A new generation of scientists? The impact of STEM-qualified workers on the Australian economy

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Abstract

Developing capacity in "STEM" (Science, Technology, Engineering and Mathematics) is often considered by policy makers to be a panacea for economic growth. We investigate the potential impacts on the Australian economy of a hypothetical stimulus to the STEM sector using the single-region, dynamic Victoria University (VU) model of the Australian economy.

We consider two scenarios. In the first, we explore the potential for growth through building up the supply of STEM qualified workers. We find a positive deviation in GDP from the business-as-usual forecast in the medium term. The benefit to the economy of additional STEM qualified workers gradually declines as the supply of these workers grows, until the average wage received by STEM workers, initially more than the national average, falls to below the national average wage. For every additional STEM worker, demographic constraints mean that the economy loses a non-STEM worker – perhaps an artist, a labourer, or a hairdresser. In the long run, this has a negative impact.

In the second scenario, we analyse the impact of a boost to demand for exports of STEM commodities. The scenario is set up to reflect a compositional change only, with the demand for non-STEM exports declining so that the terms of trade index remains on its business-as-usual forecast trajectory. Over the forecast period of 20 years, we find that this compositional change has a positive impact on economic growth.

In addition to the usual CGE framework embedded in the 115-industry VU model, in this project we use two detailed industry by occupation matrices, the first specified in wage bill weights and the second in head counts. For these matrices, 97 occupations are identified. Furthermore, we utilise matrices of occupation by skill in wage bill and head count weights, in which 56 "skills" are identified, comprised of 11 fields of study cross-classified by 5 levels of attainment and a final category for no post-school qualification.

1 Introduction

Science, Technology, Engineering and Mathematics – the “STEM” skills – play an increasingly important role in the Australian economy. Growth in occupations employing “scientists, ICT professionals and engineers (has been) about 1.5 times the rate of other jobs in recent years” (ABS 2014). An extrapolation of this trend is used to support claims such as this recent statement from The Australian Industry Group that

> *there is an urgent need to develop a national STEM skills strategy to lift the level of STEM qualified employees in the workforce (AIG 2015).*

Using a detailed CGE model of the Australian economy, we investigate the wider impact of potential stimuli to the STEM sector. We investigate two scenarios in which there is greater supply of STEM-qualified workers, and a final scenario in which there is both increased supply of STEM workers and greater demand for STEM output.

We find that if the proportion of STEM-qualified workers in the population grows more quickly, there is a short to medium term benefit to the economy. However, over time as STEM qualified workers become more abundant, this benefit diminishes. This result shows that a partial approach to supporting STEM activity – to bias skill acquisition patterns in favour of STEM – may do more harm than good if not matched by an appropriate demand response.

However, if the composition of export demand is biased towards STEM industries, there is ongoing benefit to the economy. Further, if there is stimulus both to the supply of STEM workers and to demand for STEM commodities, the impact on economic growth is greater still. This result supports Australia’s Chief Scientist in calling for a “strategic approach to STEM”. In particular, the simulations illustrate the downside of systematically encouraging people down a particular path of skill acquisition, if demand for these skills is already being adequately met.

Explicit resource constraints are an important feature of the CGE approach in the context of this modelling. Because we recognise that the size of the labour market is exogenous to the model, the opportunity cost of one type of skill acquisition – the acquisition of STEM skills – is the loss of another type of skill. As such, the benefit of extra STEM-qualified workers is eventually outweighed by the loss of relatively scarce non-STEM-qualified workers.

An obvious and much vaunted consequence of STEM skilled workers is the impact that they can have on the development of new technology, which can have a positive impact on productivity. In these simulations, we do not account for any feedback from STEM workforce into technological gains leading to productivity improvements. This link is worthy of further investigation. However, increasing the domestic supply of STEM-qualified workers is not the only path to reaping productivity gains from technological advances. Efforts to improve computing and communications, find a cure for cancer, or create drought or disease resistant crops are not confined to Australia. By running this analysis with exogenous productivity growth, in effect we assume that the technological means to productivity improvements are largely imported.

2 Modelling

The VIC-UNI model of the Australian economy is used to build several forecast scenarios for the Australian economy to 2035. VIC-UNI is a 115-industry, single-region model based on its predecessor, the MONASH model of the Australian economy (Dixon and Rimmer 2002). The version of the VIC-UNI model used for this analysis is distinguished by its very detailed treatment of the labour market. The model is solved in GEMPACK (Harrison and Pearson 1996).

Apart from the labour supply module, the model theory is described in detail in Dixon and Rimmer (2002) and again in less detail in J.Dixon et al (2014). The theory governing labour supply is set out in Section 2.1, and the data requirements to satisfy the labour market supply module are described in Section 2.2. The full baseline for the simulation is based on J.Dixon et al (2014) and is briefly described in Section 2.3.

2.1 The labour market

The VIC-UNI model uses a nested production function to determine demand for inputs – intermediate inputs of domestic and imported goods, capital, land, labour, and other costs. This production structure is routinely used in CGE models and is described in more detail in Dixon et al (1982) or Horridge (2006). As is typical, the labour input is a CES composite of several occupations. In this version of VIC-UNI, 97 occupations are identified, corresponding with the ANZSCO "Minor group" classification.[1]

2.1.1 The market for labour units

The production function suggests a relationship between employment and wages, but on its own, can only determine one or the other. One of two closure choices must be used: quantity is exogenous and the occupation wage is endogenous (a typical long run closure), or quantity is endogenous and the occupation wage is exogenous (a typical short run closure). In this paper, we introduce some endogeneity into the supply of occupations using a variation on Meagher and Pang's (2011) skills supply method. The labour force is categorised by skill, where a skill is defined as a post-school qualification distinguished by both level and subject matter, for example "Post-Graduate Degree, Natural and Physical Sciences", or "Certificate Level, Food Hospitality and Personal Services". The skill fields correspond to the Australian Standard Classification of Education (ASCED) Broad fields, of which there are 11,[2] and the levels correspond to ASCED Broad Levels, of which there are 5 post-school categories. In total, there are 11 * 5 = 55 post-school skill categories, and one category for "no post-school education", for a total of 56 categories.

Each skill supplies labour to the occupations according to a Constant Elasticity of Transformation (CET) function (Powell and Gruen, 1968). A "unit" of labour is defined as the amount of labour worth a set amount (say $1) in the model's initial database. The time required to supply a unit of labour varies across occupation and skill categories. For example, if a unit of labour supplied by a person with skill type Q2IT_GRD to occupation "PRO_Bus_Fina" is equivalent to 10 minutes of work,

[1] See Appendix for occupation descriptions and VU model code names
[2] excluding "Mixed Field Programmes"

then a unit of labour of occupation “LAB_other_frei” with skill “Q3ENG_Q5CER” is equivalent to 72 minutes of work.

An increase in the demand for any particular occupation relative to others exerts upward pressure on its relative wage, attracting more labour units to that occupation. However, labour can only be supplied to that occupation from the skill groups that supply that occupation in the initial database. More formally, a revenue maximising agent (in this case, a skill cohort) supplies products (in this case, units of labour) so that

$$\frac{A_{o1,s}}{A_{o2,s}}\left(\frac{L_{o2,s}}{L_{o1,s}}\right)^{k} = \frac{W_{o1,s}}{W_{o2,s}} \tag{1}$$

for any pair of occupations *o1* and *o2*, where the agent (the skill cohort) is operating under the CET frontier given by

$$\sum_{o\in OCC} A_{os} L_{os}^{1-k} = B_s(1-k) \tag{2}$$

in which L_{os} is the total labour units supplied by skill cohort s to occupation o;

A_{os} and B_s are parameters governing the position of the CET frontier;

$k = -1/\tau$ where τ is the CET parameter and $\tau>0$;

and W_{os} is the wage rate per labour unit for occupation *o* with skill *s*.

This leads to the percentage change form (with lowercase representing percentage change of the corresponding uppercase)

$$l_{os} = \frac{\tau}{\tau+1} b_s + \tau\left(w_{os} - \sum_{j\epsilon OCC} S_{js} w_{js}\right) \tag{3}$$

Where $S_{os} = \frac{VSKILL_{os}}{\sum_{k\epsilon OCC} VSKILL_{ks}}$ is the wage-bill weighted share of occupation o in skill s, where $VSKILL_{os}$ is aggregate wage payments to occupation o, skill s.

Weighting (3) by wage-bill shares and adding over occupations reveals that $\frac{\tau}{\tau+1} b_s$ is the percentage change in total labour is skill cohort *s*, by *wage-bill* weights.[3]

Following from ORANI, demand for labour by industry *i* is derived from the CES specification, as follows:

$$l\_s_{io} = l\_os_i - \theta(w\_s_{io} - \sum_{k\in OCC} SI_{ik} w\_s_{ik}) \tag{4}$$

where l_s_{io} is the skills composite of labour of occupation o used in industry *i*, l_os_i is the skills and occupation composite of labour used in industry *i*, and w_s_{io} is the skills composite wage of labour of occupation o used in industry *i*. The share term SI_{ik} is given by

[3] Note that we never require data for L_{js} or W_j separately. The data requirement is for the product $L_{js}W_j$ which is the aggregate wage bill for labour of occupation j and skill s. Note also that data values for the original parameters A_{js} and B_s are not required in the percentage change solution. We assume that $\tau=2$.

$$SI_{ik} = \frac{VLAB_{ik}}{\sum_{j \in OCC} VLAB_{ij}}$$

where $VLAB_{io}$ is the wage bill for industry i's use of occupation o.

Setting the total industry wage bill for each occupation equal to the total wage income over skills for each occupation, in percentage change form gives

$$\sum_{i \in IND} VLAB_{io}(l\_s_{io} + w\_s_{io}) = \sum_{s \in SKILL} L_{js} W_{js}(l_{os} + w_{os}) \quad (5)$$

If we assume that a unit of labour of occupation o is homogenous over all skills, we can assume that

$$w_{os} = fw\_s_o. \quad (6)$$

Note that w_{os} is the price of a *unit* of labour. Across skill types, the capacity of persons to supply units of labour is varied, as is picked up in variations in skill-specific occupation wages. In equation (5) we assume that the percentage change in the price of a labour unit is invariant to the skill of the person supplying that unit.

Assuming perfect competition between industries for a unit of labour of occupation o, we can assume that

$$w\_s_{io} = fw\_s_o \quad (7)$$

2.1.2 Conversion to Persons

Policy-makers and other users of model output are generally interested in measuring employment in persons rather than labour units.

We assume that the percentage change in labour units of skill type s in occupation o is equivalent to the percentage change in hours worked in this skill and occupation type. That is,

$$pers_{os} + hpp = l_{os} \quad (8)$$

where $pers_{os}$ is the percentage change in the number of persons with skill type s working in occupation o ($PERS_{os}$), and hpp is the percentage change in hours worked per person (typically exogenous). Note that hpp is assumed to be uniform across all skills and occupations. Estimates for hpp are based on external forecasts.

Setting the total number of persons supplied to occupation o to the total number employed by industry,

$$\sum_{s \in SKILL} PERS_{os} pers_{os} = \sum_{i \in IND} PERS\_S_{io} pers\_s_{io} \quad (9)$$

where $pers\_s_{io}$ is the percentage change in the number of persons of occupation o working in industry i ($PERS\_S_{io}$).

The skill composition of labour of occupation o working in industry i varies across industries. Furthermore, if the skill composition changes, then in general $pers\_s_{io} \neq l\_s_{io}$. Without explicitly modelling industry substitution between skill types, we account for the change in the skill composition of occupations by assuming that

$$pers\_s_{io} = l\_s_{io} + f\_pers_o \tag{10}$$

The restrictions imposed by equation (5) enable f_pers_o to be estimated.

Finally, some aggregates of interest are calculated. Equation (11) is the percentage change in total labour for any skill cohort by *person* weights. That is,

$$\left(\sum_{o\in OCC} PERS_{os}\right)pers\_o_s = \sum_{o\in OCC} PERS_{os}pers_{os} \tag{11}$$

The aggregate constraint on labour is given by

$$\left(\sum_{o\in OCC}\sum_{s\in SKILL} PERS_{os}\right)pers\_os = \sum_{s\in SKILL}\sum_{o\in OCC} PERS_{os}pers_{os} \tag{12}$$

With this aggregate constraint in place, if we set *pers_os* exogenously then one element of $pers\_o_s$ needs to be endogenous. In the model we achieve this by adding an extra degree of freedom via

$$skillrat_s = pers\_o_s - pers\_os + fskill \tag{13}$$

We set $skillrat_s$ and $pers_{os}$ exogenously, letting fskill adjust to find the appropriate values for $pers\_o_s$. With $pers\_o_s$ determined this way, equation (11) can be thought of as explaining b_s.

Equations (3) to (13) set out the labour supply module of the model. In the base simulation, the closure is as follows:

Exogenous		**Endogenous**		
Variable	**Dimension**	**Variable**	**Dimension**	**Matched equation**
pers_o	SKILL	*l*	SKILL*OCC	3
fskill	1	*l_s*	IND*OCC	4
l_os[4]	IND	*f_pers*	OCC	5
hpp	1	*w*	SKILL*OCC	6
		w_s	IND*OCC	7
		pers	SKILL*OCC	8
		fw_s	OCC	9
		pers_s	IND*OCC	10
		b	SKILL	11
		pers_os	1	12
		skillrat	SKILL	13

[4] Labour usage by industry (l_os(i)) is actually endogenously determined elsewhere in the model, but can be taken as exogenous in the context of the labour supply module. If the labour module was to be taken as a self-contained system, at least one element of l_os would need to be endogenous to avoid a singularity problem, given that total labour is tied down by the exogeneity of pers_o. (Alternatively an endogenous uniform shifter on the elements of l_os would provide a more elegant solution.) The system would be closed by exogenising one element of fw_s.

Boeters and Savard (2013) describe similar approaches to modelling labour supply and demand in CGE models, such as that adopted by Giesecke et al (2015) in modelling the Vietnamese economy. Although the labour supply equations differ,[5] in both models, supply to an occupation responds positively to an increase in the relative wage of that occupation. Conceptually, Giesecke et al (2015) view the supply of labour to an occupation as a utility maximisation problem in which "workers view wages earned in different occupations as imperfect substitutes." The transformation approach taken in this paper (equation 3) is based on the view that workers within a skill cohort have differentiated ability or willingness to supply labour to various occupations.

To complete the system of equations in Giesecke et al (2015), an equation defining demand for labour by occupation and skill is required. An equation such as this is not necessary in the current system. The variable f_pers_o in equation (10) captures the change in the skill composition of labour units without the need to explicitly define demand for labour classified by skill and occupation.

The STEM skill supply shock is activated by two closure swaps. Firstly, we swap the scalar *pers_os* with *fskill*. This invokes the aggregate labour supply constraint. With *fskill* endogenous, $skillrat_s$ is no longer equal to the ratio of skill type *s* to total employment. We exogenise $skillrat_s$ and endogenise $pers\_o_s$. The STEM supply shock is implemented via a uniform shock to $skillrat_s$ where *s* is an element of the set of STEM skills (a subset of SKILL). The endogenous scalar *fskill* ensures that the supply of non-STEM skills adjusts to accommodate the extra supply of STEM skills under the aggregate labour supply constraint. Under this closure, a shock to $skillrat_s$ ($s \in$ STEM) of 1 per cent means that the *difference* between share in total employment of STEM skills and non-STEM skills grows by 1 per cent, for example, the share of STEM skills grows by 0.8 per cent and the share of non-STEM skills falls by 0.2 per cent. The exact result depends on the original shares.

2.2 Labour data

A large amount of data is required to support the labour market module. Along with the industry by occupation wage bills ($VLAB_{io}$), for equation (4) we require data for the total wage bill classified by occupation and skill ($VSKILL_{os}$) for equation (3). For equations (9) we require head-counts classified by occupation and skill ($PERS_{os}$) and occupation and industry ($PERS\_S_{io}$).

2.2.1 Industry by occupation wage bills

Industry wage bills are available in the standard input-output table. We need to disaggregate the wage bill by occupation.

Both census data and labour force data provide head-counts cross classified by industry and occupation. The census data contains data at the required level of detail (115 industries and 97 occupations), most recently for year 2011. The labour force data is updated and released quarterly, and can be used to obtain head-counts at the required level of detail by industry or occupation, but

[5] Giesecke's equation (4) converted to the current notation states $pers_{os} = pers\_o_s + \phi_{os}\left(w_{os} - \sum_{j\epsilon OCC}\frac{PERS_{js}}{\sum_{k\epsilon OCC}PERS_{ks}}w_{js}\right)$ which has obvious parallels to equation (3) in this paper. However, the two equations are not quite equivalent.

not cross-classified. A RAS procedure can be used to scale the detailed census data to match the more recent control totals.

The industry by occupation head counts need to be converted to wage bills. Available data for average occupation wage at the ANZSCO sub-major group (43 occupations) is used to calculate wage relativities. These are calibrated to hit the total industry wage bills given in the input-output table. This approach implies that occupation wages are not uniform across industries, although in our modelling we typically assume that percentage changes in occupation wages are uniform across industries.

2.2.2 Skill by occupation data

As for industry by occupation data, head counts of skill by occupation are relatively simple to extract from census and labour force data. Estimation of the wage bill for skill by occupation data requires some assumptions.

From the industry by occupation wage bills, we know the total wage bill classified by occupation. We now need to disaggregate this wage bill by skill. Values were assumed for the wage premiums for the various qualification levels. These premiums were assumed to be uniform over the qualification fields within each qualification level. The wage bill data was then calibrated to reflect the wage premiums and the total occupation wage bills as required.

2.3 Baseline

The base period for the model is FY 2014 and solutions are generated for every year to 2035. The baseline represents an estimate of business-as-usual and has been set up to reflect the following assumptions about structural change in the Australian economy. These are summarised in Table 1 below and discussed in more detail in J.Dixon et al (2014).

Table 1: Key settings in the baseline

	Phase 1: 2015-2020	**Phase 2: 2021-35**
population growth	total, working age and aged population, (ABS, 2013b) Series B	As for Phase 1
participation rate, hours per worker	Inter generation report (Commonwealth of Australia, 2010)	As for Phase 1
unemployment rate	Fixed at June 2014 level by assumption, wages adjust to clear market	As for Phase 1
labour qualifications: bachelor degree and above as a percentage of working age population	Grows at 2% p.a. by assumption.	As for Phase 1
multi-factor productivity	Grows at 0.3% p.a. in all industries except mining and dwellings, consistent with Treasury publication (Carmody, 2013)	As for Phase 1
terms of trade	gradual fall to 2005/06 level (Bullen, Kouparitsas, & Krolikowski, 2014)	Remains at 2020 level
investment	damped as global interest rates rise relative to domestic rates in response to return to normal global monetary	Remains at 2020 settings

	policy settings	
government expenditure	as announced in budget 2014 (Commonwealth of Australia, 2014)	in line with private consumption
net taxation	as announced in budget 2014 (Commonwealth of Australia, 2014)	Remaining at 2020 policy settings
Selected activities		
mining: output and prices	BREE (BREE, 2014) (Barber, Penney, Cowling, & Richardson, 2014)	Model generated
Mining investment	BREE and own calculations	Model generated
Motor vehicle manufacturing	winding down to half of 2014 activity level by 2017	Model generated

In addition to the assumptions underlying J.Dixon et al (2014), we assume:

1. *This set of forecasts explicitly accounts for the skills (level and field of qualification) held by the population.*

We assume that over the period from 2014 to 2035, the proportion of the working age population holding a bachelor degree or higher qualification will increase by 2 per cent per annum. This takes the proportion from approximately 25 per cent in 2013 to approximately 40 per cent in 2035. We note that in 2013, the proportion of 25 to 34 year olds holding a bachelor degree or above was 35.2 per cent, and the proportion of 35 to 44 year olds holding this level of qualification was 31.2 per cent (ABS, 2013a). By 2035, these cohorts will make up the majority of the 45-64 year old age group. Assuming that skill acquisition in the younger cohorts remains similar or slightly higher than it was in 2013, 2 per cent seems a plausible growth scenario for the proportion of the working age population holding a bachelor degree or above.

We assume that at each qualification level, the proportion of the population in each field of qualification (e.g. Science, Engineering) does not change over time. However, the overall proportion of the population with qualifications in most fields does increase as the proportion with higher degrees increases.

We assume that the proportion of the working age population holding a non-higher-degree post-school qualification (an advanced diploma or certificate I-IV qualification) remains steady, as it has for the last 10 years. Finally, we assume that the proportion of the working age population with no qualification falls by 1.7 per cent per annum, consistent with the pattern of the last 12 years. These percentage changes are adjusted slightly each year to ensure that the proportions add to one.

As a consequence of the gradual change in the relative abundance of skills, the wages of holders of bachelor degrees and above gradually falls in relation to the average wage. Some wage relativities are shown in Table 2 for 2014 and 2035.

It is important to note that the average STEM wage is 1.25 times the economy-wide average in 2014. Although STEM workers comprise 22 per cent of all workers in 2014, they take 28 per cent of the total wage bill. However, in the baseline the average STEM wage falls to 1.07 times the economy-wide average by 2035. During this time, the proportion of STEM workers in the economy has grown from 22 per cent in 2014 to 27 per cent in 2035. These characteristics of the baseline have important consequences for the STEM scenarios.

Table 2: Wage relativities in the baseline

	2014	2035
Wage of Bachelor and above relative to no post-school qualification	2.15	1.87
Wage of STEM qualifications (as defined in Appendix) relative to average	1.25	1.07
Proportion of workers (head count) with STEM qualifications	0.22	0.27
Proportion of value added (wage bill) attributed to workers with STEM qualifications	0.28	0.29

2. *The forecast period is extended to 2035*

The Dixon et al (2014) forecast ends at 2020. Beyond 2020 there is less information on which to base forecasts. For the period 2020-35, a scenario is adopted in which:

– Demographic variables continue on their paths as described by the ABS and the Inter-generation report.
– Multi factor productivity growth continues to grow at 0.3% p.a. as described in Carmody (2013)
– There is no change in the terms of trade beyond 2020
– Global and domestic monetary policy settings remain as they are in 2020
– Government taxation and expenditure settings remain as they are in 2020

3 Results

3.1 Scenario 1: Increase in supply of STEM qualifications

The proportion of workers with STEM qualifications (defined in Appendix 1) in the baseline increases from 23 per cent in 2014 to 27 per cent in 2035. Relative to the baseline, the increase in supply of STEM qualifications modelled in Scenario 1 is imposed by allowing the supply of STEM-qualified workers to grow by 1 per cent more than the supply of other workers, while holding the total supply of workers on its baseline trajectory. Therefore, in Year 1 of Scenario 1 (2015), for which the base share of STEM workers (persons) is 23 per cent, the number of STEM workers grows by an additional 0.77% compared to the baseline, while the number of non-STEM workers grows by 0.23% less than it grows in the baseline. By 2035, the final year of the simulation, the share of workers with STEM qualifications in Scenario 1 is 32 per cent.

The initial impact on GDP of the increase in STEM qualifications is positive because value added per STEM worker is higher than the national average. In 2014, STEM workers account for 28 per cent of the wage bill (or 28 per cent of labour input) but only 23 per cent of persons working. An increase in the proportion of STEM persons working therefore a positive net impact on employment in labour units aggregated over industries, occupations and skills. This can be approximately calculated as

$$l_{ios} = \frac{\sum_{o \in OCC} \sum_{s \in STEM} VSKILL_{o,s}}{\sum_{o \in OCC} \sum_{s \in SKILL} VSKILL_{o,s}} * \frac{\sum_{o \in OCC} \sum_{s \notin STEM} PERS_{o,s}}{\sum_{o \in OCC} \sum_{s \in SKILL} PERS_{o,s}}$$

$$- \frac{\sum_{o \in OCC} \sum_{s \notin STEM} VSKILL_{o,s}}{\sum_{o \in OCC} \sum_{s \in SKILL} VSKILL_{o,s}} * \frac{\sum_{o \in OCC} \sum_{s \in STEM} PERS_{o,s}}{\sum_{o \in OCC} \sum_{s \in SKILL} PERS_{o,s}}$$

or, for 2015

l_{ios} = 0.28 * (1 - 0.23)% - (1 - 0.28) * 0.23% = 0.05%

Labour input accounts for approximately half of GDP. The impact on GDP of an increase in effective employment of 0.05 per cent is therefore around 0.02 per cent. This is approximately equal to the model result for 2015.

The positive impact diminishes over time. This is because the premium on STEM workers diminishes throughout this scenario as the supply of STEM workers increases. By 2033, the wage for STEM qualified workers is no higher than the average wage. From 2032, the additional growth in STEM workers acts as a drag on the economy. While growth is still positive, and GDP remains above its basecase level, growth is slower than in the basecase from 2032 onwards.

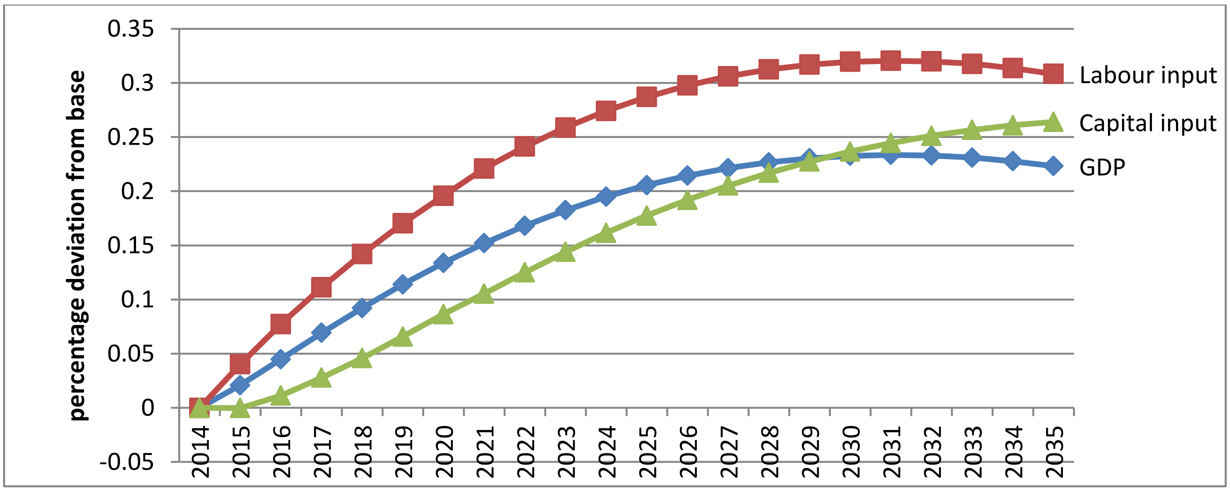

Figure 1: Labour, capital and GDP, percentage deviation from base, Scenario 1

The addition of STEM workers over the simulation period causes the occupation composition of labour to shift towards Professional[6] occupations, with further compositional change within the Professional occupations. Unsurprisingly, there are increases in “Design, Engineering, Science and Transport Professionals” and “Health Professionals” and decreases in “Business, Human Resource and Marketing Professionals” and “Education Professionals”.

[6] ANZSCO Major Group 2

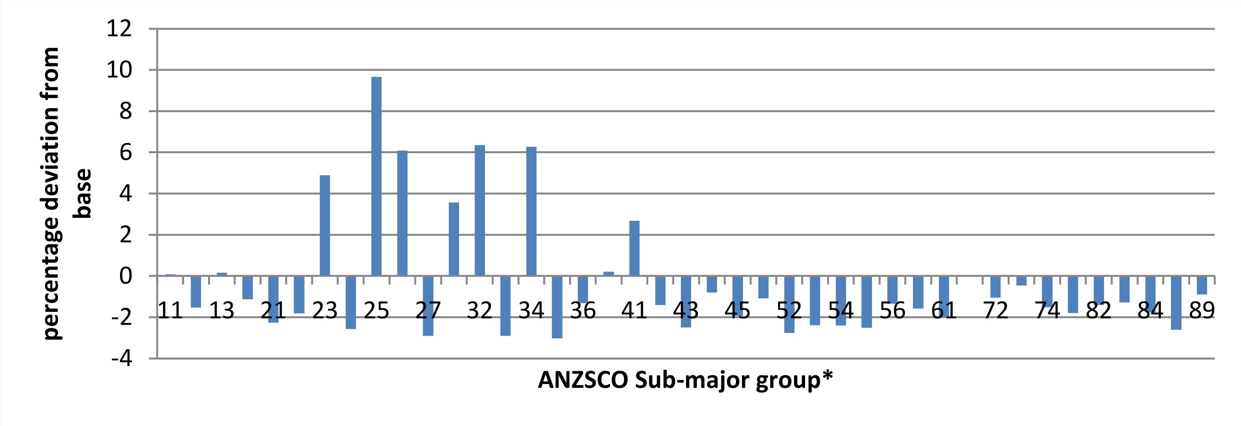

Figure 2: Employment by ANZSCO Sub-major group, percentage deviation from base in 2035, Scenario 1

* see Appendix for ANZSCO descriptions

At the industry level, the largest increases in output occur in the Manufacturing, Professional services and Health services industries. Declines in the Finance, Education and Arts industries are unsurprising given the reduction in supply of workers with the necessary skills for these industries. However, the largest decline in percentage terms is in the Accommodation industry. The decline in the supply of workers to the Accommodation industry leads to cost pressures which are difficult for the industry to pass on to consumers. Being both trade-exposed and subject to a high degree of discretionary household spending, accommodation faces fairly elastic demand, such that cost pressures tend to lead to reduced output.

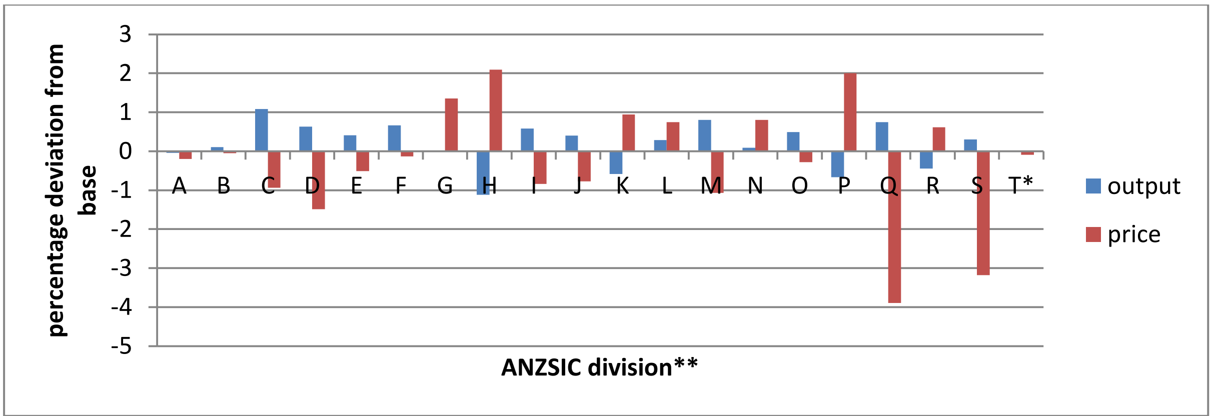

Figure 3: Aggregated industry results for output and price, percentage deviation from base in 2035

* T = ownership of dwellings
** see appendix for ANZSIC descriptions

What is behind the diminished STEM wage premium that is responsible for the eventual negative response of GDP to additional supply of STEM workers? In a small, open economy that is able to produce almost unlimited quantities of commodities at world prices, STEM workers, as relatively productive additions to the labour force, should simply boost output. Although the VU model represents Australia as a small, open economy, it is not so small or open as to face infinitely elastic demand. In particular, essential services produced for domestic consumption face demand that is inelastic. While the deviation path for wage growth of all STEM qualifications is negative, the largest negatives occur for the health qualifications at all levels of attainment.

Workers with health qualifications face particularly inelastic demand with respect to their wages. Workers with qualifications in the health fields are heavily concentrated into the "Health Professionals" occupations, with 59 per cent of their wage bill derived from these occupations. The "Health Professionals" occupations are heavily concentrated into the single industry "Health Services" with 45 per cent of their wage bill derived from this industry. The "Health Services" industry, while growing strongly through the forecast period due to the ageing population, faces a low own-price elasticity of demand. Therefore, adding more workers with health qualifications to the economy is more likely to drive down their wages than to boost their output.

This reasoning leads to the formulation of a second scenario, in which qualifications in the Health fields are omitted from the STEM labour supply stimulus.

3.2 Scenario 1a: Omit Health Qualifications from STEM supply scenario

This scenario is a variant on Scenario 1 in which the supply of labour to the Health skill groups[7] is kept at the baseline level.

One feature of the results for Scenario 1 is that the positive impact on GDP of extra STEM workers is eventually eliminated as they are in oversupply after the first 18 years of the simulation. In the model, the oversupply is evident in the declining wage premium of STEM workers. In particular, wages for the Health skill groups decline the most. This is because, apart from working in "Health Professional" occupations in Health Care Services (IOIG 8401) or Residential Care Services (IOIG 8601), there are limited opportunities for workers with these skills. In the baseline, demand for these services is already satisfied by the supply of health workers.

Scenario 1 illustrates that increasing the supply of health workers does not confer much additional benefit to the economy, and detracts from the supply of other types of workers, for a net impact that is eventually negative. Additional supply of health workers exerts downward pressure on their wages. Although lower wages to health workers translates into lower costs for health services, demand for health services is fairly non-responsive to price, so health services do not expand significantly in response to a greater supply of health workers.

In Scenario 1a, with health workers excluded from the supply-side stimulus, we find that non-health qualified STEM workers retain their positive wage premium throughout the simulation period. However, the wage premium is diminished over time, being 33 per cent above average in 2014 and falling to 16 per cent above average at the end of the simulation period in 2035. Furthermore, by excluding health workers from the stimulus, there is a smaller negative impact on the supply of non-STEM workers. The impact on GDP is positive throughout the simulation period.

[7] ASCED Field ID 06

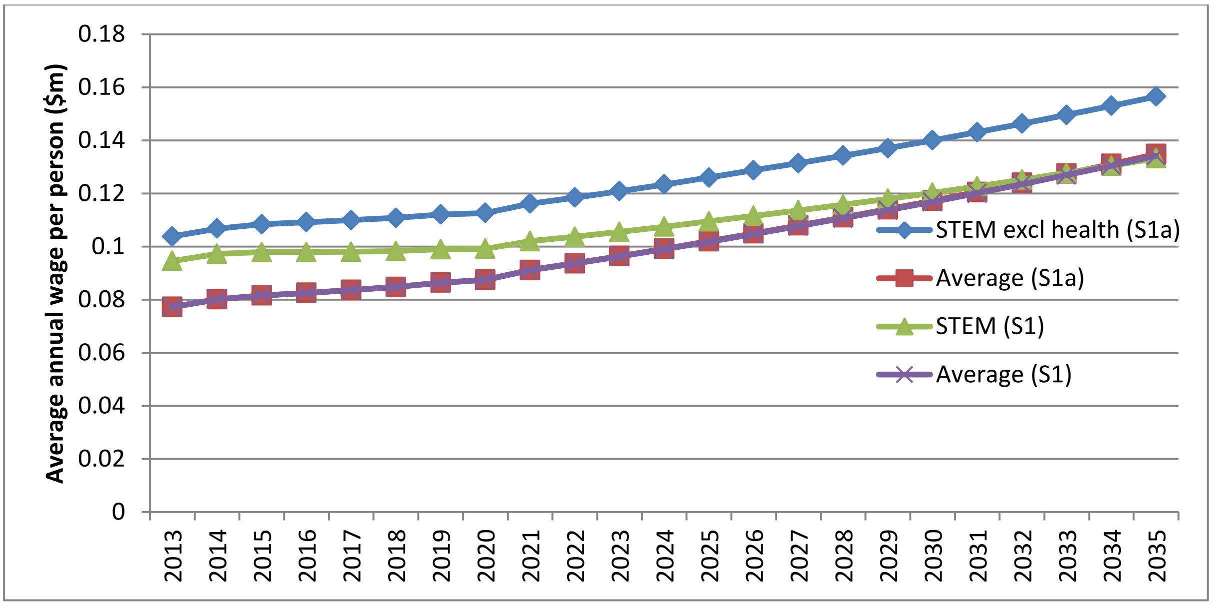

Figure 4: Wages per person, average and policy group (STEM in S1, STEM excluding Health in S1a), $m

Particular features of the health sector, such as the difficulty in finding doctors willing to work in remote locations, or the need fill positions through immigration, are not captured in the modelling results. However, a comparison of scenarios 1 and 1a emphasises the importance of a supply-side policy that is in concert with demand side policy or expectations.

3.3 Scenario 2: Co-ordinated demand approach

Returning to Scenario 1, we consider whether a better outcome for GDP could be achieved if growth in demand was biased towards "STEM industries"[8] through the simulation period. Our prior expectation is that if growth is biased towards these industries, this would lead to positive wage pressures for the skills employed in these industries, which would temper the fall in STEM skilled wages observed in Scenario 1.

Scenario 2 is formulated on the same basis of skills growth as Scenario 1, with the addition of a change in the composition of export demand. We bias growth in export demand towards the manufacturing industries which are significant employers of STEM skilled labour. In order to ensure that any "good news" in the simulation is attributable to compositional change, and not simply the result of an improvement in the terms of trade, we run the simulation with the terms of trade fixed on its baseline trajectory. In practice this means that export demand for the non-STEM industries declines somewhat.

We find that the path for GDP under Scenario 2 is higher than it is under Scenario 1, suggesting that the change in the composition of demand has a helpful impact. However, it is lower than it is under Scenario 1a, suggesting that the more important factor in stimulating GDP growth is to remove Health skills from the set of skills for which supply is increased. More generally the results illustrate that it is important not to increase supply in skills that face inelastic demand if the needs of industries are being met in the baseline.

[8] Full list of STEM industries in Appendix.

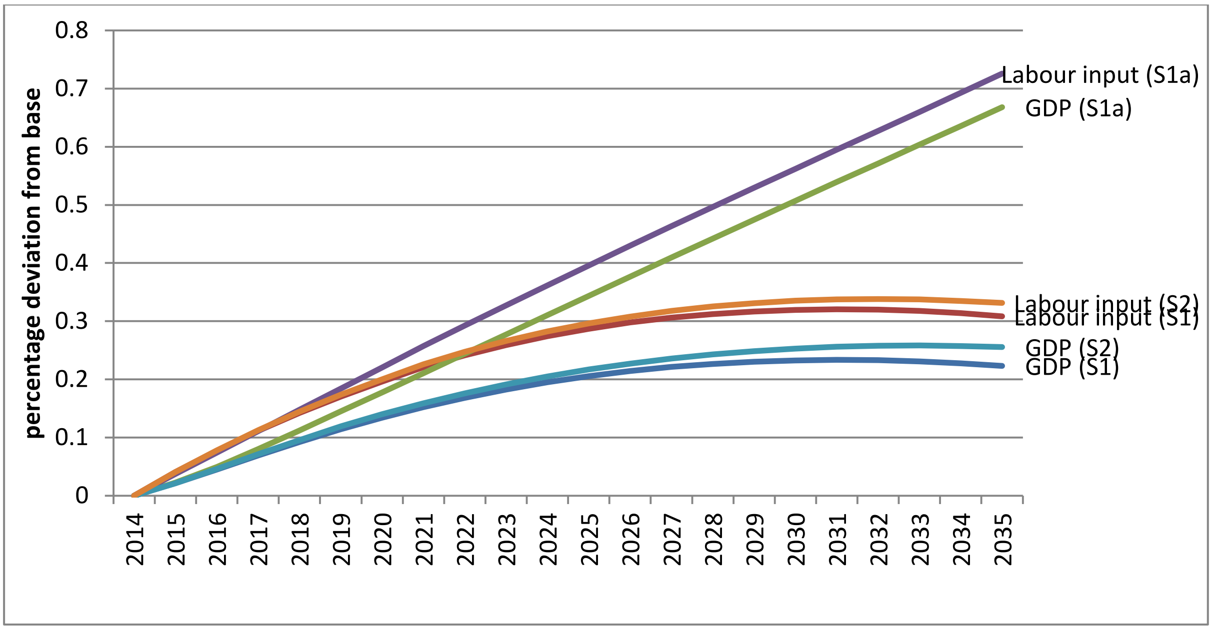

Figure 5: Labour and GDP under all scenarios, percentage deviation from base

4 Conclusions and further work

This paper makes contributions on several fronts. Firstly, a theory is formulated in which skill-based restrictions on labour supply are used to inform relative occupation wages. This theory is parsimonious in its data requirements in a model in which there are many industries, occupations and skill types. Data on labour is only ever required to be cross classified by two dimensions: industry by occupation, or occupation by skill.

Secondly, several sources of relatively current data for Australia are used to estimate the required data at a very disaggregated level of detail: 115 industries, 97 occupations and 56 skill types.

Thirdly, a policy simulation is analysed, in which a subset of skills grows at an elevated rate compared to other skills. Examination of some variants on the policy environment find that an increase in the supply of STEM-skilled workers leads to the most favourable outcome if (1) there is no increase in the supply of workers employed in industries with inelastic demand (such as health services) and (2) if compositional change in demand favours the industries in which STEM-skilled workers are employed. The simulation illustrates the perils of an uncoordinated approach to training policy in which participants in the labour market are simply encouraged to acquire certain favoured skills, even though demand for these skills may be satisfied adequately by the existing workforce.

The favourable light in which STEM skills are viewed probably has less to do with their immediate impact on the labour market and more to do with the potential that a STEM-skilled workforce has to discover productivity-enhancing technological improvements. This line of investigation could form the basis of further work under the same modelling framework used in this paper. For now, we assume that productivity-enhancing technological improvements flow freely around the world and Australia's adoption of such improvements will occur independently of the hypothetical increase in STEM-qualified workers simulated in this paper.

5 Appendix

5.1 Qualifications

The qualifications that define STEM workers are shaded in the following table.

		ASCED LEVEL				
ASCED Field ID	Description	01 Post Graduate degree	02 Graduate diploma	03 Bachelor degree	04 Advanced Diploma	05 Certificate I-IV
01	Natural and Physical Sciences					
02	Information Technology					
03	Engineering and Related Technologies					
04	Architecture and Building					
05	Agriculture, Environmental etc					
06	Health					
07	Education					
08	Management and Commerce					
09	Society and Culture					
10	Creative Arts					
11	Food, Hospitality etc.					

VU Model code names are denoted, for example, "Q1SCI_Q1PGR" for Field 1 (Science) – Level 1 (Post Graduate).

Element 56 of the SKILL set is "No Post School Qualification".

More information on ASCED is available at
http://www.abs.gov.au/ausstats/abs@.nsf/DetailsPage/1272.02001

5.2 ANZSCO Major, Sub-Major and Minor groups

Major Group	Sub-Major Group	Minor Group	VU Model Code (Minor Groups)
1 MANAGERS			
	11 Chief Executives, General Managers and Legislators		
		111 Chief Executives, General Managers and Legislators	MAN_Chi_Chie
	12 Farmers and Farm Managers		
		121 Farmers and Farm Managers	MAN_Far_Farm
	13 Specialist Managers		
		131 Advertising, Public Relations and Sales Managers	MAN_Spe_Adve
		132 Business Administration Managers	MAN_Spe_Busi
		133 Construction, Distribution and Production Managers	MAN_Spe_Cons
		134 Education, Health and Welfare Services Managers	MAN_Spe_Educ
		135 ICT Managers	MAN_Spe_ICT
		139 Miscellaneous Specialist Managers	MAN_Spe_Misc
	14 Hospitality, Retail and Service Managers		
		141 Accommodation and Hospitality Managers	MAN_Hos_Acco
		142 Retail Managers	MAN_Hos_Reta
		149 Miscellaneous Hospitality, Retail and Service Managers	MAN_Hos_Misc
2 PROFESSIONALS			
	21 Arts and Media Professionals		
		211 Arts Professionals	PRO_Art_Arts
		212 Media Professionals	PRO_Art_Medi
	22 Business, Human Resource and Marketing Professionals		
		221 Accountants, Auditors and Company Secretaries	PRO_Bus_Acco
		222 Financial Brokers and Dealers, and Investment Advisers	PRO_Bus_Fina
		223 Human Resource and Training Professionals	PRO_Bus_Huma
		224 Information and Organisation Professionals	PRO_Bus_Info
		225 Sales, Marketing and Public Relations Professionals	PRO_Bus_Sale
	23 Design, Engineering, Science and Transport Professionals		
		231 Air and Marine Transport Professionals	PRO_Des_Air
		232 Architects, Designers, Planners and Surveyors	PRO_Des_Arch
		233 Engineering Professionals	PRO_Des_Engi
		234 Natural and Physical Science Professionals	PRO_Des_Natu
	24 Education Professionals		
		241 School Teachers	PRO_Edu_Scho
		242 Tertiary Education Teachers	PRO_Edu_Tert
		249 Miscellaneous Education Professionals	PRO_Edu_Misc
	25 Health Professionals		
		251 Health Diagnostic and Promotion Professionals	PRO_Hea_Heal
		252 Health Therapy Professionals	PRO_Hea_Heal
		253 Medical Practitioners	PRO_Hea_Medi
		254 Midwifery and Nursing Professionals	PRO_Hea_Midw
	26 ICT Professionals		
		261 Business and Systems Analysts, and Programmers	PRO_ICT_Busi
		262 Database and Systems Administrators, and ICT Security Specialists	PRO_ICT_Data
		263 ICT Network and Support Professionals	PRO_ICT_ICT
	27 Legal, Social and Welfare Professionals		
		271 Legal Professionals	PRO_Leg_Lega
		272 Social and Welfare Professionals	PRO_Leg_Soci
3 TECHNICIANS AND TRADES WORKERS			
	31 Engineering, ICT and Science Technicians		
		311 Agricultural, Medical and Science Technicians	TEC_Eng_Agri
		312 Building and Engineering Technicians	TEC_Eng_Buil
		313 ICT and Telecommunications Technicians	TEC_Eng_ICT
	32 Automotive and Engineering Trades Workers		
		321 Automotive Electricians and Mechanics	TEC_Aut_Auto
		322 Fabrication Engineering Trades Workers	TEC_Aut_Fabr

		323 Mechanical Engineering Trades Workers	TEC_Aut_Mech
		324 Panelbeaters, and Vehicle Body Builders, Trimmers and Painters	TEC_Aut_Pane
	33	Construction Trades Workers	
		331 Bricklayers, and Carpenters and Joiners	TEC_Con_Bric
		332 Floor Finishers and Painting Trades Workers	TEC_Con_Floo
		333 Glaziers, Plasterers and Tilers	TEC_Con_Glaz
		334 Plumbers	TEC_Con_Plum
	34	Electrotechnology and Telecommunications Trades Workers	
		341 Electricians	TEC_Ele_Elec
		342 Electronics and Telecommunications Trades Workers	TEC_Ele_Elec
	35	Food Trades Workers	
		351 Food Trades Workers	TEC_Foo_Food
	36	Skilled Animal and Horticultural Workers	
		361 Animal Attendants and Trainers, and Shearers	TEC_Ski_Anim
		362 Horticultural Trades Workers	TEC_Ski_Hort
	39	Other Technicians and Trades Workers	
		391 Hairdressers	TEC_Oth_Hair
		392 Printing Trades Workers	TEC_Oth_Prin
		393 Textile, Clothing and Footwear Trades Workers	TEC_Oth_Text
		394 Wood Trades Workers	TEC_Oth_Wood
		399 Miscellaneous Technicians and Trades Workers	TEC_Oth_Misc
4	COMMUNITY AND PERSONAL SERVICE WORKERS		
	41	Health and Welfare Support Workers	
		411 Health and Welfare Support Workers	COM_Hea_Heal
	42	Carers and Aides	
		421 Child Carers	COM_Car_Chil
		422 Education Aides	COM_Car_Educ
		423 Personal Carers and Assistants	COM_Car_Pers
	43	Hospitality Workers	
		431 Hospitality Workers	COM_Hos_Hosp
	44	Protective Service Workers	
		441 Defence Force Members, Fire Fighters and Police	COM_Pro_Defe
		442 Prison and Security Officers	COM_Pro_Pris
	45	Sports and Personal Service Workers	
		451 Personal Service and Travel Workers	COM_Spo_Pers
		452 Sports and Fitness Workers	COM_Spo_Spor
5	CLERICAL AND ADMINISTRATIVE WORKERS		
	51	Office Managers and Program Administrators	
		511 Contract, Program and Project Administrators	CLE_Off_Cont
		512 Office and Practice Managers	CLE_Off_Offi
	52	Personal Assistants and Secretaries	
		521 Personal Assistants and Secretaries	CLE_Per_Pers
	53	General Clerical Workers	
		531 General Clerks	CLE_Gen_Gene
		532 Keyboard Operators	CLE_Gen_Keyb
	54	Inquiry Clerks and Receptionists	
		541 Call or Contact Centre Information Clerks	CLE_Inq_Call
		542 Receptionists	CLE_Inq_Rece
	55	Numerical Clerks	
		551 Accounting Clerks and Bookkeepers	CLE_Num_Acco
		552 Financial and Insurance Clerks	CLE_Num_Fina
	56	Clerical and Office Support Workers	
		561 Clerical and Office Support Workers	CLE_Cle_Cler
	59	Other Clerical and Administrative Workers	
		591 Logistics Clerks	CLE_Oth_Logi
		599 Miscellaneous Clerical and Administrative Workers	CLE_Oth_Misc
6	SALES WORKERS		
	61	Sales Representatives and Agents	

	611	Insurance Agents and Sales Representatives	SAL_Sal_Insu
	612	Real Estate Sales Agents	SAL_Sal_Real
62	Sales Assistants and Salespersons		
	621	Sales Assistants and Salespersons	SAL_Sal_Sale
63	Sales Support Workers		
	631	Checkout Operators and Office Cashiers	SAL_Sal_Chec
	639	Miscellaneous Sales Support Workers	SAL_Sal_Misc
7	MACHINERY OPERATORS AND DRIVERS		
71	Machine and Stationary Plant Operators		
	711	Machine Operators	MAC_Mac_Mach
	712	Stationary Plant Operators	MAC_Mac_Stat
72	Mobile Plant Operators		
	721	Mobile Plant Operators	MAC_Mob_Mobi
73	Road and Rail Drivers		
	731	Automobile, Bus and Rail Drivers	MAC_Roa_Auto
	732	Delivery Drivers	MAC_Roa_Deli
	733	Truck Drivers	MAC_Roa_Truc
74	Storepersons		
	741	Storepersons	MAC_Sto_Stor
8	LABOURERS		
81	Cleaners and Laundry Workers		
	811	Cleaners and Laundry Workers	LAB_Cle_Clea
82	Construction and Mining Labourers		
	821	Construction and Mining Labourers	LAB_Con_Cons
83	Factory Process Workers		
	831	Food Process Workers	LAB_Fac_Food
	832	Packers and Product Assemblers	LAB_Fac_Pack
	839	Miscellaneous Factory Process Workers	LAB_Fac_Misc
84	Farm, Forestry and Garden Workers		
	841	Farm, Forestry and Garden Workers	LAB_Far_Farm
85	Food Preparation Assistants		
	851	Food Preparation Assistants	LAB_Foo_Food
89	Other Labourers		
	891	Freight Handlers and Shelf Fillers	LAB_Oth_Frei
	899	Miscellaneous Labourers	LAB_Oth_Misc

Source: ABS ANZSCO Version 1.2

5.3 ANZSIC Divisions

A	Agriculture, Forestry and Fishing
B	Mining
C	Manufacturing
D	Electricity, Gas, Water and Waste Services
E	Construction
F	Wholesale Trade
G	Retail Trade
H	Accommodation and Food Services
I	Transport, Postal and Warehousing
J	Information Media and Telecommunications
K	Financial and Insurance Services
L	Rental, Hiring and Real Estate Services
M	Professional, Scientific and Technical Services
N	Administrative and Support Services
O	Public Administration and Safety
P	Education and Training
Q	Health Care and Social Assistance
R	Arts and Recreation Services
S	Other Services

Source: ABS ANZSIC classification 2006

5.4 STEM industries

STEM industries are those employing a significant proportion of STEM occupations (which are made up of a significant proportion of STEM skills). The following input-output industries are chosen as STEM industries:

1801	Human Pharmaceutical and Medicinal Product Manufacturing
1802	Veterinary Pharmaceutical and Medicinal Product Manufacturing
1803	Basic Chemical Manufacturing
1804	Cleaning Compounds and Toiletry Preparation Manufacturing
1901	Polymer Product Manufacturing
1902	Natural Rubber Product Manufacturing
2001	Glass and Glass Product Manufacturing
2002	Ceramic Product Manufacturing
2003	Cement, Lime and Ready-Mixed Concrete Manufacturing
2004	Plaster and Concrete Product Manufacturing
2005	Other Non-Metallic Mineral Product Manufacturing
2101	Iron and Steel Manufacturing
2102	Basic Non-Ferrous Metal Manufacturing
2201	Forged Iron and Steel Product Manufacturing
2202	Structural Metal Product Manufacturing
2203	Metal Containers and Other Sheet Metal Product manufacturing
2204	Other Fabricated Metal Product Manufacturing
2301	Motor Vehicles and Parts; Other Transport Equipment Manufacturing
2302	Ships and Boat Manufacturing
2303	Railway Rolling Stock Manufacturing
2304	Aircraft Manufacturing
2401	Professional, Scientific, Computer and Electronic Equipment Manufacturing
2403	Electrical Equipment Manufacturing
2404	Domestic Appliance Manufacturing
2405	Specialised and other Machinery and Equipment Manufacturing
2501	Furniture Manufacturing
2502	Other Manufactured Products
5401	Publishing (except Internet and Music Publishing)
5501	Motion Picture and Sound Recording
5601	Broadcasting (except Internet)
5701	Internet Publishing and Broadcasting and Services Providers, Websearch Portals and Data Processing Services
5801	Telecommunication Services
6001	Library and Other Information Services
6201	Finance
6301	Insurance and Superannuation Funds
6401	Auxiliary Finance and Insurance Services
6901	Professional, Scientific and Technical Services
7001	Computer Systems Design and Related Services
8010	Primary and Secondary Education Services (incl Pre-Schools and Special Schools)
8110	Technical, Vocational and Tertiary Education Services (incl undergraduate and postgraduate)
8210	Arts, Sports, Adult and Other Education Services (incl community education)

Source: ABS Input-Output tables 2009-10

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