# Independent Macro Model

This paper provides information on the Independent macro-econometric model, including the recent extensions in the second edition of the model to incorporate semi-endogenous economic growth.

## A.1 Economy-wide modelling methodology

The Independent Macro-econometric model (Macro Model) is Independent Economics' forecasting and policy model. It uses economic principles and evidence from the historical data to capture the broad workings of the Australian economy. This makes it a powerful tool to enhance the robustness of economic forecasting whether the time horizon is short (to 2015) or long (to 2050). Notably, the approach taken is rigorous in its application of economic theory; this means that it also delivers powerful insights into fiscal and monetary policies. For example, the six-sector Macro Model converges to a balanced growth path. In addition, a separate demographic model is used to provide population inputs and to determine long-term trends in the participation rate.

In the Macro Model, households, firms, the government and foreign agents interact in factor, product and financial markets. The role of each agent is discussed, in turn, below. This is followed by a discussion of the model's market clearing mechanisms.

### A.1.1 Economic Agents

*Households*

Households supply labour, own capital and government bonds, purchase goods and services from businesses and pay taxes to government.

The household's inter-temporal budget constraint is imposed by assuming that households have a savings target. This savings target is defined as the locally-owned stock of produced capital expressed as a multiple of labour income and its value is estimated from historical data. Since there is a target for the stock of capital that households hold, changes in the government's debt position do not affect the household's stock of real assets in the long run. Consumption gradually adjusts so that this savings target is gradually met. Consumption is positively affected by income from labour, produced capital, natural resources and bonds and transfers. Conversely, consumption is negatively affected by unanticipated inflation.

Once the aggregate level of consumption is determined it is allocated across the six industries identified in the model (Agriculture, Mining, Manufacturing, Government services and Housing services). Households choose their allocation to maximise a Constant Elasticity of Substitution (CES) utility function.

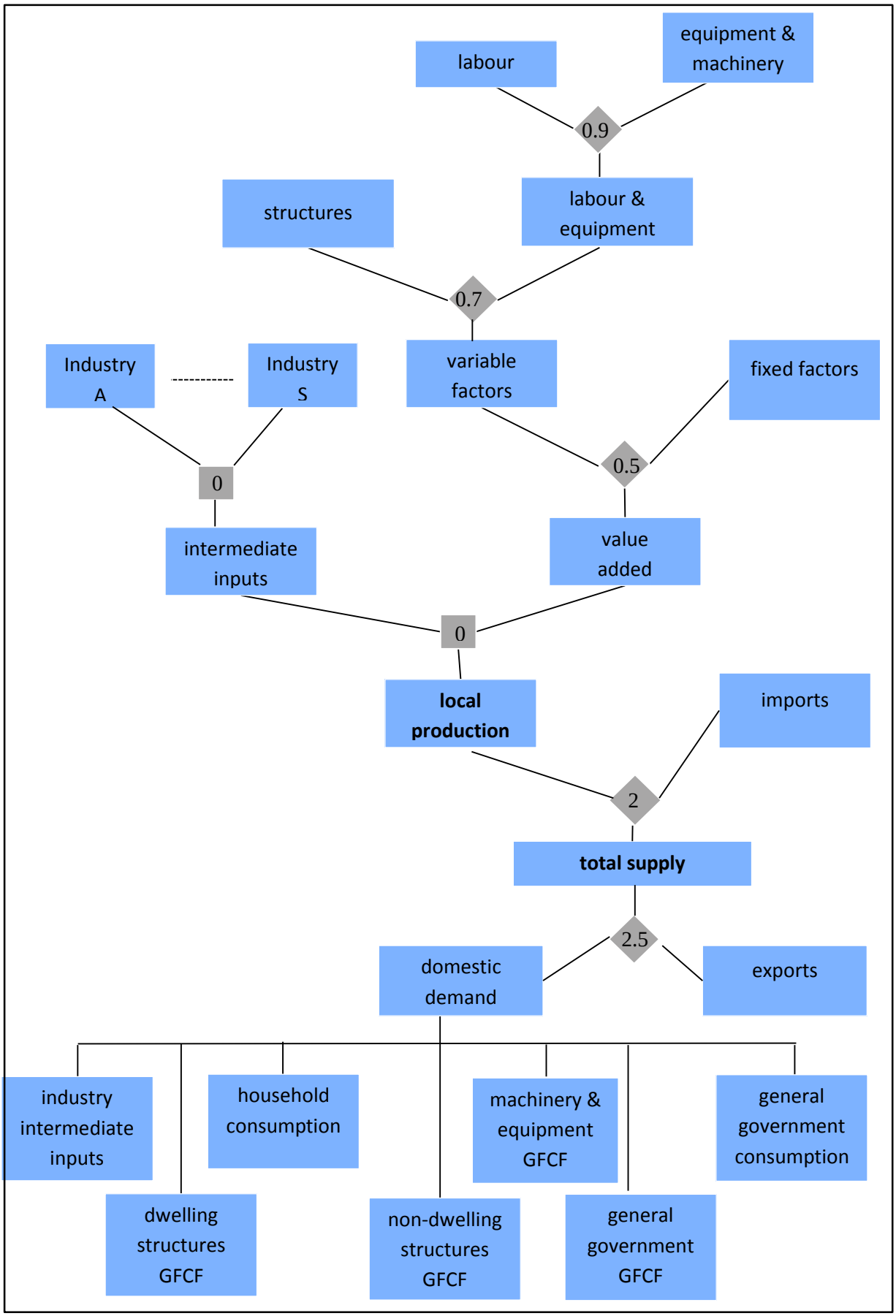
Labour supply is determined by the age, gender and education structure of the population, underlying trends in the participation rate and an encouraged worker effect.

### *Businesses*

A representative business in each industry produces goods and services using labour, natural resources, structures, other types of capital and intermediate inputs. The six industries featured in the Independent Macro-econometric model are based on the latest Australian and New Zealand Standard Industrial Classification (ANZSIC 2006). The mapping between the model's industries and ANZSIC 2006 industries is shown in the table below.

| Macro Model Industry | ANZSIC2006 Industries | ANZSIC2006 Codes |
|---|---|---|
| Agriculture (A) | Agriculture, forestry & fishing | A |
| Mining (B) | Mining | B |
| Manufacturing (C) | Manufacturing | C |
| Government services (G) | Public administration & safety<br>Education & training<br>Health care & social assistance | O<br>P<br>Q |
| Other Service Industries (S) | Electricity, gas, water & waste services<br>Construction<br>Wholesale trade<br>Retail trade<br>Accommodation and food services<br>Transport, postal and warehousing<br>Information media & telecommunications<br>Financial & insurance services<br>Rental, hiring & real estate services<br>Professional, scientific & technical services<br>Administrative and support services<br>Arts and recreation services<br>Other services | D<br>E<br>F<br>G<br>H<br>I<br>J<br>K<br>L<br>M<br>N<br>R<br>S |
| Housing services (T) | Ownership of Dwellings | - |

The production technology for a typical industry in the Independent Macro-econometric model is shown in the figure below.


labour
equipment & machinery
0.9
structures
labour & equipment
0.7
Industry A
Industry S
variable factors
fixed factors
0
0.5
intermediate inputs
value added
0
local production
imports
2
total supply
2.5
domestic demand
exports
industry intermediate inputs
household consumption
machinery & equipment GFCF
general government consumption
dwelling structures GFCF
non-dwelling structures GFCF
general government GFCF

A representative business in each industry combines labour and non-structures capital (including machinery and equipment) into a labour and equipment bundle using a Constant Elasticity of Substitution (CES) technology with an elasticity of substitution of 0.9. Similarly, structures and the labour and equipment bundle are combined using CES technology to produce a variable factors bundle. Notably, this variable factors bundle is then combined with fixed factors to produce value added. The explicit modelling of fixed factors in production is a key feature of the Independent Macro-econometric model and is important in allowing for the role of land supply in the housing services sector and the role of mineral resources supply in the mining sector.

Local production is derived by combining value added and intermediate inputs in fixed proportions, a standard assumption in these types of models. A CES function is also used by firms to produce total supply from local production and imports. A high elasticity of substitution (2) is assumed between local production and imports. Finally, domestic businesses decide whether to sell on the domestic or export market based on a Constant Elasticity of Transformation technology, with an elasticity of transformation of 2.5.

In the short term, the quantity of output produced is determined by demand. Businesses are also constrained by the amount of capital they own. Thus, businesses choose the profit maximising level of labour, imports and exports based on a given level of domestic demand, capital, fixed factors, wages, and trade prices.

Over time, domestic prices adjust to equal marginal cost. In addition, the capital stock gradually adjusts so that the marginal product of capital is equal to its user cost. A Tobin's Q formulation is used to model capital stock adjustment. Importantly, the adjustment speed of domestic prices and the capital stock is estimated from quarterly historical data. This means that over time, the short-term constraints on firms are removed and firms simply maximise profits subject to the production technology.

### *Government*

Governments collect taxes from households and businesses, purchase goods and services on behalf of households, invest in the economy, provide transfers to households, borrow from households, and set monetary policy.

The Independent Macro-econometric model recognises the key taxes collected by government and models their impact on behaviour. For example, the model forecasts revenue collections from the corporate income tax and recognises that corporate income tax affects the cost of capital and thus impacts investment decisions. Other taxes recognised in the Independent Macro-econometric model are labour income tax, production taxes by industry, and product taxes by end user.

Similar to households, the government's inter-temporal budget constraint is met by specifying a target deficit relative to nominal GDP. Labour income tax is the swing fiscal policy instrument and gradually adjusts to ensure that the deficit target is met in the long term.

Monetary policy in the Independent Macro-econometric model mimics how the Reserve Bank of Australia (RBA) pursues its inflation-targeting policy. Specifically, a Taylor rule is used to determine how the short-term interest rate reacts to deviations of inflation and the unemployment from their targets. The inflation target is set to 2.5 per cent, the mid-point of the RBA's target band, while the target unemployment rate is the NAIRU, which is estimated from historical data. The responsiveness of the short-term interest rates to deviations of the inflation rate and unemployment rate from their

respective targets is estimated using historical data from the mid-1990s, since this is when the RBA's inflation targeting regime began in earnest.

#### *Foreign sector*

The foreign sector provides funds, demands exports and supplies imports. As a small country, Australia is assumed to be a price taker for imports. However, it is assumed that Australia has some market power in export markets. That is, an increase in the volume of exports supplied by Australia leads to a small reduction in export prices.

Since households and the government meet their budget constraints in the long term, this means that external balance is also achieved in the long term and growth in net foreign liabilities is sustainable.

### A.1.2 Market clearing

There are three key types of markets in the Independent Macro-econometric model, the labour market, the goods markets and asset markets. For each, prices adjust to clear the market.

Wages are 'sticky' and gradually adjust to clear the labour market. An inflation-expectations augmented Phillips curve is used to model wage adjustment. In the long-run, wage growth is driven by consumer price inflation and growth in labour efficiency and the unemployment rate settles to the NAIRU.

As noted previously, in the short-term demand drives activity so that demand shocks cause business cycles. Over time, prices gradually adjust to clear the goods market. This means that, in the long term, activity is driven by supply-side factors such as the level of population, participation, productivity and the fixed factor.

In asset markets, the rate of return on capital is determined exogenously since Australia is a small, open economy. For financial assets, the rate of return on long-term bonds is based on the expectations theory of the term structure. Uncovered interest rate parity is used in determining the nominal exchange rate. The underlying assumption is that long-term domestic securities, short-term domestic securities and short-term foreign securities are perfectly substitutable.

### A.1.3 Empirical aspects

Behavioural equations in the Independent Macro-econometric model are estimated econometrically from quarterly data starting, in most cases, from the early 1980s. The general-to-specific approach to incorporating dynamic adjustment is used, so that dynamics are fully captured. Diagnostic tests are performed on each estimated equation to check for model adequacy and statistical fit. This high level of data consistency means that the model is not only suitable for policy analysis, but also for forecasting.

## A.2 Extensions to the Macro Model

Extending the Macro Model to incorporate semi-endogenous growth involves two separate elements of development work. The first is to explicitly model the link between government education funding and the education attainment of the population. The links between greater education attainment and more favourable labour market outcomes are also incorporated into the model. The second is to extend the firm's production technology to capture the effects of R&D investment on productivity growth.

In addition, the model is extended to capture economies of scale from government investment in public infrastructure. The production technology includes fixed factors, leading to diseconomies of scale. Introducing economies of scale allows the model to provide more robust estimates of the effects of policies, such as migration policies, which change the size of the Australian economy.

The extensions to the model are discussed in the following subsections. The diagram below summarises the structure of the extended Macro Model.

### A.2.1 Human Capital Accumulation

An education attainment module is used to estimate the effects on changes in government funding on the education attainment of the population by gender by age. Ten age groups and three education attainment levels are separately identified in the module. These education attainment groups are based on an aggregation of the Australian Bureau of Statistics (ABS) Australian Standard Classification of Education.

Several assumptions have been made to simplify the analysis of human capital accumulation. The main assumption is that there is excess demand for education, so that an increase in education funding by government always results in a boost to the number of students.

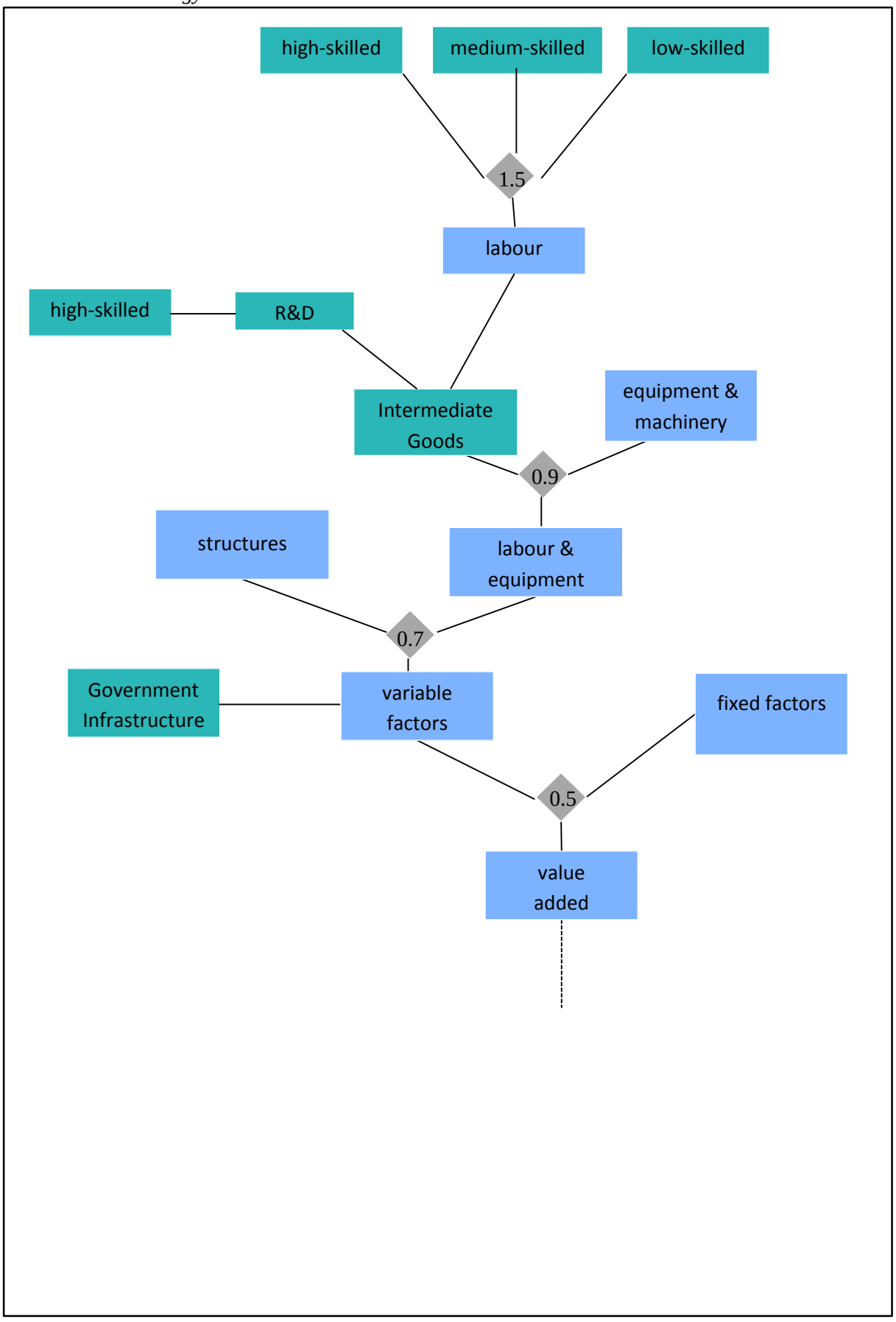
Higher education attainment leads to more favourable labour market outcomes since more educated individuals have: higher participation rates, lower unemployment rates, have greater productivity and work higher hours on average (e.g. more likely to be employed full time). The first three effects are allowed for in the extended Macro Model through the addition of heterogeneous labour. A boost to the number of university educated individuals lead to an increase in the number of high-skilled labour. In the Macro Model high skilled labour have higher participation rates, a lower sustainable rate of unemployment and are more productive than their counterparts.

The standard version of the model has a single type of labour, while the extended Macro Model features three types of labour, high-skilled, medium-skilled and low-skilled labour. The labour types are based on an aggregation of the ABS occupation classification (ANZSCO).

As noted earlier, a boost in the education attainment of the population leads to a lift in the supply of high-skilled workers. The channels through which this occurs are now discussed.

The projection of population by education attainment is converted into a projection of labour force by education attainment by modelling the participation rate for each education attainment level using an error correction model.

*Production technology in the extended Macro Model*



The labour force by education attainment projection is then converted to a labour force by occupation measure using a matrix of occupation proportions for each education attainment. This assumes that the relationship between education and occupations is fixed. Other approaches allow for some flexibility in the mapping between education and occupations. However, for simplicity that approach is not pursued here.

Notably, the majority of university-qualified individuals go on to high-skilled jobs. While the majority of VET-qualified individuals go on to medium-skilled jobs, a substantial proportion also fills low-skilled jobs.

On the demand side, firms demand each of the three types of workers and combine them into a labour bundle using CES production technology. Thus, the three types of workers are not perfectly substitutable for one another, even after allowing for productivity differences between them.

In the short term, demand for a particular type of labour or occupation depends on that occupation's relative wage and the pattern of industry demand. For example, high-skilled workers are an important input into the Government Services industry, making up approximately 50% of all employment in this industry. A boost in government spending would increase the size of the Government Services industry and hence demand for high-skilled workers. Over time, wages adjust to clear the labour market and the level of employment in each occupation is driven by supply-side factors such as the pattern of education attainment of the labour force. The wage adjustment for each type of labour is modelled as an augmented Phillips curve, while the adjustment from actual to equilibrium labour demand is modelled as an error correction model.

### A.2.2 Research & Development

To introduce endogenous growth from R&D into the Macro Model, we broadly follow the semi-endogenous growth approach used by Varga & Veld (2011). This involves extending the model to include a monopolistically competitive "intermediate goods" sector and a R&D sector, which then interact with the labour and machinery & equipment "nest" of the standard Macro Model. The new sectors are discussed in this subsection.

#### *Extended labour and machinery & equipment nest*

The labour and machinery & equipment nest now becomes an intermediate goods and machinery & equipment nest. There is a spectrum of differentiated intermediate goods, which are not perfectly substitutable. The number of intermediate goods is determined by the number of patents produced by the R&D sector.

#### *Intermediate goods sector*

A spectrum of intermediate goods firms purchase a patent from the R&D sector and then use a unit of the labour bundle to produce a unit of the intermediate good. Since these firms produce a differentiated product that are not perfect substitutes, rents are able to be extracted when they sell the intermediate good to firms in the machinery and equipment nest. Intermediate goods firms are constrained by a production technology where a unit of the labour bundle is used to produce a unit of the intermediate good.

Free entry into the intermediate goods industry drives profits to zero. This implies that the price of a patent is the discounted present value of the monopolistic producers profit flow.

*Research & Development sector*

This sector uses high-skilled labour to produce patents that are then used by the intermediate goods sector.

In the short to medium term, the profit maximising decisions of firms determine the pace of technological progress. However, in the long term, the pace of growth is determined by growth in the labour supply and growth in the stock of knowledge in the rest of the world, both of which are taken to be exogenous.

This setup is similar to that used by other large scale models to introduce endogenous growth. The Macro Model's approach differs in the following respects. Firstly, other models generally have a single aggregated industry and hence a single R&D sector. In contrast, the Macro Model has five industries which utilise labour and each has its own R&D sector. It is assumed that there are no spillovers across industries. Secondly, the production technology in the Macro Model uses a detailed nested CES structure, while other models use a Cobb-Douglas technology. Balanced growth in a model using the CES production technology requires that innovations are labour augmenting (i.e. Harrod-neutral technical progress).

### A.2.3 Government Investment in infrastructure

The standard version of the Macro Model treats the effects of a rise in general government consumption and general government investment in broadly the same manner. That is, general government investment does not result in an increase in the capital stock of the economy. This assumption is relaxed in the extended macro model. Government investment in infrastructure such as transport is capitalised and is incorporated into each firm's production function. In addition, economies of scale in government infrastructure are allowed for by incorporating the presence of fixed costs.

Government infrastructure is introduced in this nesting because it has similar production characteristics to structures and structures forms part of the variable factors bundle. Notably, the chosen production technology means that there are still constant returns to scale in the private factors; a relatively strong assumption. This implementation was chosen because it is one of the more straightforward methods of incorporating the presence of fixed costs and follows the approach used by Ratto et.al. (2008) to allow for overhead labour costs.