



Australian Government  
Productivity Commission

The Education and Labour  
Market Outcomes Model:  
Documentation and User Guide

Productivity Commission  
Technical Note

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# The Education and Labour Market Outcomes Model: Documentation and User Guide

The Education and Labour Market Outcomes (ELMO) model was developed by the Productivity Commission to estimate the benefits and costs of education policies that are primarily targeted at young adults. It is essentially a bottom-up, partial equilibrium model of the education market.

The ELMO model accounts for the heterogeneous characteristics of potential students, such that different potential students will prefer different education options. This key feature is supported by empirical evidence. The model also captures a number of potential government interventions and market distortions (such as income taxes, education subsidies, externalities and incomplete information), allowing for the analysis to take place in a realistic ‘second-best’ environment.

While the Commission has made the ELMO model publically available, it is not in a position to provide support beyond the documentation (which includes a short user guide). With the appropriate software, an analyst with intermediate GAMS experience should be able to use the model relatively easily.

Section one provides an overview of the characteristics of the Education and Labour Market Outcomes (ELMO) model. The theoretical underpinnings and limitations of the model are also discussed. Section two presents a stylised graphical version of the ELMO model, whereas section three documents the key equations in detail. Section four covers data sources and their reliability. Finally, a basic user guide is provided in section five.

## **1 Overview of the ELMO model and key issues**

The ELMO model was developed to model the benefits and costs of education policies that principally affect the education decisions of young adults. The framework assumes that individuals maximise the net benefits from acquiring a

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qualification. It was used in the context of the report on *Impacts and Benefits of COAG Reforms* (PC 2012).

There are seven different education-work types in the core model, corresponding to Australian Bureau of Statistics educational classifications and the common distinction between blue- and white-collar work:

- year 11 or lower, blue collar
- year 11 or lower, white collar
- year 12, white collar
- certificate 3 or 4, blue collar
- certificate 3 or 4, white collar
- diploma, white collar
- degree or higher, white collar

The number of education-work types can be expanded if sufficient data are available. For example, diplomas could be disaggregated into management diploma and other diplomas.

Australian States and Territories are represented as separate regions.

The ELMO model can be used to model the effects of changes to relative costs and returns to education. As such, it can be used to model a wide array of education policies, including:

- changes to the costs of education (for example, an increase in education subsidies that reduce the private costs of degrees)
- changes to the quality of education (for example, reforms that could alter the probability of finding employment that is associated with a qualification type)
- changes to returns to education (for example, an increase in the demand for certain skills could increase the returns associated with a qualification type).<sup>1</sup>

The key outputs are estimates of the effect of education policies on:

- education and work decisions

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<sup>1</sup> The ELMO model can also be used to predict budgetary implications associated with changes in relative returns across qualification types or occupations.

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- net social benefit and its components and determinants (including changes in the money and time costs of education, average wages and hours worked, external benefits, value of non-market activity, and effects of changes in tax revenue)
  - public finances (capturing education subsidies and changes in tax revenue).

Sensitivity analysis can be undertaken to explore the responsiveness of the estimates to assumptions concerning key parameters, and to generate confidence intervals.

Running the ELMO model requires access to the General Algebraic Modeling System (GAMS), and an appropriate solver (the Commission uses GUROBI). The model code is reasonably simple and is accessible to users with intermediate GAMS experience. The ELMO input file is prepared with Microsoft Excel.

## **Economic principles**

The ELMO model was developed to address two conceptual weaknesses of other models of education decisions — specifically (a) the implicit assumption that individuals are homogeneous and (b) deficient measures of welfare.

### *All students are not the same*

Many education models implicitly assume that all individuals receive the same benefits (such as increases in wages) and incur the same costs (such as forgone wages and time costs) when undertaking education, irrespective of their individual characteristics. For example, the most academically-talented person is assumed to receive the same benefits from a PhD as the least academically-talented one. This is not only implausible but also inconsistent with the diversity of education decisions made by potential students. If all potential students were homogenous, rational and did not face liquidity constraints, they would all make the same education decision.

An assumption that everyone receives the same net benefits from education effectively precludes the explicit modelling of education decisions. Instead, in models based on such an assumption, changes in education decisions associated with education policies must be applied exogenously. For example, based on some judgement about the effect of a particular policy, the number of people with a diploma might be increased exogenously from 6 to 7 per cent. The models then calculate the effects (such as changes in GDP) of the exogenously imposed changes in education decisions. The effects estimated with such models are likely to be biased, because the models do not account for differences between people who are motivated by education subsidies to complete diplomas and those who would

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complete diplomas without the education subsidies. In general, the former group is likely to experience lower private net benefits.

### *Measuring net benefits*

Some models exclusively report impacts of policies on measures such as Gross Domestic Product (GDP). Notwithstanding that changes in GDP are an indicator of effects on market and government sector economic activity, there are a number of important drawbacks to GDP as a measure of economic benefits. A limitation especially relevant to education policy is that GDP does not account for many non-market activities, such as leisure and caring for family members.

To illustrate the importance of this, suppose an education policy moves people into paid employment where they produce \$30 an hour worth of goods and services, but which comes at the expense of non-market activities valued at \$20 an hour. GDP increases by \$30 for each additional hour worked, but the net benefit per hour is only \$10. The ELMO model addresses this issue, providing a rigorous framework for benefit–cost analysis.

### *ELMO addresses these issues*

The ELMO model addresses these issues and provides a rigorous framework for benefit cost analysis. In developing the model, the Commission built on economic theory to develop an optimisation model with heterogeneity.

Becker (1974) developed a theory to explain how people make education decisions. He argued that people invest in education to improve their human capital (to secure better work) as well as for non-monetary reasons. Potential students compare the benefits and costs of different education options and make the decision they expect to benefit them most.

If education decisions are based on some assessment of benefits and costs, and education decisions differ across individuals, it follows that the benefits or costs of education must also differ across individuals. Heckman, Stixrud and Urzua (2006) offer evidence that an individual’s underlying abilities can influence the wage premium received from education. For example, a person with low cognitive ability might struggle to learn and apply the knowledge taught at university. Hence, differences in underlying abilities is a plausible source of heterogeneity and explanation for the wide range of education decisions.

The ELMO model is a partial equilibrium education investment model. It is consistent with both Becker (1974) and Heckman, Stixrud and Urzua (2006). The

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model estimates how potential students respond to education policy, and then applies conventional benefit–cost analysis techniques to produce welfare measures (Boardman et al. 2001 and Mishan 1971). The main innovation of the ELMO model is the economic framework, which is consistent with welfare economics (box 1).

**Box 1 Consistency of the ELMO model with welfare economics**

If no market failures exist, then markets tend towards efficiency in the absence of government intervention (Ng 1983). Similarly, if no market failures are assumed in education markets, welfare is maximised in the ELMO model when no government intervention is present.

The primary value of the ELMO model relates to the more likely case where there are market failures and existing government interventions in education markets. If these distortions are substantial, it is likely to be difficult to reliably estimate the direction or magnitude of net benefits of a policy change without a quantitative model such as the ELMO model.

- The model accounts for a number of potential government policies and market distortions potentially influencing education decisions, including: income taxes, education subsidies, externalities and incomplete information.

## Some limitations

The ELMO model is based on a number of important assumptions, including:

- People are able to borrow at the discount rate to finance education.<sup>2</sup> This rules out the possibility that people do not undertake education that would deliver private net benefits because of credit market constraints. This is not an unreasonable assumption if students are able to access a deferred loan scheme (such as FEE-HELP).<sup>3</sup>
- Ability has an effect on the wage premiums from education, but does not affect education costs. This is a simplification, since people with higher ability might be able to absorb the course material more quickly.
- People can acquire any education they are willing to pay for. That is, there are no quotas or entry requirements. However, it is trivial to adjust the model to limit the number of places in an education option.

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<sup>2</sup> The default discount rate is 6 per cent.

<sup>3</sup> It would be possible to relax this assumption by introducing an available income parameter. However, assumptions would need to be made regarding the correlation between available income and ability.

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- People undertake education early in their lives. (The effects of education policies on mature learners are probably more appropriately addressed through other methodologies, due to the complexity of evaluating the opportunity cost of mature learners.)
  - The education policies are small enough to have minimal impact on prices, such as wages and education fees. This assumption could be violated if education policies caused a large influx of students into an occupation. In the short term, the costs to providers of running, say, hairdressing courses would increase demand for qualified teachers. This is likely to increase the price of hairdressing courses. In the long term, the increase in the supply of hairdressers could depress wages. These effects are not modelled. Labour demand curves are assumed to be approximately flat over the relevant range and labour markets are assumed to clear. For many education policies, these partial equilibrium assumptions are likely to be reasonable approximations.

Most of these maintained assumptions can be alleviated, for example, by making education costs a function of ability, or by building a small labour market into the model. However, doing so could detract from the relative simplicity of the model and the insights gained from it.

## 2 Stylised representation of the ELMO model

The concepts behind the ELMO model can be explained with simple diagrams, based on simplified assumptions. The complexities of the model itself are found in section 3.

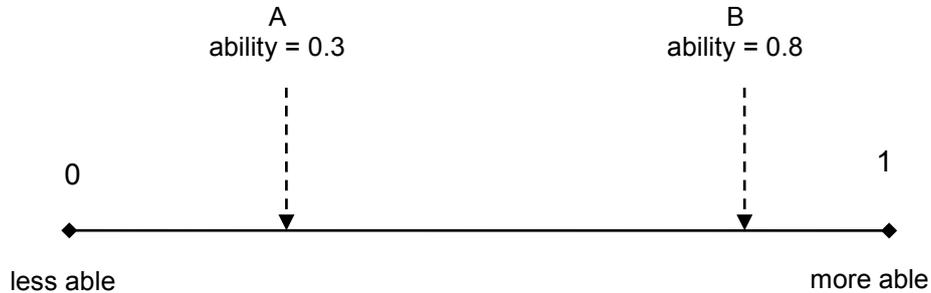
### Ability

The ELMO model is built on a conventional, Becker-type education investment framework, but the benefits and costs of education depend on ability. Suppose that childcare is the only type of work available. In this case, ability would be defined as the potential to learn the skills necessary to be a good childcare worker and apply those skills in the workplace. To model ability, every person is assigned a score — the least able person is given zero and the most able is given one. Figure 1 shows two hypothetical people, A and B. The scores are interpreted as percentiles, so that Person A, who has a score of 0.3, has higher ability than 30 per cent of the relevant population.

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Figure 1     **Continuum of ability**  
Single dimension of ability

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## Optimisation

The ELMO model is essentially a two-period model. In period 1 education–work decisions are made and costs are incurred. Period 2 reflects individuals’ working lives, when they receive discounted benefits from applying in the labour market the skills learnt in period 1.

Ability determines the benefits of different education options in the ELMO model. Two education options are illustrated in figure 2. The year 11 curve (Y11) represents the benefits from work (and other activities) associated with a year 11 education for people of different abilities. The curve slopes upwards, indicating that benefits increase with ability. The certificate III curve (Cert III) has a similar interpretation. Since having a certificate III tends to increase wages and employment prospects relative to year 11, the certificate III curve is above the year 11 curve.

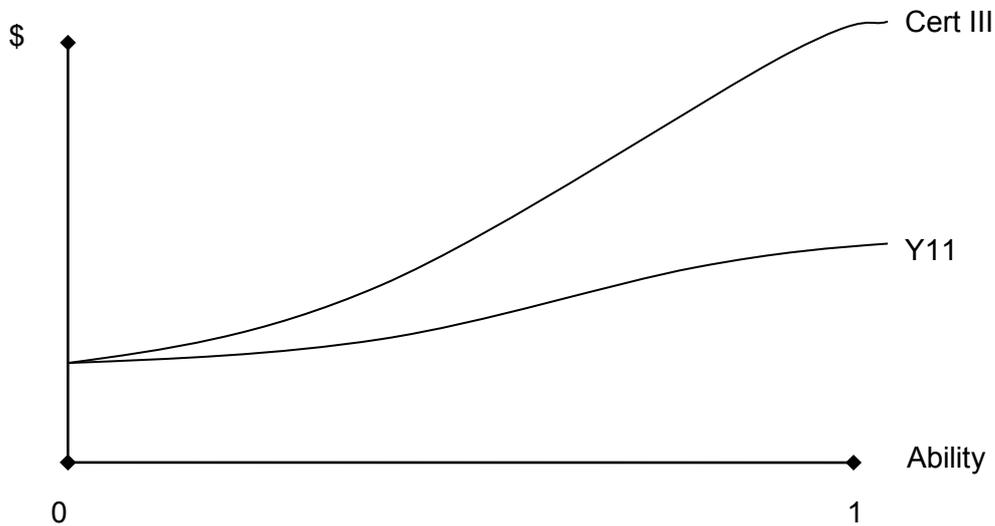
The benefits of additional education could depend on ability. One possible explanation is that people with higher ability might be better at learning and applying the skills acquired from additional education. This manifests as an increase in the vertical distance between the curves as ability increases.

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Figure 2 **Benefits associated with different education options and abilities**

Two education options

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The costs of education are also relevant, and include course fees and reduced income due to time studying. Certificate III is more costly than year 11. Unlike benefits, the costs are assumed to not depend on ability.

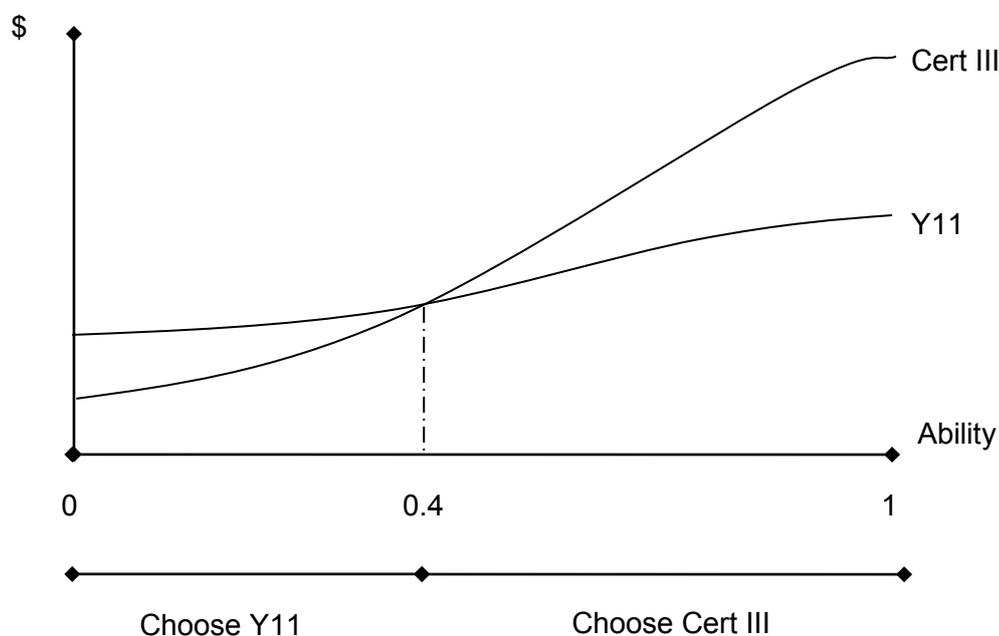
Net benefit curves are derived by subtracting the costs from the benefits (figure 3). People select the education option with the highest net benefit. The net benefit associated with year 11 exceeds the net benefit associated with a certificate III for people with ability below 0.4. In other words, the increase in benefits from a certificate III are not sufficient to cover the increase in costs, and these people are unlikely to undertake a certificate III. By contrast, the net benefits associated with a certificate III exceed the net benefits associated with year 11 for people with ability above 0.4.

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Figure 3 **Net benefits associated with different education options and abilities**

Two education options

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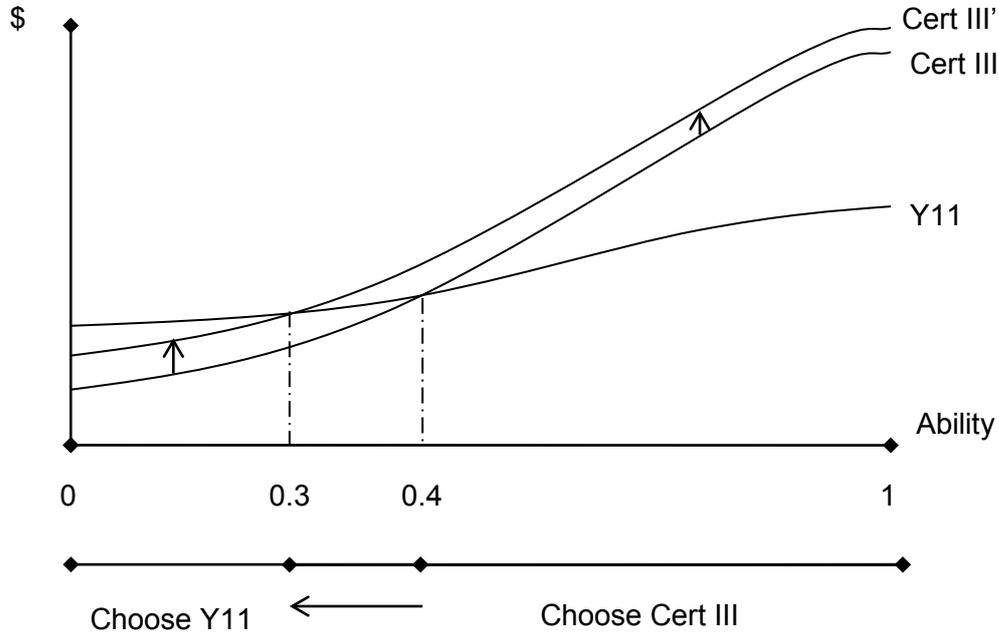
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This stylised representation of the ELMO model can be used to illustrate the effects of various education policies. Given that education decisions are based on an assessment of net benefits, any reform that influences the net benefits of education has the potential to alter the number of people undertaking a certificate III.

Assume that the government introduces a subsidy for certificate III qualifications, thereby increasing the net benefits relative to year 11 (figure 4). In this case, the year 11 curve is unchanged, but the certificate III curve shifts upwards (to Cert III'). As a result, some people who previously would not have undertaken a certificate III would now find it worthwhile to do so.

In this hypothetical example, the ability score at which people are indifferent between the education options moves from 0.4 to 0.3 and this causes a shift towards certificate III qualifications.

Figure 4 The effect of a subsidy on education decisions



The effect of the subsidy depends on the magnitude of the subsidy (which determines the extent to which the curves shift) and the slopes of the curves. In general, the more similar the slopes of the curves, the greater the effect of the subsidy. That is because with similar slopes there are many people who are almost indifferent between the education options, and could easily be induced to change their decisions.

### 3 Key equations in the ELMO model

The key equations of the ELMO model are documented in this section. The documentation is not exhaustive — readers can refer to the ELMO GAMS file to view the complete model. The model is documented in GAMS code rather than standard mathematical notation to make the link between the documentation and the model clearer, and to introduce new users to GAMS code.

The structure of this section follows the structure of the GAMS file, specifically:

- Core code
  - sets
  - costs

- 
- benefits
  - net benefits
  - weighting
  - objective function and constraints
  - reporting parameters
  - Supplementary code
    - sensitivity analysis
    - model calibration
    - disaggregation

### **Core code**

The core of the ELMO model performs four functions. First, the net benefits associated with different education-work types and abilities are calculated. This is the most complex and important part of the model. Second, representative agents are assigned weights that reflect the number of people they represent in each region. Third, each representative agent selects the education-work type that maximises private net benefit. This part of the model is just two equations. Fourth, the aggregate public net benefits and other reporting parameters are calculated based on the decisions of the representative agents.

### *Sets (section 1.A GAMS file)*

The main sets used in the ELMO model are shown in table 1.

**Table 1 Key sets used in the ELMO model**

<i>Set</i>	<i>Index</i>	<i>Elements</i>
Representative agents	i	1*10000
Education-work types	ew	year 11 or lower, blue collar year 11 or lower, white collar year 12, white collar certificate 3 or 4, blue collar certificate 3 or 4, white collar diploma, white collar degree or higher, white collar
Abilities	a	blue collar white collar
Regions	r	Queensland New South Wales Australian Capital Territory Victoria Tasmania South Australia Northern Territory Western Australia
Scenarios	s	base policy

*Costs (section 1.B GAMS file)*

There are various costs associated with education-work types and education policies in the ELMO model. There are financial costs in providing places in education courses, and time costs as students have less time for other activities such as paid work. There can be further costs if education and education policies result in reduced tax revenue or higher government spending (through education subsidies), as the excess value of an additional dollar of government revenue could be positive.<sup>4</sup> Education subsidies and income taxes mean that only some costs are borne by individuals when making education decisions.

The key cost equations are:

$$privcost(ew,s) = fee(ew,s) + privtimecost(ew) \quad (1)$$

$$pubcost(ew,s) = moneycost(ew,s) + timecost(ew) - vtaxrev * tax1(ew,s) \quad (2)$$

where:

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<sup>4</sup> Marginal excess burden is assumed to be 24 per cent.

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$privcost(ew,s)$  is the private cost of education-work type  $ew$  in scenario  $s$

$fee(ew,s)$  is the private component of the money cost of education-work type  $ew$  in scenario  $s$  (course fees)

$privtimecost(ew)$  is the private component of the time cost of education-work type  $ew$  (forgone after tax earnings in period 1)

$pubcost(ew,s)$  is the public cost of education-work type  $ew$  in scenario  $s$

$moneycost(ew,s)$  is the money cost of education-work type  $ew$  in scenario  $s$  (including course fees and subsidies)

$timecost(ew)$  is the time cost of education-work type  $ew$  (forgone before tax earnings in period 1)

$vtaxrev$  is the excess value of an additional dollar of tax revenue (due to distortions associated with taxation)

$tax1(ew,s)$  is the net tax revenue in period 1 of education-work type  $ew$  in scenario  $s$  (changes in subsidies and net tax payments).

### ***Benefits (section 1.C GAMS file)***

Like costs, there are various benefits associated with education-work types in the ELMO model. Education-work types result in payments to labour that reflect the marginal value of labour in the production of goods and services and any potential externalities. For example, there could be positive externalities in the production of some non-excludable environmental goods. Increased payments to labour increase tax revenues and can reduce government payments, which can be another source of benefit (as discussed in the cost section). Finally, increases in time spent working must come at the expense of other activities including leisure. The cost of non-market activities forgone is subtracted from the benefits. Income taxes and externalities mean that only some of the benefits are received by individuals when making education decisions.

This section calculates the public and private benefits for all education-work types, representative agents, and scenarios. All benefits are discounted so that a dollar of benefit in period 2 is worth less than a dollar of cost in period 1. The baselines used for the costs and benefits parameters are discussed in box 2.

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The key benefit equations are:

$$\text{privben}(i,ew,s) = \text{privgrossearnings}(i,ew,s) - \text{vnma}(ew,s) \quad (3)$$

$$\text{pubben}(i,ew,s) = \text{grossearnings}(i,ew,s) + \text{vtaxrev} * \text{tax2}(i,ew,s) + \text{extben}(i,ew,s) - \text{vnma}(ew,s) \quad (4)$$

where:

$\text{privben}(i,ew,s)$  is the expected private benefit of education-work type  $ew$  for agent  $i$  in scenario  $s$

$\text{privgrossearnings}(i,ew,s)$  is the private component of expected gross earnings of education-work type  $ew$  for agent  $i$  in scenario  $s$  (after tax earnings)

$\text{vnma}(ew,s)$  is the expected value of non-market activity forgone of education-work type  $ew$  in scenario  $s$  (in period 2)

$\text{pubben}(i,ew,s)$  is the expected public benefit of education-work type  $ew$  for agent  $i$  in scenario  $s$

$\text{grossearnings}(i,ew,s)$  is the expected gross earnings of education-work type  $ew$  for agent  $i$  in scenario  $s$  (before tax earnings)

$\text{tax2}(i,ew,s)$  is the expected net tax revenue in period 2 of education-work type  $ew$  for agent  $i$  in scenario  $s$  (changes in net tax payments)

$\text{extben}(i,ew,s)$  is the expected external benefit of education-work type  $ew$  for agent  $i$  in scenario  $s$ .

#### Box 2 **Baselines for cost and benefit parameters**

All cost parameters are defined as the difference between the costs of obtaining the chosen qualification minus the costs incurred by an individual who undertakes a 'year 11 or lower' qualification. The benefit parameters are defined relative to a baseline where the representative agents do not participate in any market employment. The differences do not affect the results since the baselines are applied consistently across education-work types.

#### *Net benefits (section 1.D GAMS file)*

The net benefits combine the benefits and costs from the previous sections with two new sources of perceived benefits and costs.

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The net benefits combine the benefits and costs from the previous sections with two new sources of perceived benefits and costs.

First, the ELMO model captures the potential to overestimate or underestimate the net benefits of education-work types. Potential students are unlikely to know the benefits and costs of education-work types with certainty. Some will overestimate, others will underestimate the net benefits. Any systematic tendencies towards over- or underestimation will potentially bias the results. To address this, decisions in the ELMO model are based on potentially flawed perceptions of private net benefits.

Second, the net benefits also reflect an adjustment for *residuals*. The residuals are used to capture information from observed data on the decisions that people make to obtain better estimates of the perceived private net benefits. In a sense, the other parameters determine the shapes of the perceived private net benefits functions while the residuals determine the heights. The residuals are the difference between the perceived private net benefits required to generate the observed mix of education-work types and the perceived private net benefits from the other parts of the model (that is, the part described above, which excludes the residuals). The residuals are estimated through calibration (see below and box 3) and are included in both the net public and perceived private benefits. As a result, optimisation based on perceived private net benefits (which includes the residual) reproduces the mix of education-work types that is observed in the data.

The key net benefit equations are:

$$\begin{aligned} perprivret(i,ew,s,r) = & privben(i,ew,s) - privcost(ew,s) + residual(ew,r) \\ & + overest(ew) \end{aligned} \quad (5)$$

$$pubret(i,ew,s,r) = pubben(i,ew,s) - pubcost(ew,s) + residual(ew,r) \quad (6)$$

where:

$perprivret(i,ew,s,r)$  is the expected perceived private net benefit of education-work type  $ew$  for agent  $i$  in scenario  $s$  and region  $r$

$residual(ew,r)$  is the residual net benefit of education-work type  $ew$  and region  $r$

$overest(ew)$  is the expected overestimate of the net benefits of education-work type  $ew$

$pubret(i,ew,s,r)$  is the expected public net benefit of education-work type  $ew$  for agent  $i$  in scenario  $s$  and region  $r$ .

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### *Weighting (section 1.E GAMS file)*

Each agent in the ELMO model is defined by their mix of blue- and white-collar abilities, and assigned a weight to indicate the number of people in the population they represent. The weights depend on the abilities of the agent, how common those abilities are in the population, and the size of the population. The function used to apply the weights preserves the interpretation of abilities as percentiles, and allows the correlation between blue-collar and white-collar abilities to be altered.

The weighting equations are:

$$\frac{densfn(i)}{ability(i,'W')} = \gamma + 1 - ability(i,'B') + (2*ability(i,'B')-1) * \quad (7)$$

$$weight(i,r) = densfn(i) * pop(r) / sum(i, densfn(i)) \quad (8)$$

where:

$densfn(i)$  is the value of the discrete probability density function for agent  $i$

$\gamma$  is the parameter that controls, but is not equal to, the correlation between blue-collar and white-collar abilities across the population

$ability(i,'B')$  is the blue-collar ability of agent  $i$

$ability(i,'W')$  is the white-collar ability of agent  $i$

$weight(i,r)$  is the weight for agent  $i$  in region  $r$

$pop(r)$  is the population of region  $r$ .

### *Objective function and constraint (section 1.F GAMS file)*

The ELMO model is solved to find the education-work type for each individual, in each region and scenario that maximises the perceived private net benefit. As mentioned earlier, this part of the model is very simple. The constraint is that people can only choose one education-work type. This is not restrictive, as education-work types are defined in terms of the highest level of education obtained. The model is solved as a mixed integer programming problem.

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The objective function and constraint that limits an individual's choice of education-work type are:

*Maximise...*

$$privobj = e = \text{sum}([i, ew, s, r], \text{perprivret}(i, ew, s, r) * \text{choicepriv}(i, ew, s, r)) \quad (9)$$

*Subject to...*

$$\text{sum}(ew, \text{choicepriv}(i, ew, s, r)) = e = 1 \quad (10)$$

where:

*privobj* is the expected value of the private objective function

*choicepriv*(*i, ew, s, r*) is the binary decision variable that indicates individual *i* in region *r*'s choice of education-work type in scenario *s*.

#### ***Reporting parameters (section 1.G GAMS file)***

The ELMO model can be used to report on many different parameters relating to the behaviour of potential students in response to education policies and the economic implications of those responses, including public net benefits. This is accomplished by estimating the effects under the policy and base scenarios and taking the difference. To estimate the effects under the policy and base scenarios, the solution level of the decision variable is multiplied by the weight and the relevant parameters from previous sections. This is then summed across agents and other sets (if desired).

The following equations are used to derive the projected effect of an education policy on the total public net benefit, and provide a good example of the process.

$$\text{totalpubret}(s, r) = \text{sum}(ew, \text{sum}(i, \text{pubret}(i, ew, s, r) * \text{weight}(i, r) * \text{choicepriv.l}(i, ew, s, r))) \quad (11)$$

$$d\text{totalpubret}(r) = \text{totalpubret}(\text{"policy"}, r) - \text{totalpubret}(\text{"base"}, r) \quad (12)$$

where:

*totalpubret*(*s, r*) is the total expected public net benefit in scenario *s* and region *r*

*choicepriv.l*(*i, ew, s, r*) is the optimal level of the binary 'decision' variable

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$dtotalpubret(r)$  is the effect of the policy on total expected public net benefit in region r

$totalpubret("policy",r)$  is the total expected public net benefit in the policy scenario in region r

$totalpubret("base",r)$  is the total expected public net benefit in the base scenario in region r.

## Supplementary code

The supplementary part of the ELMO model can be activated to conduct sensitivity analysis, calibrate the model, and disaggregate education-work types.<sup>5</sup>

### *Sensitivity analysis (section 2 GAMS file)*

The ELMO model allows users to perform sensitivity analysis to better understand how changing the values of key parameters influences results. This means that the reporting parameters can be expressed as probability distributions or as confidence intervals, rather than point estimates.

Sensitivity analysis is undertaken by running the model many times with different combinations of parameters. The impacts of varying several parameter values can be analysed simultaneously; they are drawn from independent normal or uniform probability distributions. As an example, table 2 shows the input into some of the sensitivity analysis performed in a recent application of the ELMO model.

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<sup>5</sup> This part of the code is commented out. See the user guide below on how to implement these functions.

**Table 2 Assumed distribution of parameters in recent sensitivity analysis**

<i>Parameter</i>	<i>Description</i>	<i>Distribution</i>	<i>Lower</i>	<i>Mean</i>	<i>Upper</i>
<i>tax</i>	flat tax rate	Normal	0.28	0.38	0.48
<i>vtaxrev</i>	excess value of tax revenue	Uniform	0.04	0.24	0.44
<i>g</i>	growth in wages	Uniform	0.005	0.015	0.025
<i>hoursworked</i>	hours worked in period 2	Uniform	62 576	72 576	82 576
<i>vnmafactor</i>	value of non-market activity relative to base wage	Uniform	0.25	0.5	0.75

It is important to note that varying some parameters will result in the model no longer being calibrated to the inputted data on the share of individuals in each education-work category.

### *Calibration (section 3 GAMS file)*

As discussed below, the calibration section is used to estimate the residuals (box 3). The estimated residuals alter the perceived private net benefits of different education-work types to ensure that the model results are consistent with data from the Survey of Education and Training (ABS *cat. no. 6278.0*). For example, if 22 per cent of the relevant Tasmanian population has a degree, the residuals will be estimated so that the model reproduces this result.

The model only needs to be recalibrated if applied to a new population or substantial changes are made that alter the perceived private net benefits to education-work types in the base scenario. For example, substantial changes to the baseline employment parameters will necessitate recalibration, whereas changes that only affect parameters in the policy scenario will not necessitate recalibration.

A slightly different solving technique is used to solve the ELMO model in the calibration section. This technique enables the model to solve relatively quickly and thus increases the number iterations that can be completed within a reasonable time frame. That said, the underlying structure of the model is exactly the same for both the base ELMO model and the version used for calibration purposes.<sup>6</sup>

<sup>6</sup> The method used in the calibration module can also be more accurate than the solver method used in the standard model. In some cases, the calibration method may be preferred to the solver method, for example, the quicker solution time can make it a preferred option in sensitivity analysis.

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### Box 3      **Interpreting the residuals**

Interpreting the residuals is complex. The residuals reflect differences between the predictions from the first part of the model (the part without residuals), and the calibrated model. These include:

- the possibility that relevant benefits and costs have not been accounted for
- benefits and costs that are included in the model (such as the relationship between education-work types and wages across abilities, or ignoring general equilibrium effects) that might have been estimated incorrectly
- the likelihood that some aspect of the complex decision being made by individuals are not captured in the model (for example, pursuing a qualification for reasons other than human capital investment)
- noncomparability with the population that is being used for calibration (some people could have received their highest level of education when the perceived private net benefits were different from those being used in the model, which are based on current, observed returns).

That said, the first part of the model is not intended to be a predictive model but to generate estimates of the 'shapes of the perceived private net benefits functions. The second part of the model (the residual calibration process) determines the 'heights' of the perceived private net benefits functions.

In the default version of the ELMO model, some of the differentials in residuals are quite large (around \$100 000 between the smallest and largest in most regions). The pattern of residuals suggests that the first part of the model has a tendency to predict relatively high net benefits of blue-collar certificate 3 or 4 and degree education. This is a potential issue to the extent that it stems from errors in the shapes (rather than heights) of the perceived private net benefits functions in the first part of the model. Unfortunately, it is not simple to distinguish between the two by examining the residuals.

In summary, the residuals should not be interpreted as errors in the ELMO model, but rather as the combination of several effects that are not accounted for by the simple theory underlying the first part of the model. Future improvements in model theory could contribute to reducing the size of residuals.

### *Disaggregation (section 4 GAMS file)*

The disaggregation section allows the user to disaggregate an education-work type into several components. For example, the blue-collar certificate 3 or 4 education-work type could be disaggregated into electricians and non-electricians. A subsidy can then be applied specifically to electrician courses.

The ELMO model assigns agents randomly into two groups — for instance, those who prefer to be electricians and those who prefer to work in other blue-collar

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certificate 3 or 4 education-work types in the base scenario. This assignment is based on shares that must be specified by the user. These shares could be obtained from data (such as from the ABS) or chosen arbitrarily.

The perceived private net benefits accruing to individuals in the disaggregated education-work type category are then adjusted so that the assigned subcategory for each individual produces greater net benefits than the non-assigned category. This is accomplished by subtracting a penalty (which is determined by a random number and linear function) from the net benefits of the non-preferred disaggregated education-work type category. The disaggregated model is solved using the same approach as the core model.

## **4 Data**

Table 3 summarises the parameters used in the ELMO model. The parameter values can be accessed through the model. The third column shows the data source. Most of the parameters have been estimated based on data from the ABS or other sources. Where this was not possible, transparent assumptions were made and sensitivity analysis undertaken. The fourth column indicates the reliability of the parameter estimates, based on judgments.

A key area for further research is developing fully empirical estimates of the wage parameters, since these are central to driving many results and confidence in them is low.

The data specific to the disaggregation section is for illustrative purposes only.

**Table 3 Key parameters used in the ELMO model**  
Data sources and reliability

<i>Data</i>		<i>Source</i>	<i>Confidence</i>
moneycost(ew,s) fee(ew,s)	money cost of education	Productivity Commission estimates based on DEEWR (2011), DEEWR (nd), Access Economics (2010), ABS (2010b), Chapman, Rodrigues and Ryan (2007), SCRGSP (2011), Gonski (2010) and ABS (2011b)	high
time(ew)	time taken to complete education	Productivity Commission estimates based on ABS (2008)	moderate
timecostperhour	opportunity cost of study time	Productivity Commission estimates based on ABS (2010b)	moderate
tax	flat effective tax rate	Productivity Commission estimates based on ABS (2006)	moderate
vtaxrev	excess value of a dollar of government revenue	Productivity Commission estimates based on KPMG Econtech (2010)	moderate
wpar(ew,s,wlabels)	parameters in wage function	Productivity Commission estimates based on ABS (2010a) and by assumption	low
g	growth in present value of wages	by assumption	low
empl(ew,s)	parameters in employment function	Productivity Commission estimates based on ABS (2010a)	moderate
hoursworked	hours worked over lifetime	Productivity Commission estimates based on ABS (2010a) and ABS (2009)	moderate
vnmafactor	value of non-market activity relative to the base wage	by assumption	low
avebasewage	base wage	Productivity Commission estimates based on ABS (2010a) and by assumption	low
ebfactor(ew)	external benefits from labour	by assumption	low
overest(ew)	overestimate in net benefits	by assumption	low
residual(ew,r)	residual net benefits	through calibration	n.a.
pop(r)	population by region	ABS (2011a)	high
gamma	related to correlation between blue- and white-collar abilities	Williams and Cummings (1996)	low

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## 5 User guide

This section provides a brief user guide for the ELMO model.

### Downloading and running ELMO

The computer files required to run the ELMO model are available at: <http://www.pc.gov.au/projects/study/coag-reporting/elmo>. There are several files required to run ELMO:

- the ELMO GAMS file
- an Excel input file to assign the unique mix of blue and white collar ability scores to each representative agent
- two Excel output files — one for the base model and one for sensitivity analysis. Neither of these files are required for the model to successfully solve, but they display the model results in an easily accessible form.

Users must copy the input and output files to the GAMS project directory. In addition to these files, users require the following licensed software:

- Microsoft Excel
- GAMS, including the GUROBI solver (available at [www.gams.com](http://www.gams.com)).

### Running basic policy shocks

The ELMO model can be used to model the effects of education policies such as, subsidies that reduce the private costs of education and changes that increase the benefits of education. The ELMO model is shocked using the following steps:

1. Change the appropriate parameters in the policy scenario to implement the policy shock, taking care not to change the parameters in the base scenario — if the returns to education are changed in the base scenario, the ELMO model must be recalibrated.
2. Optional: specify any new reporting parameters that are not in the defaults, and ensure that they are followed by a display command.
3. Run the ELMO model.

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4. Refer to the list (.lst) or ELMO output (ELMOoutput.xls) files for results. The ELMO model cannot write to the output file if the output file is open. Thus the ELMO output file should not be open while ELMO is running. The default parameters that are sent to the ELMO output file are:
    - (a) the total number of people choosing each education-work type in each scenario, disaggregated by region
    - (b) the change in total expected value of non-market activity forgone in each region
    - (c) the change in total money cost associated with study in each region
    - (d) the change in total expected external benefit in each region
    - (e) the change in residual net benefit (public and private) in each region
    - (f) the change in total expected public benefit less public costs in each region
    - (g) the total expected gross earnings (excludes residual) disaggregated by education-work type, scenario and region.

## Running sensitivity analysis

Sensitivity analysis is performed using the following steps:

1. Comment out (by inserting a ‘\*’ at the start of the line) the \$ontext and \$offtext commands at the start and end of section 2 of the ELMO GAMS file. This turns the text from a comment into an executable command.
2. Optional: set the number of iterations by adjusting the set m (default is 500 iterations).
3. Set desired distribution of parameters. For example, the default distribution for the tax parameter is a normal distribution with a mean of .38 and a standard deviation of .05. This is implemented by the command *tax = normal(.38,.05)*.
4. Run the ELMO model using the desired policy shock.
5. Refer to the list (.lst) or sensitivity analysis output (sensitivityanalysisoutput.xls) files for results. The sensitivity analysis output file must not be open when running sensitivity analysis. Note that the sensitivity analysis output file is developed for 500 iterations and will need to be altered to report fewer or more iterations.
6. Turn the sensitivity analysis off (by removing the ‘\*’ that precede the \$ontext and \$offtext commands at the start and end of section 2).

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## Running calibration

The ELMO calibration module estimates the residuals required for the ELMO model to reproduce as closely as possible the shares for education-work categories inputted by the user. The ‘calibration problem’ is not continuous when the changes in residuals are small, thus it is not necessarily possible to find a set of residuals that results in the ELMO model exactly reproducing the shares inputted by the user.

The calibration process has two parts. First, the calibration model iterates through a different set of residuals 400 times. If the percentage of individuals in a certain education-work category is too small (too large) for a given iteration, then in the next iteration the residual for that category will be increased (decreased). Furthermore, the model uses the results of previous iterations to improve the accuracy of its adjustments to the residuals.

Second, the calibration process is repeated four times. The set of parameters that influence the aforementioned adjustment process are varied for each repetition. Four sets of residuals are produced by this process. The model chooses the set of residuals that produces the smallest difference between the ELMO model results and the inputted data.

The ELMO model is calibrated using the following steps:

1. Comment out (by inserting a ‘\*’ at the start of the line) the \$ontext and \$offtext commands at the start and end of section 3 of the ELMO GAMS file.
2. Insert data on shares of individuals in each education-work category into the table labelled ‘target shares’. (The calibration model will be impeded if the shares in each education-work category do not exactly sum to 1 for each region. Therefore, it is preferable for shares to be inputted to four or more decimal places.)
3. Run the ELMO model. The model should take approximately 15 minutes to run.
4. Refer to the calibration output (ELMOcalibration.xls), which will display the calibrated results for two key parameters:  $pcenttotalchoice(ew,s,r)$  and  $residual(ew,r)$ .
5. Save the results for the parameter  $residual(ew,r)$ , and update the  $residual(ew,r)$  parameter table in section 1.D of the ELMO GAMS file.
6. Turn the calibration model off (by removing the ‘\*’ that precede the \$ontext and \$offtext commands at the start and end of section 3).

The calibration model may struggle to accurately calibrate the residuals if the inputted shares differ markedly from the default shares. For example, it will be

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difficult to calibrate the model if the proportion of individuals choosing to undertake a university degree is very low. The equations linking ability to wages for different education-work types would need to be altered to obtain better calibration results.

## Running the disaggregated version of the model

The disaggregated version of the model allows the user to disaggregate the certificate 3 or 4, blue-collar worker category into two subcategories. This version of the model can be run as follows:

1. Comment out (by inserting a ‘\*’ at the start of the line) the \$ontext and \$offtext commands at the start and end of section 4 of the ELMO GAMS file.
2. Specify the parameter values *share(ndew)* (the share of workers in the certificate 3 or 4, blue-collar category who are in each subcategory) and *alpha(ndew)* (the penalty applied to individuals for whom the subcategory is not preferred).<sup>7</sup> All existing parameter values in section 4 are for illustrative purposes only.
3. Determine the subsidy applied to each disaggregated education-work type (these are in addition to any subsidies applied in the core model) by adjusting *dissub(ndew,s)*.
4. Run the ELMO model.
5. Refer to list (.lst) file for results.
6. Turn the disaggregated version of the model off (by removing the ‘\*’ that precede the \$ontext and \$offtext commands at the start and end of section 4).

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<sup>7</sup> Refer to the earlier section on disaggregation in section 3 for more information on this process.

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