimulus for a new research program. It is essential that more research is undertaken to understand the processes that give rise to economies of scale at the aggregate level before designing any new policy to enhance productivity growth. Thomson and Webster (2013) point clearly in the direction that research should go: it is the interconnected processes of innovation and entrepreneurship that are the ultimate drivers of productivity growth and therefore these should be at the core, not the periphery, of economic studies in this field (Banerjee 2012; Foster 2014). To this end, it would be a good time for the PC to reassess the value of producing estimates of MFPG using the standard OECD accounting methodology and to engage fully in this new research program.

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Appendix 1: Data Sources

Gross Domestic Product

The annual GDP series from 1965 to 1990 are taken from Snooks (1994, p. 181, Table 7.9). The remaining 14 years of data are obtained from the ABS's national accounts, given in current prices but converted to constant prices by chaining the relevant ABS deflator with the Snooks (1994) deflator.

Capital Stock

The annual capital stock index used is taken from DCITA (2005, p. 15, Table 1).

Labour

The annual total labour hours index used is taken from DCITA (2005, p. 15, Table 1).

Energy

The *BP Statistical Review of World Energy* contains annual data on the production and consumption of energy of various kinds in Australia since 1965, courtesy of the International Energy Agency.

Multi-Factor Productivity Growth

The ABS multi-factor productivity and Diewert–Lawrence total factor productivity estimates are drawn from DCITA (2005, p. 15, Table 1).

Endnotes

1. What the PC does not discuss is the validity of its methodology, given the widely acknowledged problems, both theoretically and empirically, involved in using an aggregate measure of capital (Cohen and Harcourt 2003). It is notable that Phelps Brown (1957) raised many of these methodological issues just after Robert Solow published his seminal work on economic growth. However, outside University of Cambridge, this had little impact.

2. See Felipe and McCombie (2013) for an extended discussion of the problems of measuring technical change using aggregate production functions and see Harcourt (2007) for discussion of the econometric issues that arose out of the Cambridge Capital Theory Controversy.

3. A defence that the PC can offer is that its methodology conforms to the accepted international standard for calculating MFPG as laid out in, for example, OECD (2001). See Koutsogeorgopoulou and Barbiero (2013) for a recent OECD study of Australian productivity growth using this methodology.

4. Snooks (1994) argued that household non-market production, in particular, is a serious omission in the measurement of GDP, particularly in an era when female participation in the labour force increased strongly. So, in the DCITA (2005) sample, an underestimate is likely to be a bigger problem early in the sample. Gradually, household services became more capital-intensive, releasing female labour into the market sector, where productivity became measured in monetary terms.

5. Salter (1960, 1965) was a strong Australian critic of the use of aggregate measures of the capital stock. He argued that we are dealing with a historical process, whereby

aggregate output flows derive from flows of inputs and technical progress is embodied in new additions to the capital stock. See Foster (2014) for extended discussion of why energy consumption can be used as a measure of the flow of capital services and why the capital stock is best viewed as a repository of technical knowledge.

6. This lag in the impact of energy growth is consistent with the findings of Wei et al. (2012).

7. As a check, the growth in the capital stock was retained in the general specification with two lags but was not found to be statistically significant.

8. Four impulse dummies, for 1974, 1977, 1978 and 1990, were included to correct for potential outlier bias. These were identified in actual-to-predicted plots and from Chow test statistics derived from recursive estimation results.

9. When the database is extended beyond that published in DCITA (2005), up to 2008 (that is, prior to the Global Financial Crisis), the estimated model remains stable, with the estimated coefficients on the growth of labour hours and energy consumption once again summing to around 1.5.

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