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Employment, Investment, Inflation and Productivity: Decisions by the Firm

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This document is based on the research and development work undertaken in recent years in the Modelling Section of the Treasury. It has been released in the interests of evaluating the research results embodied in the model and to encourage public discussion.

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This document is one of a series presented at the June 1993 Treasury Conference on *The TRYM Model of the Australian Economy*. The full set of papers presented at the conference are listed below.

- *An Introduction to the Treasury Macroeconomic (TRYM) Model of the Australian Economy*

  (TRYM Paper No.1)

- *Documentation of the Treasury Macroeconomic (TRYM) Model of the Australian Economy*

  (TRYM Paper No. 2)

- *Employment, Investment, Inflation and Productivity: Decisions by the Firm*

  (TRYM Paper No. 3)

- *Exports, Imports and the Trade Balance*

  (TRYM Paper No. 4)

- *Savings, Dwelling Investment and the Labour Market: Decisions by Households*

  (TRYM Paper No. 5)

- *Australia's Trade Linkages with the World*

  (TRYM Paper No. 6)

- *The Macroeconomic Effects of Higher Productivity*

  (TRYM Paper No. 7)

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1 INTRODUCTION

Issues concerning the supply side play an important part in economists' understanding of the economy. In the TRYM model, considerable attention is devoted to the relationships that constitute the supply curves of the macroeconomy. This paper considers the largest and probably the most important component of aggregate supply, the part concerning the private business sector.

Some studies investigate macroeconomic supply relationships by directly estimating production as a function of labour and capital input measures. For example, Carmichael and Dews (1987) adopt this methodology. In the TRYM model we have used a different approach.

The level of output or production measured in the National Accounts is treated as being largely demand determined. This is consistent with the way that mainstream macroeconomists commonly explain movements in GDP and make short term forecasts. Obviously, this demand must actually be produced, and in that sense must reflect short run supply. However, this does not necessarily imply that production is at a profit maximising or equilibrium level.

When macroeconomists talk about an economy experiencing excess demand or excess supply they usually mean that demand is not matching some underlying or longer term concept of supply. It is this idea of supply that is addressed in this paper.

Supply is rarely directly observable. However, this does not mean that it is unimportant or that it can be safely ignored. Usually its influence must be inferred from its effect on the economy. For example, when an economy has excess demand then, ceterus paribus, inflation will rise. In this way supply can be measured by examining the interaction between output and prices.

Aspects of supply can also manifest themselves in other ways, particularly through the demand for factor inputs. The demand for labour, ie employment levels, should reflect the conditions under which firms intend to use labour. Similarly, investment should reflect to some extent the need for capital by the supply side, in meeting demand.

These considerations suggest that the best way to investigate supply in the macroeconomy is to use information from all the above mentioned relationships. This is the approach taken in the TRYM model and is described in this paper.

There are also other key decisions made by firms which extend beyond just dealing with supply issues. Investment is one of the important determinants of aggregate demand, while inflation and employment are two key targets of economic policy.

In the TRYM model equations are specified for inflation (ie prices), employment and investment that utilise the production technology of firms, among other things. These equations are then jointly estimated using data since 1970, simultaneously determining both the long run relationships and the short run dynamics. This procedure ensures that both theory and data play their role in determining the above equations.

This paper has the following structure. Section 2 examines some key features and options relevant to the specification of the production function in the TRYM model. Section 3 describes the data considerations, the theoretical issues, the specification and the estimated results for the employment equation. Sections 4 and 5 treat, in the same way, the investment and price equations respectively. Section 6 summarises the key estimated results for the common parameters in the production function and section 7 contains some concluding remarks.

2 SPECIFYING THE PRODUCTION FUNCTION

2.1 Summary

The important features of the supply side in the TRYM model are listed below. They provide an overview that is described in more detail in subsequent sections.

<u>Properties of Business Supply</u>

- Business sector covers private enterprises, excluding production through the ownership of dwellings.
- Supply is a function of two factor inputs: labour and capital.
- A CES (constant elasticity of substitution) functional form is used with constant returns to scale.
- Harrod-neutral technical efficiency is used and the rate of technical progress is treated as exogenous.
- Business capital is assumed to be putty-putty.
- Labour input is measured in hours worked.
- Imports are not treated as a factor input.

2.2 Defining the Private Enterprise or Business Sector

The data for the equations contained in this paper and the coverage of the business sector in the TRYM model, was the subject of considerable investigation. As in most macroeconomic models, the ABS National Accounts form the primary data source and influence the approach to model construction on both the demand and supply side. These accounts contain implicit production functions for dwelling services, general government capital services, general government labour services and 'enterprise' output. The production functions for the first three components are conceptually straight forward and total output is disaggregated along these lines in the TRYM model.

The 'enterprise' category is the largest component of GDP. Hence, the first major issue to be considered is whether further disaggregation of the 'enterprise' output component is desirable.

The disaggregation of farm and non-farm sectors, which is measured on the National Accounts, gained some consideration. Although the relative importance of the farm sector in aggregate production is declining, the share of farm exports in total exports is still quite significant.

To fully model the farm sector would require the separate identification of factors for this sector (including intermediate inputs) and the matching of production with final demand components. This would add to the size, if not the complexity, of the model. However, a separate production function would add some theoretically desirable properties and may fit the data better. On balance, the less detailed approach of combining farm and non-farm output, employment and the capital stock in the production block of the model is chosen in this model. Farm exports are included in commodity exports and their treatment in the TRYM model is described in TRYM Paper 4.

The disaggregation based on the ABS construction of output measures in the non-market sectors of the economy, where output is measured solely on the basis of employment data (eg Finance, Property and Business Services; Community services; and Public Administration and Defence) was also considered[1]. In these cases labour productivity is heavily influenced by the data construction methodology and may not reflect actual trends in these industries. Another problem is that these sectors have not always grown at the same rate as the market sector. Although productivity growth would be permanently understated, it would be a consistent understatement. Unfortunately, the non-market sector has tended to grow somewhat faster than the market sector and hence any gap between the two is changing over time. This faster growth has also been more marked in the last decade.

An additional problem is that the latest rebasing of the National Accounts may have incorporated different data construction methodology at different times due to the splicing procedures adopted. This creates serious difficulties when trying to model the non-market sector over long time periods.

There may be some value in splitting output into market and non-market sectors to closely analyse trends in measured productivity, and to match published ABS data. However, such a split cannot be justified in terms of the requirements of a model constructed for use in policy analysis, unless it can be determined how different policies might affect that split.

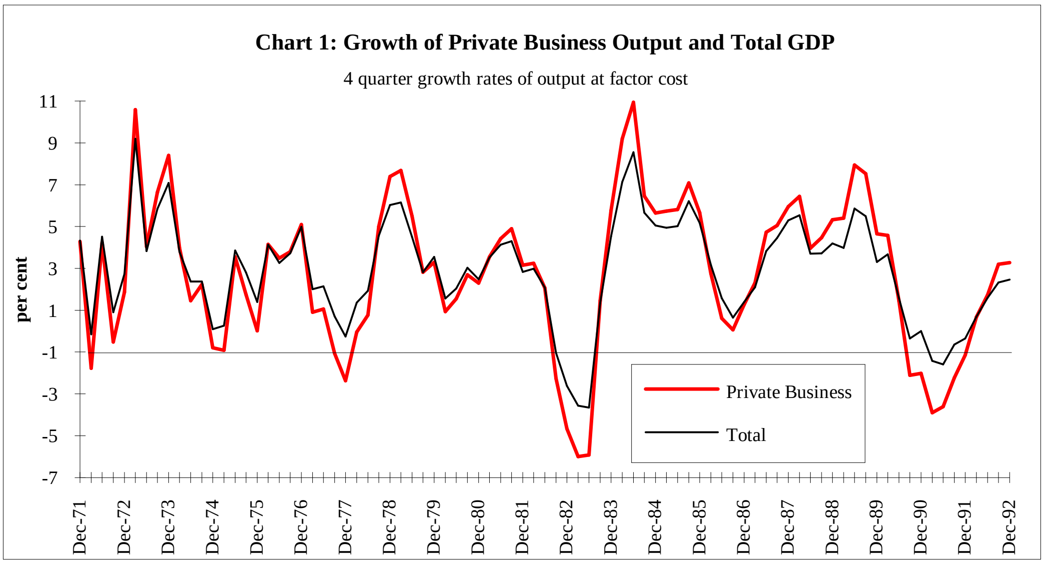
[1]Although Finance, Property and Business Services are part of the market sector, the ABS estimates output based on labour input.

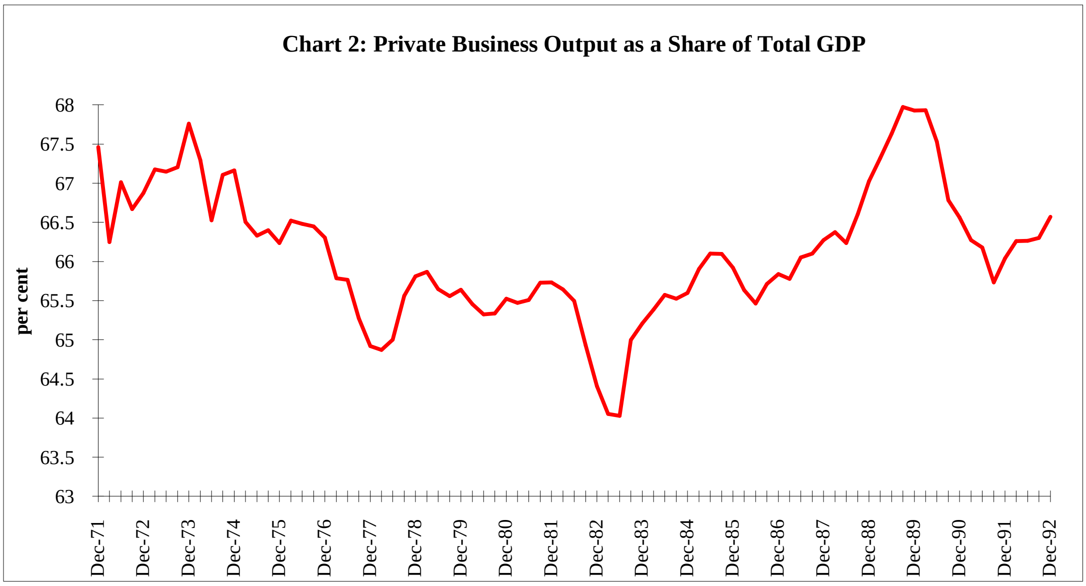
More relevant is a split between the output of the public and private sector. Not only is much of the public sector in the non-market sector, but the objective functions and the observed behaviour of the two sectors are likely to be quite different. For example, there is potentially different investment behaviour by public enterprises due to the effect of government policies or regulations on their ability to finance projects. Public employment is also affected by different considerations to private employment, including hiring/firing arrangements. Further, over the sample period there was some reclassification between the general government sector and the public enterprise sector. An early and important example was the creation of Telecom. By considering private enterprise behaviour separately, we abstract from these difficulties.

It therefore makes more sense to disaggregate aggregate business output between the private and public enterprise sectors.

The private sector can be expected to exhibit profit maximising behaviour, at least in the long run. Allowance can be made for the public enterprise sector to exhibit different behaviour. Of course, it can be argued that the difference relates more to possible variances in pricing, employment and investment behaviour (eg for public sector infrastructure) than to the physical transformation of factor inputs to final output (especially with the new emphasis on efficiency of public enterprises). However, since pricing behaviour is closely related to assumptions about the production technology, there is still a strong case for the separation of the two sectors.

Private business sector output is not measured in the National Accounts and data must be calculated separately. The method by which private business sector output is calculated is briefly outlined in the Appendix. Chart 1 compares the growth rates of the private business sector and total output. It shows that the fluctuations of these components differ in terms of magnitude, but not timing. However, it is clear from Chart 2 that the share of private business output fell during the mid 1970s from about 67 per cent and continued to fall to as low as 64 per cent by the beginning of 1982. Since then the private business sector share has steadily increased.





2.3 Factor Inputs

In the TRYM model the only factor inputs into the business sector are labour and capital.

It is also tempting to treat 'land' as an input. Land is particularly important in the agriculture and mining industries. While arable land is most important for agriculture, it is the mineral resources that lie underneath the land (or the sea floor) that are particularly relevant to the mining industries. However, the contribution to production made by both these factors is difficult to measure. The aggregate physical quantity of land is less important than the flow of services that can be used from agricultural land or the amount of resources that can be extracted by the mining industry.

Even if land's contribution to production could be measured, the task of explaining fluctuations of this contribution remain. It is not clear that the specification of linkages between macroeconomic variables and the supply of land would be easy.

For these reasons land is not included as a factor input. However, there are two ways in which factors other than land and capital have an influence on production.

First, rainfall is a determinant of commodity production for export purposes. The contribution of rain to the supply of commodities for exports, was determined by calculating the contribution that an index of rainfall makes to farm product, as measured in the National Accounts. This contribution of rain to commodity production is included in both the commodity supply and the commodity stock building equations. Further details of how rainfall affects the economy in the TRYM model are contained in TRYM Paper 2 and TRYM Paper 4.

Second, the elasticity of transformation between business commodity and non-commodity production is estimated to be relatively low, at about one half. This elasticity could be small due to the presence of a fixed factor, such as land, that is not explicitly incorporated in the production technology. Nevertheless, the presence of land may affect the data, estimated elasticities and the simulation properties of the TRYM model in this sector.

2.4 Functional Form

In the TRYM model the economy is modelled as producing a single output from two inputs, capital and labour, using a CES (constant elasticity of substitution) functional form. This approach has a number of advantages.

First, the functional form used needs to be relatively simple. The macroeconomic time series data is often not sufficient in either quality or quantity to discriminate between more complex alternatives. Unless there is some other reason, we have generally chosen the simplest alternative consistent with the data. The CES functional form is relatively easy to implement and understand.

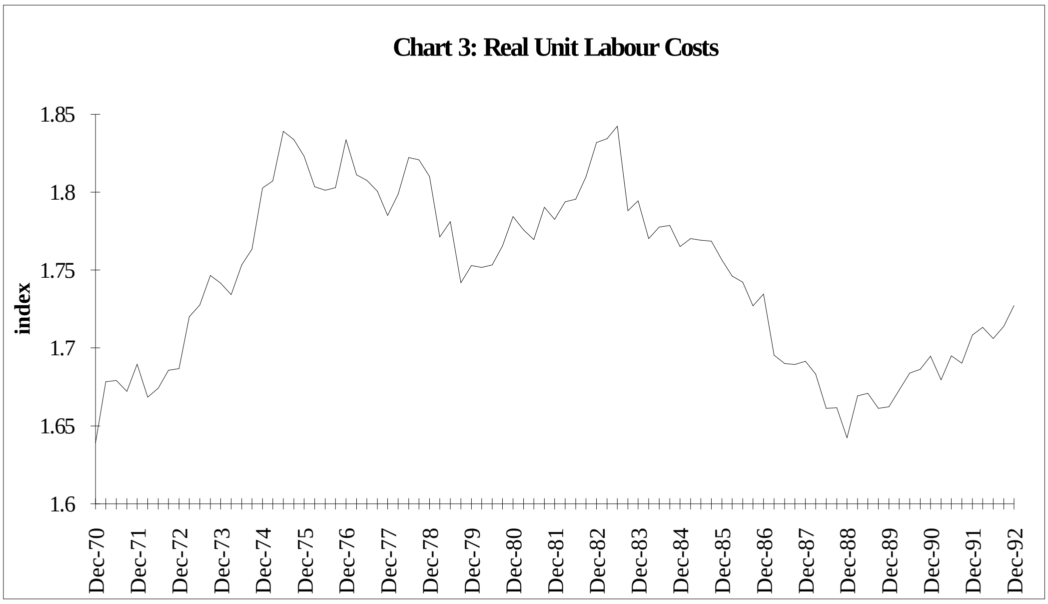
Second, the functional form has to be relatively general for the parameters of interest. The CES has this property. Two parameters of this function measure the importance of labour and capital inputs into production. These are often referred to as the labour and capital share parameters since their relative size is pertinent to the equilibrium income shares of output. The magnitude of these is an indication of units of measurement and the level of productivity.

One important property of this production function is the degree of substitutability between factor inputs. The elasticity of substitution is a measure of how much relative factor proportions change for a change in relative factor prices. The CES production function allows for a positive elasticity of substitution that can be estimated.

The Cobb-Douglas production function assumes that the elasticity of substitution between labour and capital is equal to unity, and can thus be considered as a special case of the CES family of production functions. However, many studies - using both cross sectional and time series data - provide evidence that the elasticity of substitution is significantly different from unity.

It is important to estimate the elasticity of substitution rather than impose it. It may not affect the equilibrium quantity of output by a significant amount for given factor inputs, and this is the reason why some studies impose a unitary elasticity. However, the elasticity is very important when calculating the effects of the first order conditions. Imposing a unitary elasticity could lead to an overestimate of the effect of wages on output.

In addition, while the Cobb-Douglas production function may fit the data in some other developed countries, it is not particularly consistent with the Australian data in one key respect. The Cobb-Douglas production function has as one of its features a constant equilibrium level of real unit labour costs (RULC). Chart 3 shows that in Australia RULCs have not been constant over the last 25 years. Movements in RULCs have been correlated with movements in real wages and this suggests an elasticity of substitution of less than one.



The production function is defined in the TRYM model as follows:

$$GBA=[CLAB*L^{\rho}+CKAP*KB^{\rho}]^{(1/\rho)}$$

where CLAB and CKAP are the share parameters on labour and capital and ρ = (CSIG–1) / CSIG, where CSIG is the elasticity of substitution, GBA is rain business output, L is labour input and KB is business capital input.

The above production function exhibits constant returns to scale. There are some considerations that suggest there are non-constant returns to scale. The presence of fixed factors, such as land, would yield decreasing returns to scale for land and capital. However, the presence of fixed costs, such as costs associated with gathering information, would lead to increasing returns to scale for labour and capital. This is a difficult issue to resolve at the aggregate level.

Constant returns to scale is a plausible and convenient assumption and we chose to impose it in the TRYM model. The data was not exploited to estimate the returns to scale because it is difficult to differentiate between increasing returns to scale and the trend increase in efficiency.

2.5 Technical Efficiency

The inputs of labour and capital into the production technology must be adjusted for the level of efficiency of factors. The same quantity of factors could be producing different amounts of inputs of factor services at different times. It is the quantity of factor services of constant efficiency that is the actual factor input into the production function in the TRYM model.

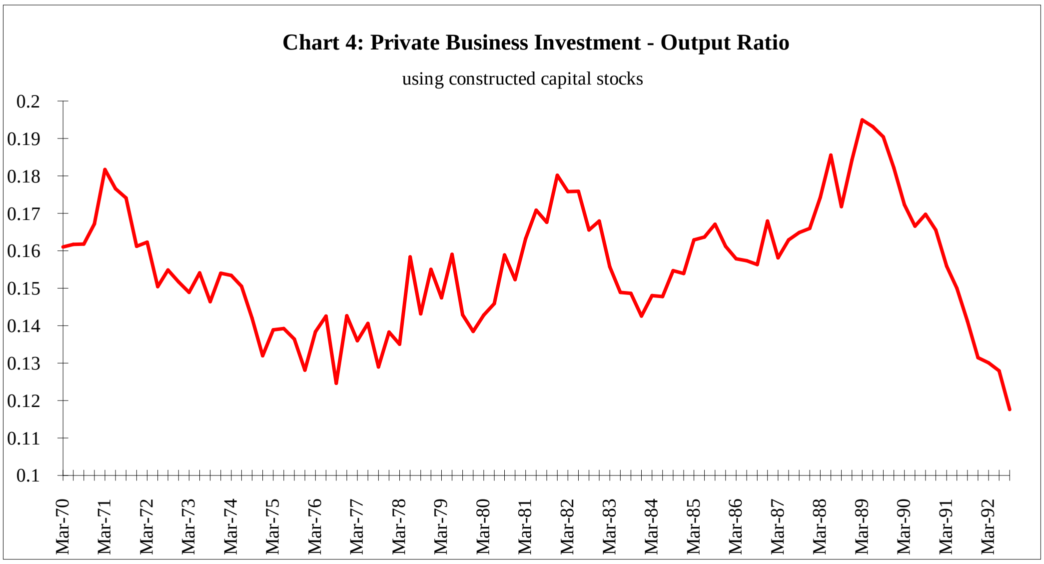
There are a number of ways in which technical efficiency can be implemented. Some different definitions of technical progress include Hicks, Harrod and Solow forms of technical progress.

Technical change is Hicks neutral if it does not change the marginal rate of substitution between the inputs. That is, the labour-capital ratio does not change, but multi-factor productivity rises. Solow's definition measures growth in efficiency as producing a constant labour-output ratio. Both the output-capital and the labour-capital ratios rise. Harrod neutral technical efficiency measures increases in efficiency that produce a constant capital-output ratio.

The most convenient and common working assumption related to total factor productivity in macroeconomic models is that of Harrod neutral technical progress. It is often assumed that Harrod neutral technical progress is exogenous and constant over long periods of time in these models.

There are a number of reasons for favouring the use of Harrod neutral efficiency. One is that it enables balanced long run growth to be attained in the full model. If the efficiency of capital rose then the capital-output ratio would fall, ceteris paribus, as would the investment-output ratio. However, Chart 4 shows that the business investment-output ratio is relatively stable over a long period of time.

Another reason is that increased efficiency of capital, for example with computers, should increase the quality of capital. However, according to the ABS' 'Concepts, Sources and Methods' (1990) the data construction methodology may measure this change as a fall in the price of capital and an increase in the quantity of investment and capital. In this way, increases in capital efficiency may not be captured in the data and so cannot be modelled easily.



In the TRYM model technical efficiency is specified to increase at a constant exogenous rate over time. We investigated the hypothesis that the growth rate of efficiency declined during the 1980s[2]. However, estimations over a sample period from 1980 showed no statistically significant decline in this parameter.

Estimation over later periods did show changes in the growth rate of efficiency. However, there were changes in many other parameters too. We suspect that the shorter sample range fails to include episodes of both wage restraint and marked wages growth and so cannot clearly differentiate between the elasticity of substitution and the rate of efficiency growth. Our investigations lacked the power to identify whether the growth of efficiency had changed in recent years and we leave this as a task for further analysis, perhaps using a different methodology.

While no statistically significant change in the growth of aggregate technical efficiency was estimated, this does not mean that efficiency cannot be altered. In the TRYM model the growth rate of technical efficiency is treated as exogenous, ie. it is unaffected by other macroeconomic variables. We believe that the rate of efficiency growth is actually endogenous and is a function of determinants such as education, health, competition etc. However, none of these variables is modelled in the TRYM model. For this reason it is treated as exogenous, with adjustments being made as necessary. TRYM Paper No. 7 describes a simulation that shows the effect of a permanent increase in technical efficiency on the macroeconomy.

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[2]See for example declines in productivity contained in the ABS publication 'Multifactor Productivity'.

We considered the hypothesis that Harrod neutral technical efficiency was embodied in capital. By this we mean that although the efficiency of labour may improve, say due to increased skill levels, an update in the capital stock may be necessary before the improvement can be realised. For example, a person could learn word-processing skills that raise their potential efficiency, but only if they can use a word-processor rather than a typewriter.

Under this hypothesis the efficiency of labour rises only as earlier vintages of capital are replaced. If the efficiency of the marginal unit of capital is $e^{\lambda t}$, where λ is the growth rate of efficiency and t is time, then $e^{\lambda(t-a)}$ is the average efficiency of capital, where *a* is the average age of the existing capital stock. The average age of capital rises when investment is low, and falls when investment is high. Econometric estimation suggested that changes in the efficiency of labour were not significantly correlated with investment. Therefore, we do not treat efficiency as embodied in capital.

We also assume that the passage of time raises the efficiency of all labour. One workable alternative treatment would be to assume that people have the same level of efficiency over their lifetime. The average efficiency of the workforce would then only be raised by young entrants joining the labour force or by retirements. However, this ignores the contribution that on-the-job learning and other sources make to increases in efficiency, and so was not implemented.

The next issue to be considered is whether to treat capital as putty-putty or putty-clay. The treatment of capital as putty-putty is simpler and easier to implement, but there is some support for modelling capital as putty-clay as described in the NIF88 model. Putty-clay capital may or may not be associated with embodied technical progress, but instead is an alternative view of the flexibility of capital which deserves separate consideration. However, if technical progress is disembodied, it is less likely that capital is putty-clay. Therefore, if the earlier test of embodied technical progress is rejected it is more difficult to accept that capital is putty-clay.

With putty-clay capital, output is produced by applying labour to different vintages of capital stock, whose output-labour ratios are fixed and are selected at the time the capital was installed, usually with regard to the expected level of real wages. Unfortunately it is difficult to devise a framework in which the competing hypotheses can be satisfactorily tested using the available data.

One feature of putty-clay capital is that the average mix of factors can only be altered through new investment or the retirement of capital. The absence of data on retirements of capital precludes testing the association between the speed of adjustment and the level of retirements. However, a (weak) test of putty-clay is that the speed of adjustment of the labour-output ratio should be positively correlated with the level of investment. However, the time-series data does not support this correlation.

In addition to the (weak) lack of data support for putty-clay capital, much of the business capital is unlikely to be putty-clay, on a priori grounds. One third of business investment is in buildings and structures. This type of capital is relatively unlikely to impose fixed labour capital ratios. For example, the ratio of labour to office accommodation, retail floor space and factory space can and does change. Most plant and equipment has this same characteristic. Examples include cars, carpets, office furnishings, shop fittings and telephones in a range of service industries where variations in the labour-capital ratio and the labour-output ratio are not constrained to any great extent by the age of capital. Thus, it is not surprising that the macroeconomic data provides little evidence that putty-clay capital is important.

In summary, the TRYM model treats capital as putty-putty. Technical efficiency is Harrod neutral, disembodied, exogenous and affects the whole workforce.

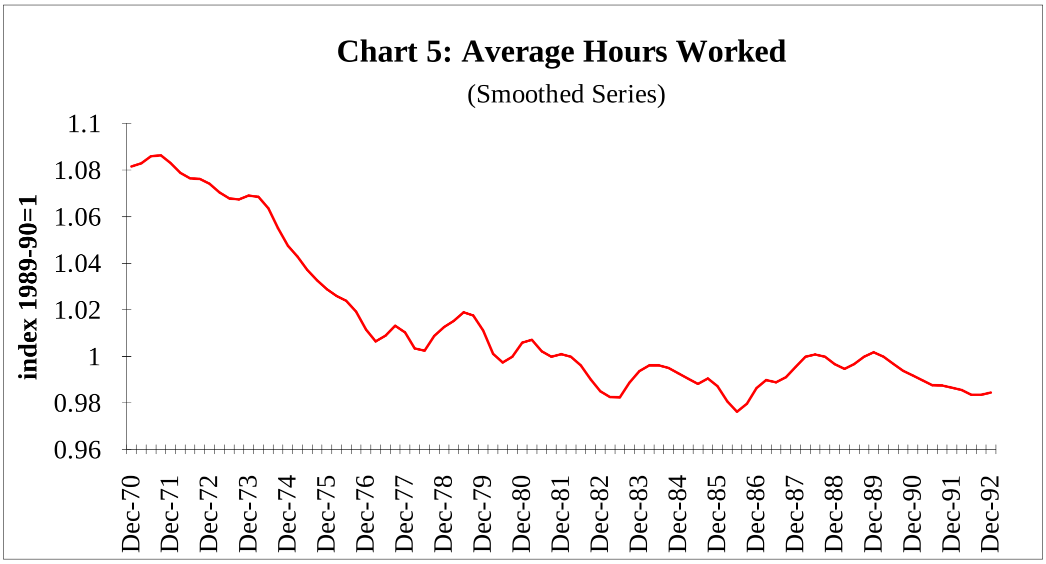
2.6 Measurement of Labour Inputs

Private business sector output is matched with private employment.

The two measurement options for labour inputs are the number of employees or the number of employee-hours worked (employees multiplied by average hours).

Structural factors, such as the rise in female participation rates, have tended to raise the number of people in part-time employment and reduce average hours worked per employed person. Average hours worked declined in the 1970s with the move towards shorter working weeks for full time employees. Further, in the face of high labour costs, many firms switched to using contract labour, thereby making the part-time component higher Over the economic cycle the availability of overtime varies and the level of part-time employment is likely to change relative to full-time employment. For these reasons, and because there is significant variation in the hours worked series during the estimation period, the TRYM model measures labour demand in hours worked.

Chart 5 shows a smoothed series of average hours worked. This series needs to be smoothed because there are considerable erratic movements in the underlying series. The ABS advised us that the quarterly movements could be unreliable and the series they publish in the National Accounts is trended. While the use of this trend series poses some econometric difficulties, these are considered to be smaller than the problems incurred by ignoring hours worked or using seasonally adjusted data.



Hours worked declined dramatically during the mid-seventies, presumably due to the structural factors mentioned above, but shows little variation over the economic cycle. After the structural break in measurement methodology in 1978 there is less structural movement and more cyclical variation apparent. Given these data difficulties, which have become more pronounced since the rebasing of the National Accounts, the TRYM model currently treats average hours worked as exogenous.

2.7 Measurement of Capital Inputs

In the TRYM model, private business output and employment are matched with private business fixed capital, excluding real estate transfer expenses.

Real estate transfer expenses are excluded for two reasons. They are not split into their dwelling and business investment components in the published National Accounts. Also, there are conceptual difficulties associated with the 'stock' of real estate transfer expenses. Complex measurement problems arise when treating capital as an input in the production process. Aggregates of capital include very diverse components in terms of production characteristics, asset lives and patterns of usage. Nevertheless, because the TRYM model is a model of the aggregate economy, it is aggregate capital and investment that need to be dealt with.

It is the supply of capital services that should be used as a factor in the production function. Therefore, only capital that is actually utilised should be included as a capital input. However, reliable data on capacity utilisation for the whole economy over the last 20 years is very difficult to obtain. Hence, we are constrained to using the aggregate net capital stock in existence as an approximation of capital services actually provided.

ABS measures of the capital stock show a persistent rise in the capital-output ratio for the business sector. This rise in capital-output ratio is not matched by a corresponding rise in profit shares, yet investment was high during the late 1980s. These observations have led to some doubts about whether the ABS measures of physical capital are an appropriate approximation of the business capital stock. The main area of concern appears to be the rate of depreciation used by the ABS. NIF10, AMPS, AEM and McKibbin and Seigloff (1988), for example, have all used depreciation rates considerably higher than the ABS, which have the effect of producing a more stable capital-output ratio. More recently, Edey and Britten-Jones (1990) have raised similar questions about the ABS series. Although assumptions about the capital stock in 1960 are less important for the growth rate of capital in the 1970s and 1980s, the starting level for the capital stock is also an issue which could bear on the behaviour of the capital-output ratio.

While this behaviour of the capital-output ratio is a puzzle, it is not just a phenomenon of the Australian data. Over the last thirty or so years most OECD countries have experienced rising capital-output ratios (see, for example, Englender and Mittlestadt (1988)). One possible explanation is that output growth is generally being underestimated. This can occur because it is very difficult to capture all the improvements in the quality of services. Another reason for this parallel is that the ABS depreciation rates for plant and equipment were adjusted to be broadly consistent with those in other OECD countries. The asset lives were first constructed on the basis of Australian sources, but were then increased by 50 per cent in most categories to make them conform to the OECD average asset lives.

In any case, estimates of capital stocks consistent with the rebased National Accounts were unavailable when data construction, specification and estimation of the TRYM model commenced with the release of the December 1992 National Accounts in March 1993. We were forced to develop our own capital stock series. Starting values for capital stock construction were obtained using investment series from the Butlin database back to the turn of the century. For modelling purposes, shorter asset lives, more in line with the ABS' Australian sources, were adopted in the TRYM model.

Interestingly, the use of shorter asset lives appears to help explain the behaviour of employment, investment, and inflation. The construction methodology is briefly discussed in more detail in the Appendix.

2.8 Treatment of Imports

Another consideration in specifying the production technology is the treatment of imports. In NIF88 and AMPS, imports are treated as final goods, while in the AEM model they are treated as intermediate inputs which are combined with domestic factors in the second level of a two level CES production function. Ideally, imports of goods and services should enter the production function at the level appropriate to each import, and that may be at any stage from raw materials to finished products. At the aggregate level it appeared sensible to treat all imports in the same way according to the dominant component.

Our investigations were based upon a split of imports into intermediate and final components.

Although there are some measurement and classification difficulties, the intermediate component constitutes, on average, less than half of the total imports of goods. However, some of these 'final' goods may actually be further transformed in Australia, so the actual proportion may be close to a half. Service imports include freight and insurance on shipment, passenger and port services, travel overseas and various other official and non-official services. The first two categories may be more reasonably classified as intermediate goods and the second two as final goods. On this basis, the intermediate component of imports of services is about a half of the total. This data is discussed in more detail in the imports section of TRYM Paper 4. Therefore, on a compositional basis, it is not clear whether it is a more reasonable approximation to treat imports as a final or intermediate good.

On balance, in the TRYM model it has been decided to continue to treat imports as final goods and services, in the sense that imports are not direct substitutes for domestic factors.

This has a number of advantages. It simplifies the specification and estimation of the production technology. Further, it allows for potential variation between the import penetration of different components of final demand. However, it also assumes that there is no direct substitutability between domestic factors and imported goods (although indirect substitution can still occur). A future area of research is to test whether imports are best treated as final or intermediate goods or whether some split is desirable.

3 LABOUR DEMAND EQUATION

3.1 The Historical Data

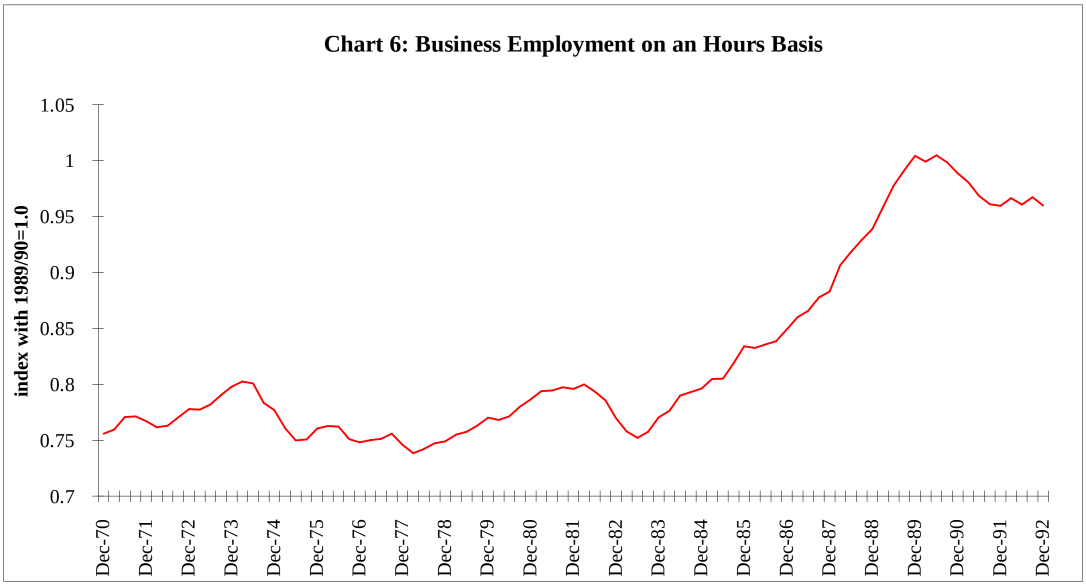


Chart 6 shows total hours worked converted to an index (business employment*hours worked with 1989-90=1). It is interesting to note that unlike the business employment series, which exhibits a consistent upward trend, significant increases in the hours worked series occurred only during the last decade. The fall in average hours worked that occurred during the mid 1970s, reflecting the shift towards part time employment, accounts for much of the slowing in growth of total hours worked prior to 1980.

3.2 Theoretical Issues

Given the specification of the production function described above, labour demand can be expressed in two different ways. Labour demand can be related to production and wages, using the first order condition for labour, or labour can be related to production and capital using the production function in level form. These two functional forms are equivalent in equilibrium but could produce different adjustment paths and short run dynamics.

The first order condition for labour, derived from the CES production function, provides the basis for the functional form of the equilibrium level of labour demand. In particular, if the marginal product of labour is given as real wages (W/P), then

$$\log(L/GBA) = CSIG*\log(CLAB) - CSIG*\log(W/P)$$

We experimented with expressing the demand for labour using the second approach. The data preferred the functional form that included wages to the one that included capital. However, the role of capital was still important in the short run.

3.3 Specification

The labour demand equation, measured in hours worked **(NBH)**, is specified as an error correction model with the long-run relationship determined by the equation above. Since technical progress is assumed to be labour augmented, the marginal product of labour has to be adjusted for the rate of Harrod Neutral Technical Progress (or the underlying growth in private sector productivity, **CLAM**). As mentioned earlier, business sector output is adjusted for the effect of rainfall in order to obtain an underlying measure.

An error correction format has been specified to incorporate both short and long run effects. A number of short run dynamics are included in the specification.

- The underlying or equilibrium growth rate of private employment is assumed to be the growth rate of the adult population. This is measured as its average growth rate over a two year period **($\Delta_8$log (NAP)/8)**.
- Wages are important in the long run and hence changes in wages are included in the short run. The variable used to capture this effect, described as W/P above, is real wages deflated by output prices (**PGB**) and adjusted for payroll tax **(RTPRB)** and hours worked **(WBH)**.
- Output **(GBA)** is important in the long run and is also included in the short run. The change in output is expressed relative to the change in capital **(KB)**. This helps capture the effect of the production function in levels form, even though this is not important in the long run. This can also be interpreted as the change in the output-capital ratio or the change in capacity utilisation.
- Not all the change in hours worked **(NH)** flows through to employment in the first quarter. This could be caused by adjustment costs in hiring and firing. Therefore, in the short run an adjustment parameter for hours worked is estimated.

The preferred equation incorporated all these features.

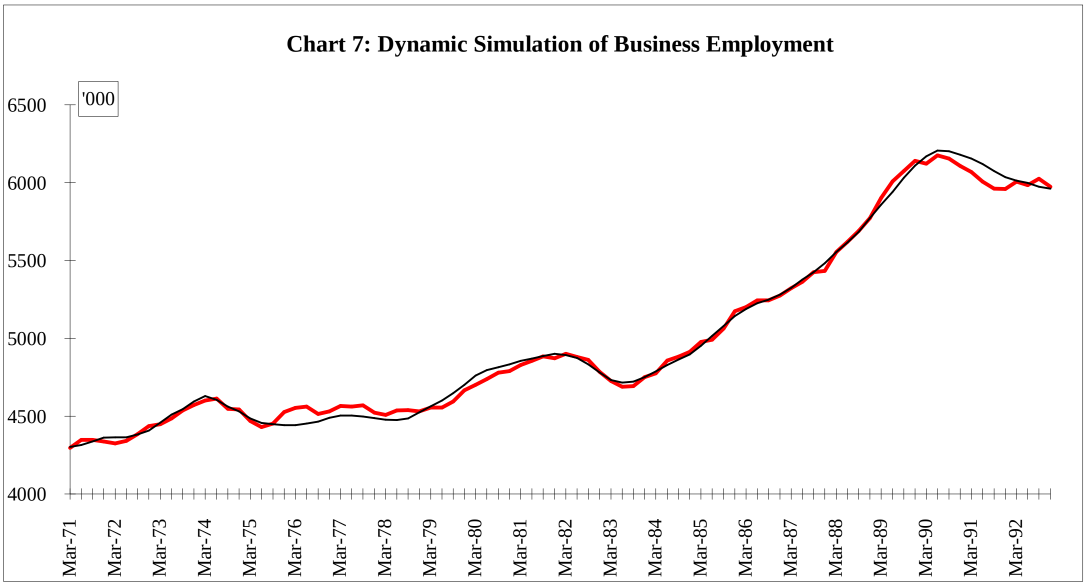
$$
\begin{aligned}
\Delta\log(NB) = {} & \Delta_8\log(NAP)/8 \\
& - A2LD*CSIG*[\Delta\log(WBH*RTPRB/PGB) - CLAM/4] \\
& + A3LD*\Delta\log(GBA/KB(-1)) \\
& - (1-A5LD)*\Delta\log(NH) \\
& - A0LD*[\log(NB(-1)/GBA(-1)) + \log(NH) - CSIG*\log(CLAB) \\
& \qquad + CSIG*[\log(WBH(-1)*RTPRB(-1)/PGB(-1)) - CLAM*QTIME(-1)] \\
& \qquad + CLAM*QTIME(-1)]
\end{aligned}
$$

where QTIME is a time trend.

3.4 Estimation Results

Sample: 70:2 to 92:4		
Parameter	Estimate	t-Statistic
A2LD	0.147	3.12
CSIG	0.755	19.24
CLAM	0.011	8.35
A5LD	0.706	3.90
A3LD	0.130	3.60
A0LD	0.245	10.94

R^2=0.60	SE=0.54%	DW=1.84

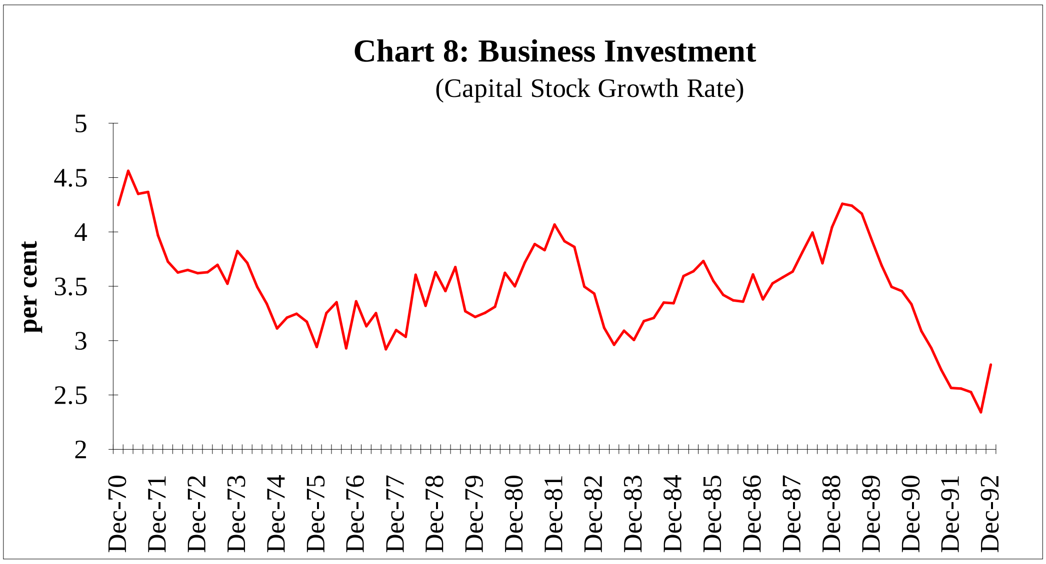


All estimates are signed as expected and are significant. The adjustment toward equilibrium is fairly quick, with a quarter of any difference between actual and desired labour demand eliminated each quarter. Other elasticities in this equation imply that, in the first quarter, an increase of one per cent in:

- the output to capital ratio (ie. if output were to rise 1.0 per cent faster than the level of the capital stock) would increase employment by 0.13 per cent;
- real wages would decrease employment by 0.15 per cent; and
- average hours worked would decrease employment by about 0.29 per cent.

4 BUSINESS INVESTMENT EQUATION

4.1 Historical Data



Business investment proves more difficult to model than many other variables, such as employment. This is a common result for macroeconomic modellers, but a disappointing one nevertheless.

The first difficulty lies in explaining why investment appeared to be so high during the 1970s and 1980s. The growth rate of the ABS capital stock only occasionally falls below that of trend output, such as during recessions. This is surprising given that there has been considerable concern over the last twenty years about apparently low levels of investment. The adjustments made to the depreciation rate of the capital stock, to construct a different measure of the capital stock for model purposes, reduce the trend rise in the capital-output ratio but does not remove it altogether. Either the equilibrium growth rate of capital was significantly higher than the growth in output over extended periods of time or there were disequilibrium effects which together had a persistently positive effect on investment. This was experienced despite significant rises in real labour costs for much of those twenty years which, ceteris paribus, should have depressed investment and capital growth.

The second difficulty lies in adequately measuring the variables which theory says are important, but which are largely unobservable. Confidence and 'animal spirits' are the most obvious examples.

The treatment of taxation is simplified in a number of ways. The tax rate applying to profits from business capital is very difficult to measure owing to the complexities introduced by tax deductions and the different regimes applying to various types of ownership. The appropriate tax treatment of the cost of funds or alternative uses of funds is even more problematic. Hence, variables of the investment equation are formulated in pre-tax terms, because of these measurement problems. The exception is the inclusion of the implicit rate of investment tax credits, which can be measured.

4.2 Theoretical Issues

The preferred equation models the growth rate of the capital stock (relative to its desired long-run rate) as a function of a lagged Q-ratio, a demand/supply balance term, and a mining boom dummy variable. The growth rate of capital is gross investment **(IB)** relative to capital stock **(KB)** less the rate of depreciation **(RDKB)**. The desired long-run growth rate of capital is set equal to population growth plus the rate of technical progress. Deviations of the Q-ratio from unity are measured by the difference between the expected and the required rates of return. These terms and concepts are explained below.

The long run properties of the investment equation are easy to specify. Investment must be at a level that is sufficient to make capital grow at its desired rate. The resulting long run equation for business investment is of the form;

$$IB/KB(-1) = g + RDKB$$

where g is the long run growth of the capital stock. This g is specified as the growth rate of adult population plus the growth rate of efficiency **[exp(CLAM/4) + Δ_8(NAP)/8]**.

The specification of the short run response is more difficult. There are a number of competing hypotheses about the determinants of investment. One is neoclassical influences, such as the effects of wages, efficiency, interest rates and risk combined in a Tobin's Q-ratio. Another is the more Keynesian demand side factors such as capacity utilisation. Other considerations include the long implementation times required for some investment and the role of special factors such as mining booms. The TRYM model includes each of these influences in the specification of business investment.

In the short run, the investment equation is driven by a Q-ratio, to assist in capturing fluctuations in investment over the business cycle.

A stock market based Q-ratio was used in NIF88 and has the advantage of implicitly incorporating market expectations. However, the Q-ratio constructed by the Reserve

Bank which was used in NIF88 is no longer available. The alternatives are to either derive a synthetic Q-ratio or use a stock market measure based on the dividend yield and National Accounts dividends paid data (available on the current NIF10 data base).

An equation is required to endogenously determine the Q-ratio in the model regardless of whether it is based on a synthetic or stock market measure. On this basis the synthetic approach is preferred as it allows a more direct route from fundamentals to investment. It also allows us to ensure consistency with the production technology.

This Q-ratio is calculated as the ratio of the expected rate of return on capital to the cost of funds. This is equivalent to a comparison between the market value of capital and its replacement value. When the Q-ratio is greater than one, agents will invest at more than an equilibrium level while if the Q-ratio is less than one, agents will invest at lower than the equilibrium level. The expected rate of return **(ERR)** is derived from the first order condition for capital from the CES production function.

$$ERR = (PGB/PIB)*(CKAP)*(KB/GBA)^{(\rho-1)}.$$

where PIB is the price of investment, and PGB is the price index on output.

The capital-output ratio **(KB/GBA)** is affected by cyclical fluctuations in demand that are not necessarily persistent. If firms believe that demand will be sufficient to ensure 'normal' utilisation of capital then the capital-output ratio should be set to its equilibrium level. Substituting out the capital-output ratio **(KB/GBA)** for real wages provides the following equation.

$$ERR = (PGB/PIB)*(CKAP)^{(1+1/(1+CSIG))} *[1- CLAB^{CSIG} \{(WBH/PGB)/exp(CLAM*QTIME)\}^{(1-CSIG)}]^{1/(1-CSIG)}$$

The cost of funds **(CF)** is calculated as the 10 year government bond rate **(RGL)**, less inflationary expectations **(INFEXP)**, plus a risk premium **(RISK)** and the rate of depreciation on business capital stock **(RDKB)**. **RISK** is an estimated parameter in the investment equation.

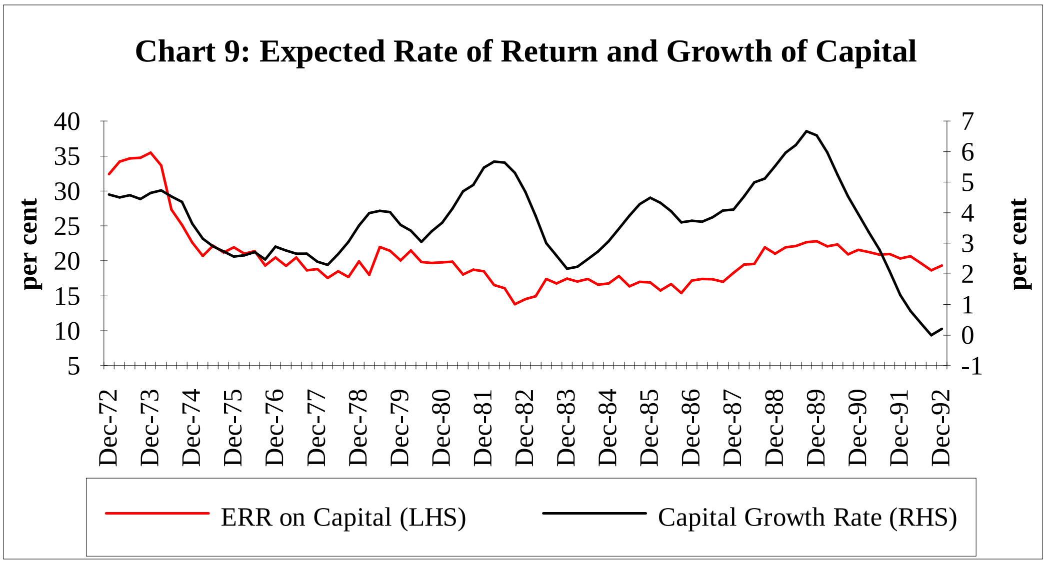
$$CF=[\{(RGL-INFEXP+RISK)/400\} + RDKB].$$

Therefore the Q-ratio that determines investment in the long run is defined as

$$Q = \{(PGB/PIB) (CKAP)^{(1+1/(1+CSIG))} * [1- CLAB^{CSIG}\{(WBH/PGB)/exp(CLAM*QTIME)\}^{(1-CSIG)}]^{1/(1-CSIG)} \}$$

/[{(RGL-INFEXP+RISK)/400} + RDKB]

The numerator of this expression is relatively easy to calculate and is the expected rate of return given the current level of real wages and the production technology estimated above. This numerator appears to be reasonably well correlated with movements in business investment. Chart 9 shows the expected rate of return given the real wage and the growth of the business capital stock.



In contrast, the actual value of the denominator is not directly observable. Its expected value is even more difficult to identify because of the difficulties in measuring expected inflation. Nonetheless, for a range of plausible assumptions the required rate of return would appear to have been lower in the mid 1970s than in the 1980s because real interest rates were lower in the earlier period. This is difficult to reconcile with the observation that investment was generally higher in the 1980s than the mid 1970s.

If the goal was merely to explain business investment in a single equation context then a satisfactory equation could be constructed using the expected rate of return and a constant required rate of return. However, we have a strong theoretical prior, supported by evidence from business contacts, that investment does respond in the long run to the cost of funds. We also aim to specify an investment equation that will produce desirable full model properties. For these reasons it is necessary to construct a measure of real expected interest rates and to include them within the equation. In this way the theoretical properties of the equation and the model are improved.

Another determinant of business investment in the TRYM model is the ratio of demand to supply **(GBA/YSTAR)**. This ratio can be related to theory in two ways.

The utilisation rate of capital varies over the business cycle. When demand is low capital may be idle or under-utilised, while capital may be used more intensively at times when demand is high. If capital is idle then it may be more profitable to utilise existing capacity than to invest in new capital. Similarly, if capital is being used at above the normal level of utilisation then more investment to expand capacity will be considered.

The utilisation of capital cannot be measured directly and so the TRYM model uses a comparison of demand and supply, where supply is a short run concept based on existing labour and capital.

Alternatively, this demand/supply balance term may be capturing other effects.

When demand exceeds supply firms may be more confident of future profits and so find it easier to justify current investment. Therefore, this term may be important because of its correlation with confidence.

Excess demand may also lead to higher profits and this may be causing higher investment. Firms could find it easier to raise debt when cash flow is high and they may fund investment from retained earnings. Just as some households may fund expenditure from current income alone, some firms (particularly unincorporated enterprises) may spend extra profits on investment.

It is very difficult to discriminate between these different explanations as to why the demand/supply term works. This is due to both measurement and conceptual difficulties. However, its inclusion in the equation is important even if the exact interpretation of its role is uncertain.

A lagged dependent variable is included because many investment projects, particularly construction projects, have a considerable gap between commitment and completion and are difficult to cancel once commenced. Additionally there is inertia apparent in investment decisions.

Finally a dummy variable **(DMIN)** is included in the equation to help capture the effects of the mining booms of the early 1970s and early 1980s.

4.3 Specification

The business investment equation in TRYM is

$$
\begin{aligned}
IB/KB(-1) = {} & RDKB + [\exp(CLAM/4) + \Delta_8 (NAP)/8]*(1-C0IB-C01IB-C02IB) \\
& + C0IB*[IB(-1)/KB(-2) - RDKB(-1)] \\
& + C01IB*[IB(-2)/KB(-3) - RDKB(-2)] \\
& + C02IB*[IB(-3)/KB(-4) - RDKB(-3)] \\
& + C5IB*\{Q(-2) + (XRITC(-2)-1)\} \\
& + C3IB*\log(GBA/YSTAR) \\
& + C4IB*DMIN
\end{aligned}
$$

where XRITC is investment tax credits.

4.4 Estimation Results:

Sample: 70:2 to 92:4		
Parameter	Estimate	t-Statistic
C0IB	0.54	5.5
C01IB	0.37	3.2
C02IB	-0.18	-1.8
RISK	2.12	0.8
C5IB	0.004	2.9
C3IB	0.047	4.9
C4IB	0.001	1.8

Diagnostic Statistics:

R^2=0.84	SE=0.17%	DW=1.79

Since the dependent variable is a *stock flow* measure, it is rather small in numerical terms, varying from 2.5 to 4.5 per cent. Hence, the estimated coefficients also tend to be small numbers. It should be noted that the coefficients of this equation cannot be interpreted in the usual manner as elasticities.

A number of observations can be made about the estimated parameters.

- The Q-ratio has a significant influence on investment. The coefficient on the Q-ratio has a large effect in the long run due to the presence of lagged dependent variables in the equation.

- The capacity utilisation rate is highly significant. A one per cent rise in demand through this term has the same effect as a rise in the Q ratio from 1.0 to 1.1.

- The risk premium is about 2 per cent per annum. This implies that, in equilibrium, business capital has to yield a rate of return which is 2.0 per cent greater than the real rate expected on government bonds in order to compensate investors for the relatively higher risk of business investment. Although RISK was not statistically significant, due to its large standard error, it was included in the equation since it produced a sensible estimate.

- The mining boom dummy variable is barely significant, but its inclusion seems sensible and improves some of the other coefficients.

- The lagged dependent structure is unusual in that the coefficients change sign as the lag length increases. The estimated parameters imply that an initial one per cent increase in investment through one of the other variables rises to an increase of over three per cent in the long run.

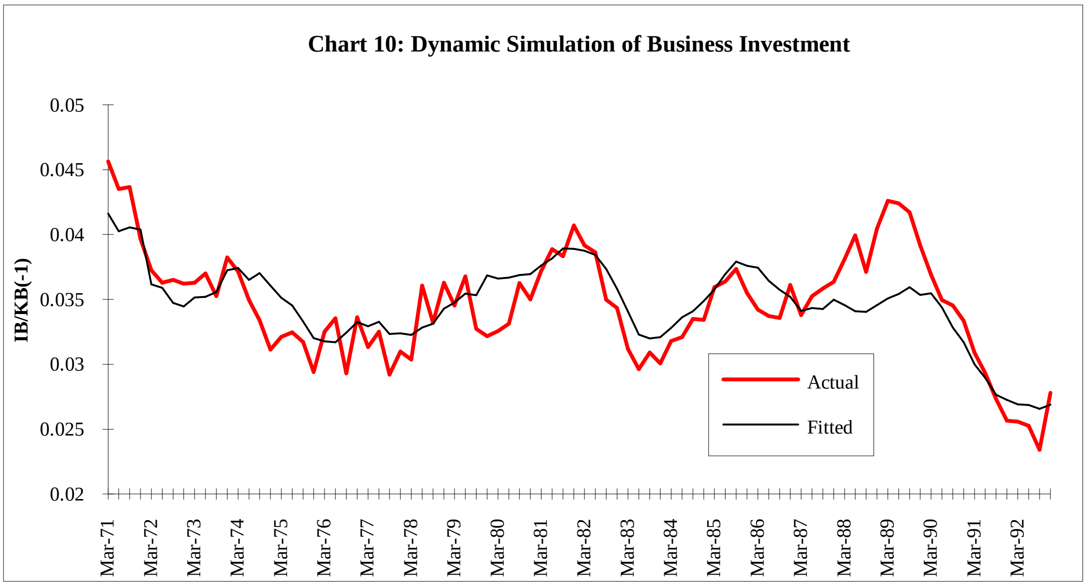


Chart 10: Dynamic Simulation of Business Investment
IB/KB(-1)
0.05
0.045
0.04
0.035
0.03
0.025
0.02
Mar-71
Mar-72
Mar-73
Mar-74
Mar-75
Mar-76
Mar-77
Mar-78
Mar-79
Mar-80
Mar-81
Mar-82
Mar-83
Mar-84
Mar-85
Mar-86
Mar-87
Mar-88
Mar-89
Mar-90
Mar-91
Mar-92
Actual
Fitted

5 PRICE EQUATION

5.1 Historical Data

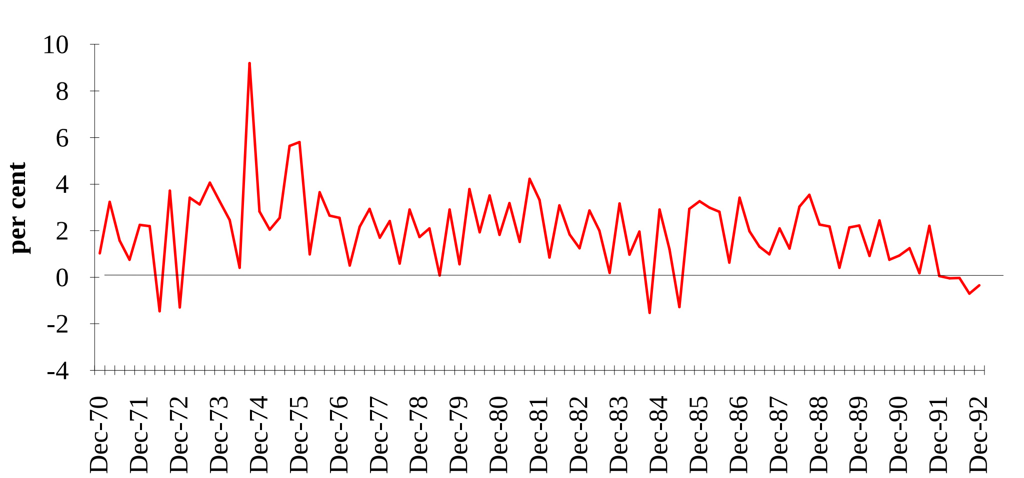


Chart 11: Change in Price of Non -Commodities

Business output covers both commodity and non-commodity production. The price of commodity output is largely determined in world markets and is analysed in TRYM Paper 4. The price of non-commodities is calculated by taking the price of business sector output and removing the effect of the price of commodity production for export. This distinction is made because, in the TRYM model, non-commodity prices are relatively sticky in the short run, while commodity prices are found to be flexible and to clear the market for commodities. In this way, the features of a 'classical' commodity sector are combined with a 'Keynesian' non-commodity sector. Chart 11 depicts the quarterly movements in the price of non-commodities. It is clear that this series, like many other price series, has considerable short term volatility that is difficult to capture in an econometric equation.

5.2 Theoretical Issues

The long run level of the price of business output (PGB) is derived as a function of nominal wages, capital stock and output by using the first order condition for labour in the CES production function, shown below. Appropriate substitution and incorporation of productivity yields the following equation.

$$PGB = [WBH*RTPRB/\exp(CLAM*QTIME)/CLAB] * [1/CLAB - (CKAP/CLAB)*(KB/GBA)^{(CSIG-1)/CSIG}]^{1/(CSIG-1)}.$$

The relationship defining the equilibrium price of non-commodities **(PSTAR)** is then obtained by removing the price effects of commodity exports **(XC)** and farm stocks **(SFM)** from the price of business sector output:

$$PSTAR=\{[WBH*RTPRB/\exp(CLAM*QTIME)/CLAB] * [1/CLAB - (CKAP/CLAB)*(KB/GBA)^{(CSIG-1)/CSIG}]^{1/(CSIG-1)}\}* GB -(XC*PCX -SFMZ)]/ (GB-XC-SFM).$$

5.3 Specification

This relationship will not necessarily hold in the short run. Rather, non-commodity prices may adjust slowly towards their equilibrium level. Reflecting this stickiness, growth in the actual price of non-commodities (**PNC**) is driven in the short run by:

- a weighted average of current and past growth in the equilibrium price of non-commodities, with contemporaneous and lag changes, with lags of up to 4 quarters;
- acceleration in import prices **(PMGS)**; and
- any past disequilibrium between the actual and desired level of PNC (with an appropriate lag).

In order to ensure that the equation exhibits homogeneity with respect to inflation, the sum of the changes in the equilibrium growth of non-commodity prices is constrained to one.

The growth in the price of non-commodities is therefore specified as

$$\begin{aligned}\Delta\log(PNC) = {} & A0PNC *\{\Delta \log(PSTAR)\} \\ & + \{1-A0PNC-A2PNC-A3PNC-A4PNC-A5PNC\}*\{\Delta \log(PSTAR(-1))\} \\ & + A2PNC*\{\Delta \log(PSTAR(-2))\} \\ & + A3PNC*\{\Delta \log(PSTAR(-3))\} \\ & + A4PNC*\{\Delta \log(PSTAR(-4))\} \\ & + A5PNC*\{\Delta \log(PSTAR(-5))\} \\ & - A6PNC*\{\Delta \log(PMGS)\} \\ & + A6PNC*\{\Delta \log(PMGS(-1))\} \\ & + C0PNC*\{\log(PSTAR(-6)) - \log(PNC(-6))\}\end{aligned}$$

5.4 Estimation Results

Results:

Sample: 70:2 to 92:4		
Parameter	Estimate	t-Statistic
A0PNC	0.323	6.06
A2PNC	-0.057	-1.05
A3PNC	0.109	1.99
A4PNC	0.189	3.59
A5PNC	0.169	3.19
C0PNC	0.036	2.10
A6PNC	0.143	4.06

Diagnostic Statistics:

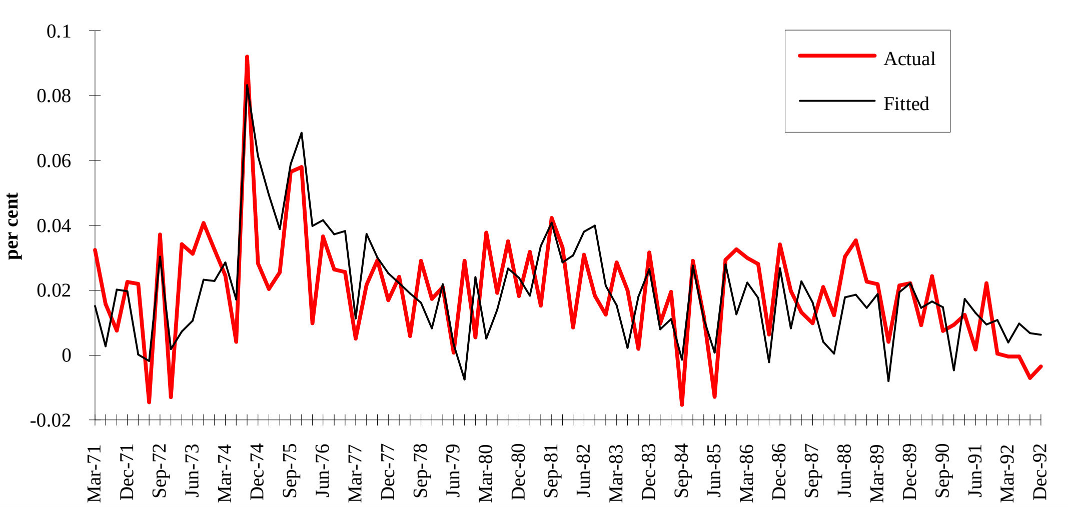
R^2=0.44	SE=1.3%	DW=1.92

The lag distribution reflecting the effect of changes in PSTAR on the growth of PNC is well determined, except for the coefficient on the second lag which is negatively signed and insignificant (A2PNC). This has been included to maintain continuity in the dynamics of PNC, even though it appears implausible. Any disequilibrium between actual and desired PNC after five quarters is only slowly eliminated - by around 3.5 per cent each quarter.

It is commonly assumed that increased import prices will result in a rise in domestic non-commodity prices. However, in this equation higher import prices lead to a lower domestic deflator for one quarter. After two quarters, however, higher import prices lead to a higher domestic price. This initial response could reflect either:

- a tendency for importers to temporarily squeeze their margins in the face of a rise in import prices in order to maintain market share; or
- the ABS method of constructing some expenditure deflators (such as the plant and equipment deflator) with lagged import prices which will introduce a negative short run correlation between import prices and the value added deflator.

Chart 12: Dynamic Simulation of the Change in Non-Commodity Prices



6 INTERPRETATION OF THE ESTIMATED COMMON PARAMETERS

The equations above, when estimated together, give estimates of the common parameters in the production functions. These results are estimated in the following table.

Parameter	Estimate	t-Statistic
CLAM	0.011	8.35
CSIG	0.755	19.24
CLAB	0.353	6.21
CKAP	0.404	9.52

The growth rate of technical efficiency, CLAM, for the private business sector, ie. underlying productivity growth, is estimated to be about 1.1 per cent per annum on average since 1970. While there is some other evidence to suggest that there has been some decline in this estimate over the sample period, there is no significant evidence for a structural break since 1980.

The elasticity of substitution between labour and capital, CSIG, is another key model parameter. It is estimated to be about 0.75. The importance of this estimate is that it implies that a real wage increase will lead to a rise in labour's share of income, consistent with events of the 1970s and 1980s.   More precisely, a 1.0 per cent increase in the real wage will raise labour's share by about 0.75 per cent (or, for example, from 60 per cent of nominal business output to 60.45 per cent).

The table below shows a comparison with other model results.

COMPARISON OF TECHNICAL PROGRESS AND FACTOR SUBSTITUTION

	TRYM	AEM	AMPS	NIF88
Annual Technical Progress (%)	1.1	0.2	1.4	1.5
Capital/Labour substitution	0.75	0.77	0.32	1.0*

* Cobb-Douglas functional form imposed.

One feature of this comparison is that the TRYM model's estimated rate of technical progress is considerably larger than that of the AEM model. One reason for the higher rate in the TRYM model and NIF 88 is the use of labour on an hours, rather than heads basis. Earlier estimates using employment in the TRYM model specification yielded estimates of about 0.9 per cent per annum. Average hours per worker have declined steadily over the sample period so that underlying labour productivity is higher than is apparent from the heads data.

7 CONCLUSION

This paper describes the equations in the TRYM model that involve decisions made by firms in the private business sector. These are the equations for private employment, private business investment and the price of private business output.

The three equations also share the common theme of reflecting the underlying production technology of firms. They all reflect supply side considerations that are very important in the Australian macroeconomy, particularly in the long run.

The paper summarises the detailed investigations that were made into the various options available for specifying the production function and the relative merits of each. The equations incorporate the following desirable production function properties.

- The business sector covers private enterprises, excluding production through the ownership of dwellings.
- Supply is a function of two factor inputs: labour and capital.
- A CES (constant elasticity of substitution) functional form is used with constant returns to scale.
- Harrod-neutral technical efficiency is used and the rate of technical progress is treated as exogenous.
- Labour input is measured using hours worked.
- Business capital is assumed to be putty-putty.
- Imports are not treated as a factor input.

The employment equation shows that the demand for labour in terms of hours worked is a function of output, real wages and efficiency in the long run. Changes in the output-capital ratio, real wages and average hours worked also have an additional effect on employment.

The private investment equation ensures that capital grows in line with output in the long run. The specification has investment being determined in the short run by: a Q-ratio that captures neo-classical variables such as wages and interest rates; a variable that reflects imbalances between demand and supply that might also capture confidence or liquidity effects; a dummy variable for mining booms; and lagged dependant variables that reflect the lumpy nature of many investment projects.

The inflation equation ensures that the price level is at a profit maximising level in the long run. In the short run, output prices are affected by the rate of change in the equilibrium price level (with lags), by acceleration in import prices and by any gap between actual and desired output prices.

These equations are all estimated on the rebased 1989-90 constant price data for the December quarter 1992 National Accounts, published in March 1993. We are very encouraged with the estimated results reported here given the new data and the limited time to explore specifications and document the results. No doubt further investigations and feedback from others will produce further improvements in the future.

8 APPENDIX

Data Construction

Private business output is constructed by taking total GDP at factor prices, subtracting general government and dwelling output and dividing the difference between public and private enterprises.

First, **dwelling output** is subtracted. The gross product by industry estimates of dwelling sector output at constant prices are rebased to factor prices. The price of private consumption of rental services is used to obtain the value of output.

Second, **general government capital output** is subtracted. The ABS assumes that the output of the general government capital stock is equal to the depreciation of that stock. The value of that depreciation is the general government gross operating surplus. The quantity of depreciation is obtained from the annual estimates of capital stocks by quarterly linear trend interpolation.

Third, **general government labour output** is subtracted. The ABS assumes that the value and quantity of this output are equal to the value and quantity of the inputs, with productivity reflecting compositional movements. Total public sector employment is obtained from ABS surveys plus defence force employment. It is split using the general government and public enterprise shares of the annual total public sector wages bill. The quarterly public sector wage rate is derived from the implicit annual rate by using quarterly linear trend interpolation on the ratio of the public to award wages. The value of expenditure is the product of the employment and wages series.

Fourth, the ratio of public enterprise output to private enterprise output (excluding dwelling output) was constructed. Both these series are available in current factor prices. Constant prices output by industry rescaled to factor prices was split into private and public enterprise components according to shares of annual nominal output. The exception was the Finance, Property and Business Services industry where, because of the presence of persistently large negative public gross operating surpluses, the nominal wages bill was used to split the quarterly output.

These ratios were used to split GDP excluding dwellings into **public enterprise** and **private enterprise** components.

Labour

Private employment was derived by subtracting public employment from total employment. The implicit level of wages, salaries and supplements per wage and salary earner was calculated for the whole private sector and that level of labour income was attributed to every employed person in the private sector. Payroll taxes were split between public and private enterprises according to their wage bills and then shared among all private employment on a pro-rata basis.

Capital

Private business fixed capital consists of plant and equipment and buildings and structures. The rebasing of the National Accounts required Modelling Section to construct its own series for capital stock, since an ABS series was unavailable. The ABS constructs a measure of the stock of physical capital using mean asset lives equal to about 1.5 times the asset lives used for taxation purposes. The corresponding capital-output ratio rises almost continuously except for a period after the 1982-83 recession. From a production system point of view this rise seems implausible given the seemingly low levels of investment during parts of the 1970s and 1980s and a decision was made to use a different measure of the capital stock.

The capital stocks used in the TRYM model are constructed using the taxation office asset lives, ie. the depreciation rates implicit in the ABS series are multiplied by 1.5. Capital is treated as depreciating geometrically.

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