

Modelling the Movement of Natural Persons

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1. Introduction

While the liberalisation of trade has been at the forefront of the global agenda for many decades, the movement of natural persons remains heavily guarded. Nevertheless restrictions on the movement of natural persons across regions impose a cost on developing and developed economies that may far exceed that of trade liberalisation.

More recently, the issue of the movement of natural persons has come to the forefront, under Mode 4 of the Uruguay Round's General Agreement on Trade in Services (GATS). Many developed economies currently suffer from shortages of both skilled and unskilled labour. As a result of the need for skilled workers, the services sector have been urging for reforms that would allow more temporary workers to enter the country. Developing countries, as the largest suppliers of temporary labour, are also interested in the effects of such reforms on their own populations.

The purpose of this paper is to develop a model and dataset, which can be used to address the question of who benefits from the liberalisation of the movement of natural persons. The model allows us to examine the effects of an increase in the temporary movement of labour into the services sectors of an economy, where demand for these reforms is highest, or alternatively into any other sectors within the economy. The effect of these temporary movements in labour on wages, remittances, income and welfare of both the labour importing and labour exporting countries can be captured by the model. In addition, the model also takes account of differences in the productivities of the temporary workers and resident workers; these differences are reflected in the different wages earned by the two types of workers.

Following the introduction, section 2 provides a brief overview of the model and defines some of the terms used to distinguish between the different types of workers. The remaining sections describe, in detail, the data collected, the methods used to infer other

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values required by the GMig model, the calibration of the database and the extensions to the GMig model itself. Sections 3 and 4 examine the data and calibration issues, while section 5 describes the model. Finally in section 6, the paper is summarised and concluded.

2. Overview of Model

The model and data used in this paper are based on the GTAP model and database. The GTAP model is a global applied general equilibrium and was developed by Hertel (1997), where it is described in greater detail. The GTAP model is a fairly standard applied general equilibrium model with competitive market behaviour. There are no scale or clustering effects, which often pervade the skilled migration literature. A regional household allocates income across private and government consumption, and saving according to a Cobb Douglas utility function. Firms supply commodities for private and government consumption, and to firms for intermediate usage in the domestic market; and for export, while minimising the costs of production. Some of the features of the GTAP model include:

- the use of the Constant Difference Elasticity (CDE) system for allocating private consumption across commodities;
- trade flows by commodity, source and destination based on Armington assumptions; and
- international transportation margins.

The database used in this paper is Version 5 of the GTAP database. Version 5 includes input-output and trade data for 66 regions and 57 sectors (Dimaranan and McDougall, 2001). The high level of regional and sectoral detail in the GTAP database provides the user with a great deal of flexibility when investigating policy issues.

Significant changes have been made to the GTAP model and database to incorporate the movement of natural persons. The changes made to the GTAP model and database were undertaken in such a way as to retain the extensive regional and sectoral detail available in the GTAP database. Data on the movement of natural persons was

collected at the country level and aggregated to the 66 GTAP regions. The data collected are used to support the extensions to the model. The new model developed in this paper is referred to as GMig.

The model and data make a number of simplifying assumptions which should be noted at the outset. With regard to the data, although every effort was made to collect quality data on the flows of temporary labour, data is scarce and of questionable quality. Assumptions had to be made to fill in any missing data. The model also makes a number of simplifying assumptions which may affect the results of the analysis. Firstly, it is assumed that outward migration is not selective. Borjas (2000) argued that there was evidence to suggest that permanent migrants were often the most skilled of their counterparts. This is probably less so for temporary migrants however, if temporary workers are more highly skilled then this may increase the losses which are expected to accrue to the permanent residents in the developing economies as a result of the removal of restrictions on the movement of labour. Secondly, the model treats the movement of labour as the export and import of labour, not as the export of services, which require the temporary movement of labour. Therefore the removal of restrictions on the movement of labour, affects the service sectors only to the extent that they demand permanent and temporary labour, and not via a reduction in the cost of exporting.

Before commencing, it is first necessary to define a number of terms, which will be used to distinguish between the various groups within the population and the labour force (Table 1). In particular a distinction is made between a temporary migrant and a temporary worker. Although technically these are the same person – a temporary migrant of one region is a temporary worker in another region – a distinction is made in the model to improve the tracking of these guest workers². The basic idea is that once a temporary migrant crosses the border into the host region they become a temporary worker.

² In a limited number of cases, the term guest worker may also be used if neither of these terms is appropriate. For example if we are referring to guest workers in general, not by their home or host region.

Table 1: Definitions used in GMig

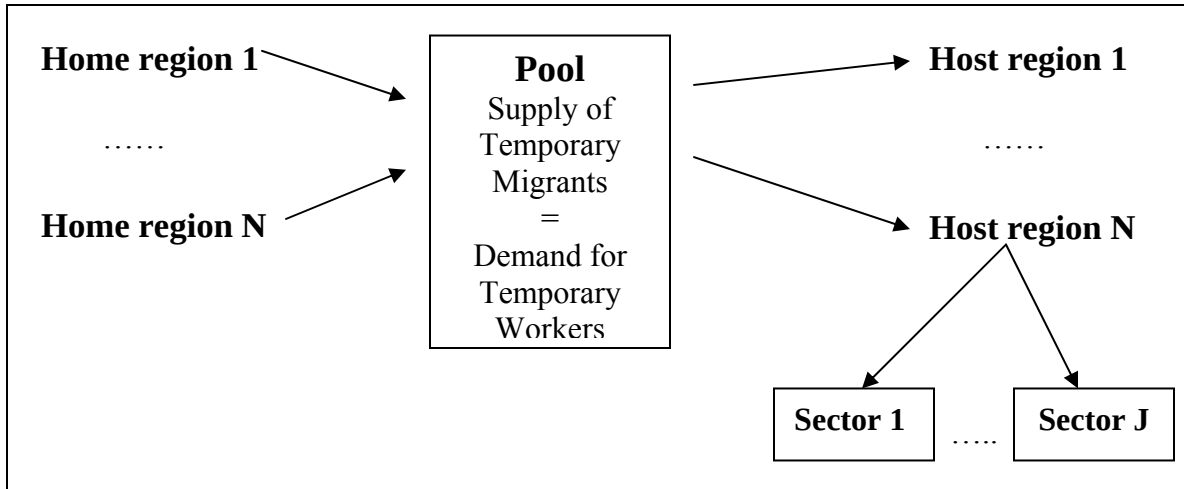
Term	Definition
Home	Permanent Residence. Supplier/exporters of temporary workers.
Host	Temporary Residence. Demanders/importers of temporary workers.
Temporary Migrant	Permanent residents of the home region who work abroad.
Temporary Labour/Worker	Temporary residents of the host regions.
Permanent Labour/Worker	A person who is working/living in their home region

Since bilateral flows of guest workers between regions are generally unavailable or of dubious quality, the movement of natural persons has been incorporated into the model in such a way as to minimise the amount of data required. Figure 1 illustrates the method used. The model makes use of a global labour pool, which collects the temporary migrant's from their home region and allocates them across host regions. The temporary workers are then combined with permanent labour and allocated across sectors within the region. In the host country temporary workers earn a wage for their labour, which compensates them according to their productivity³. Part of this wage is then sent back to the home region via the global pool as remittances, the remaining income is added to the income of the host population where it is then allocated across consumption, saving and government spending to maximise utility⁴.

³ It is assumed that all temporary workers have the same productivity as the average temporary migrant adjusted slightly to reflect the fact that productivity may alter towards the productivity of a typical worker in the host region. E.g. a Mexican working in the USA has the productivity of the average temporary migrant plus half of the difference between the productivity of the average temporary migrant and a USA worker. This allows for the fact that the temporary worker is using the host country's technology, which may increase (or decrease) his/her usual productivity.

⁴ Again restrictions on the availability of data preclude us from allocating the income of the temporary worker across consumption, saving and government spending separately. See Walmsley (forthcoming) for an example of how this could be incorporated using a number of simplifying assumptions and an extensive calibration procedure.

Figure 1: Allocation of Migrant Workers to the Host Region and Sector



The allocation of temporary migrants across host regions can be achieved in a number of different ways, depending on the choice of the user. These methods include:

a) *Exogenous Shocks Method*

Applying exogenous shocks to the number of temporary migrants leaving the home region or to the number of temporary workers permitted to enter the host region. The latter example is used to examine the case where the host country increases its quota on temporary workers.

b) *Shares Method*

Under this method, temporary migrants are allocated across host regions or temporary workers are obtained from home regions in proportion to their labour force or other relevant shares.

c) *Wages Method*

Temporary migrants are allocated across host regions or temporary workers are taken from home regions according to wage differentials. For example, temporary workers are drawn from those regions (home) where wages are lower than the average wage obtained by a migrant worker.

There are a number of issues which must be considered before applying any particular method. In most cases a change in the quota of temporary labour permitted to enter the host region is represented by an exogenous shock to the number of temporary workers, the shares method is then used to determine the home regions of this temporary labour. The three alternative methods are discussed in greater detail in Section 5.2.

3. Data

The primary database used to support the GMig model is version 5 of the GTAP Database (Dimaranan et al., 2001). Version 5 of the GTAP database contains 66 countries/regions and 57 sectors. The GTAP database was supplemented with additional data on the labour force, numbers of temporary migrants and workers and their remittances. In this section we provide the sources for this additional data, outlining the assumptions made for filling in any missing data and the calculation of wage data.

Data was collected at the country level for 211 countries. The benefits of collecting data at such a high level of disaggregation are that: a) it improves the quality of the data; and b) it increases the number of regions/countries which can be examined. This data was then aggregated to obtain data for the 66 regions in version 5 of the database.

The new data include information on population, labour force, numbers of skilled and unskilled labour, the number of temporary workers by skill level located in each (host) region and the number of temporary migrants by skill level from each (home) region and the value of remittances received by permanent residents and paid by temporary labour in the region. Data were found for as many countries as possible, missing data was then filled to get estimates for all 211 countries.

The filling process involved using data on the numbers of temporary migrants and temporary labour to estimate remittances in and out respectively or alternatively using remittance data to obtain estimates of numbers of temporary migrants or labour. In some cases, no data on remittances or the number of people were available, where this occurred no estimate was made and the values were assumed be zero. This was the case for temporary migrants from the United States, Canada, UK and Germany and for temporary labour working in Mexico. The data was obtained from the International Labour Organisation's (ILO) International Labour Migration Database⁵.

In a limited number of cases the ILO International Migration database also included estimates of the skill level of the temporary labour; these estimates were used wherever possible to obtain a split between skilled and unskilled workers. In the other regions, the skill level of migrants was assumed to reflect the skill level of their home labour force. The skill levels of the temporary workers were then assumed to reflect the average skill level of the temporary migrants.

Once the number of workers were obtained, these were then used to find the wages or the value of labour services earned by the temporary workers. A measure of the productivity of a worker in the home region relative to the average migrant worker was estimated based on the wage rate in each of the regions relative to the average wage of the temporary migrant in the home economy. When the temporary worker enters the host region they have the productivity of the average migrant plus they obtain a portion of the difference between the average productivity of the migrant and the productivity of a permanent resident of the host region. This reflects the fact that the temporary worker's productivity will partially adjust to reflect the productivity in the host region. For example, the productivity of an African entering the UK will increase relative to his productivity at home as he/she will now have more productive tools, however, it will not increase to become the same as a permanent resident as they do not have specific tools required for the UK, e.g. language, UK education etc. Borjas (2000) examined the case

⁵ A handful of these numbers were altered if other evidence suggested that the number provided by the ILO migration database was a significant underestimate. For example the number of temporary migrants from the Philippines and the number of temporary workers in the USA were revised upwards to reflect other data collected by Walmsley (1999). The revisions to temporary workers in the USA reflect estimates of the number of illegal temporary workers in the USA.

for a permanent migrant entering the USA and found that they received 80-90%⁶ of the wages of a permanent resident, this portion increased as the migrant spent more time in the country and additional USA specific skills were gathered⁷. It is expected that temporary workers would earn a smaller proportion of the permanent residents wage⁸.

4. Calibration

Remittances are an important source of income for many of the labour exporting regions, such as Thailand and the Philippines. The inclusion of remittances in the income of the region means that income is now defined as income earned on land, labour and capital located in the region plus taxes minus net remittances paid. The GTAP database must be altered to reflect this new definition and ensure that this new definition of income is consistent with spending, i.e. $\text{Income} = C + S + G$.

To ensure that income equals spending in the extended model, GMig, one of the components of spending must be altered. In this case we choose to reduce saving by the value of remittances. This method is used for the following reasons:

- In the construction of the GTAP database C and G are calculated to equal externally collected consumption and government spending data. Therefore in the GTAP database construction process it is saving which would be allowed to adjust to take account of the fact that the GTAP database takes no account of remittances. Hence if we wish to include remittances, saving should be adjusted.
- The use of saving minimises the calibration required. The only restriction pertaining to saving in the GTAP data base is that global saving equals global investment. Since global remittances received equal global remittances paid,

⁶ Whether the average migrant received 80% or 90% depends on the skills of the migrant worker. In the 1970s migrants to the USA earned 90% of the wage of a USA worker as many of them were from Europe and had higher skills. More recently, with the increase in immigrants from Latin America, skills and hence wages have declined.

⁷ In fact Borjas (2000) found that as time progressed Migrants wages increased to 10% more than the average natives wage. He suggested this may be the result of self-selection, i.e. a migrant who chose to move permanently is probably very entrepreneurial.

⁸ As they are temporary they do not have time to adapt and a temporary migrant is unlikely to have the same entrepreneurial characteristics as a permanent migrant.

the global saving – global investment identity is automatically satisfied when these remittances are added to or subtracted from saving.

5. The Model

The extensions made to the GTAP model to incorporate the movement of natural persons are outlined below⁹. In these sections we focus on the fundamental equations of the GMig model. The equations are divided into five groups: definitions, allocation methods, income, welfare and sectoral allocation.

5.1 Definitions

The first group of equations relate to the accounting relations and definitions. These are non-behavioural equations and include the balancing equation, definitions of population and labour force, and those that adjust for productivity. In this sub-section we examine each of these in turn.

Equation 1 is the balancing equation. This equation ensures that the total number of temporary migrants (QTM_i) from all home regions equals the total number of temporary labour (QTL_i) in all host regions¹⁰. For example if we increase quotas on temporary labour, then the number of temporary migrants must also increase so that the number of temporary migrants by skill equals the number of temporary workers by skill¹¹.

Balancing Equation

$$\begin{aligned} \forall i \in LAB \\ QTL_i = QTM_i \end{aligned} \tag{1}$$

⁹ For those familiar with Gempack notation, Appendix 1A contains a list of these equations as they might appear in the GTAP model. Appendices 1B, 1C and 1D also describe the variables, coefficients and the closure rules required, respectively.

¹⁰ In the GMig model, we include a slack variable ($d_gwslackp(i)$ in Appendix 2). In the standard closure this slack variable is endogenous as other equations in the model ensure this equations validity. Thus the slack variable acts as a check on the model to ensure that the number of temporary migrants equals the number of temporary workers. Although this equation is not imposed, except under special closures, the user should always check to ensure that it is valid. The special closures are described in Appendix 2D on Alternative Closures.

¹¹ Note that the quantity of temporary labour ($QTL_{i,r}$) usually has an i and an r subscript to indicate the skill level and the region, respectively. Unless otherwise stated the removal of a subscript means that the variable has been added across all of the elements of the missing subscript. For example, in this case, QTL_i equals the sum of $QTL_{i,r}$ across all regions.

where:

QTL_i is the quantity of temporary labour by skill i located in all host regions.

QTM_i is the quantity of temporary migrants by skill i from all home regions.

Equations 2 to 6 relate to the labour supplies and populations of temporary labour and migration and permanent residents. Equation 2 determines the change in permanent labour supply ($\Delta QPL_{i,r}$) permanent residents who supply their labour to the home region). The permanent labour supply can be affected by two changes: firstly, if permanent residents choose to become temporary migrants ($\Delta QTM_{i,r}$) this will reduce the permanent labour supply; and secondly, if there is an exogenous change in the permanent labour supply itself, unrelated to migration. The possibility of other exogenous changes to the permanent labour supply are incorporated through a shift variable ($\Delta QPL^S_{i,r}$).

Equation to find Changes in Permanent Labour force

$\forall i \in \text{LAB} \forall r \in \text{REG}$

$$\Delta QPL_{i,r} = -\Delta QTM_{i,r} + \Delta QPL^S_{i,r}$$

where:

Δ represents the change in a variable.

2

$QPL_{i,r}$ is the quantity of permanent labour by skill i in region r .

$QTM_{i,r}$ is the quantity of temporary migrants by skill i from home region r .

$QPL^S_{i,r}$ takes account of the possibility that the quantity of permanent labour by skill i in region r may change for other exogenous reasons, which are unrelated to the movement of temporary labour. For example, aging populations.

Changes in the labour force due to temporary migration will also affect the population of temporary migrants (Equation 3) and the population of permanent residents (Equation 4) in the home region.

Population of Temporary Migrants

$\forall r \in \text{REG}$

3

$$\Delta \text{POPTM}_r = \Delta QTM_r$$

Population of Permanent Residents

$\forall r \in \text{REG}$

4

$$\Delta \text{POPPL}_r = -\Delta \text{POPTM}_r + \Delta \text{POPPL}^S_r$$

where:

$POPPL_r$ is the population of permanent residents of region r , whether they work at home or temporarily abroad.

$POPTM_r$ is the population of temporary migrants from home region r who chose to work abroad.

$POPPL_r^S$ is a shift variable and is used again to take account of the possibility that the population of permanent residents of region r may change for reasons other than migration.

Similarly temporary labour in the host region will affect the population of temporary labour (Equation 5), and also temporarily effect the population in the host region (Equation 6). The population of a region will depend on the population of its own permanent residents, which in turn depends on any temporary migration (Equation 4) and on the population of temporary labour (Equation 5). Since the labour flows are temporary only the worker moves to the host region, the family of the worker remains in the home region. As a result the population only changes by the change in the number of people migrating for employment.

Population of Temporary Labour

$\forall r \in REG$

5

$$\Delta POPTL_r = \Delta QTL_r$$

Population of Host

$\forall r \in REG$

6

$$\Delta POP_r^{HOST} = \Delta POPPL_r + \Delta POPTL_r$$

where:

POP_r^{HOST} is the population residing temporarily or otherwise in the host region r

$POPPL_r$ is the population of permanent residents in the host region r

$POPTL_r$ is the population of temporary residents in the host region

The differences between the productivities of permanent labour and temporary labour are a significant factor that could potentially affect the expected benefits from the relaxation of restrictions on the movement of natural persons. In the following equations we examine how the difference in productivities of the temporary and permanent labour supply are taken into account.

In GMig we define both the number of temporary migrants and the equivalent number of average temporary migrants, given their home productivity. This is done using estimates of productivity obtained from the wage data in the GTAP database. The productivity of the permanent residents ($APL_{i,r}$) of a region is assumed to remain fixed throughout the solution period, however their productivity relative to the average productivity of a temporary migrant (Equation 8) may change with changes in the average productivity of the migrants workers (Equation 9). It is assumed that wage differentials in the 1997 database reflect productivity differences between workers from these regions, part of which will arise due to the fact that there are quotas on the movement of labour.

Productivity of temporary migrants relative to average temporary migrant

$\forall i \in LAB, \forall r \in REG$

$$ATM_{i,r} = APL_{i,r} / ATM_i^{AV}$$

where:

$ATM_{i,r}$ is the productivity of a permanent resident/temporary migrant with skill level i from region r , relative to the average temporary migrant. 8

$APL_{i,r}$ is the productivity of a permanent worker from region r .

ATM_i^{AV} is the average productivity of a typical temporary migrant with skill level i .

Average productivity of temporary migrants

$\forall i \in LAB$

$$ATM_i^{AV} = \sum_r \frac{\Delta QTM_{i,r}}{\Delta QTM_i} \times APL_{i,r} \quad 9$$

It is possible that the average productivity of the permanent resident/temporary migrant relative to the average may have changed, even though productivities of permanent residents from individual regions are fixed. The reason for this is that the average productivity depends on the home regions of the temporary migrants. Thus if the shares change then the average productivity may also change (Equation 9). For example if more temporary migrants come from home regions with lower productivities the average productivity of the temporary migrant will decline. This has been occurring in the United States, over the last two decades, as more workers from Mexico have entered,

replacing the foreign workers from Europe. Since the productivity of a Mexican worker is lower than that of a European worker, the productivity and hence the relative wages of the average temporary worker has fallen (Borjas, 2000).

The number of temporary migrants is then converted into a number of average temporary migrant equivalents using the productivity of home residents relative to the average of a temporary migrants ($ATM_{i,r}$) according to Equation 10. The purpose of this is to ensure that remittances sent back to the home region and welfare calculations are adjusted to reflect the fact that these temporary migrants may have higher/lower productivities than the average migrant and hence their wages will be expected to reflect this fact.

Number of temporary migrant equivalents

$\forall i \in LAB, \forall r \in REG$

$$\Delta QTM^*_{i,r} = ATM_{i,r} \times \Delta QTM_{i,r}$$

where:

10

$\Delta QTM^*_{i,r}$ is the number of equivalent temporary migrants with the average productivity of a temporary migrant.

$ATM_{i,r}$ is the productivity of a migrant with skill level i from home region r relative to the average productivity of the typical temporary migrant

Prior to commencing work in the host region, a guest worker is assumed to have the same productivity as the average temporary migrant. Once working in the host region, temporary labour will acquire some of the productivity of the host region. For example a temporary worker, from the USA who goes to work temporarily in Mexico cannot be expected to be as productive as he/she would have been in the USA, thus the productivity falls slightly to reflect the productivity of the workers in Mexico. Likewise a Tunisian worker entering the UK would increase his/her productivity to reflect the higher productivity in the UK. Equation 11 states that the productivity of temporary labour will equal the initial productivity (QTM_i^{AV}) prior to entry plus a portion of the difference between the productivity of permanent residents in the host region and their initial productivity. Hence, changes in the average productivity of a typical temporary migrant, prior to moving, will also affect the productivity of the temporary worker once working in the host region.

Productivity of a temporary worker

$\forall i \in \text{LAB}, \forall r \in \text{REG}$

$$\text{ATL}_{i,r} = \text{ATM}_i^{\text{AV}} + \beta(\text{APL}_{i,r} - \text{ATM}_i^{\text{AV}})$$

where:

11

$\text{ATL}_{i,r}$ is the productivity of a temporary worker of skill level i in host region r .
 β is related to the gain in productivity made by a temporary migrant on entering the host region. It is the proportion of the host regions productivity which is gained by the temporary worker

This productivity of temporary labour is then used to determine the equivalent, productivity weighted, quantity of temporary labour, which enters the labour force of the labour importing region (Equation 12)¹². Finally the temporary labour and permanent labour are combined to determine the labour force, taking the differences in productivities into account.

Number of temporary migrant equivalents

$\forall i \in \text{LAB}, \forall r \in \text{REG}$

$$\Delta \text{QTL}^*_{i,r} = \text{ATL}_{i,r} \times \Delta \text{QTL}_{i,r}$$

12

where:

$\Delta \text{QTL}^*_{i,r}$ is the number of equivalent temporary workers of skill i , given the productivity gained on entering the host region r .

Equation to find Changes in Labour force

$(\text{all}, i, \text{LAB})(\text{all}, r, \text{REG})$

$$\Delta \text{QO}_{i,r} = \Delta \text{QPL}^*_{i,r} + \Delta \text{QTL}^*_{i,r}$$

where:

13

$\text{QO}_{i,r}$ is the quantity of labour by skill i in region r

$\Delta \text{QPL}^*_{i,r}$ is the number of equivalent permanent workers of skill i , base on exogenous productivity ($\text{APL}_{i,r}$).

Finally it should also be pointed out that the productivity equivalent wages of permanent and temporary labour are equal (Equation 14). Thus permanent and temporary labour are compensated equally for the same level of productivity.

¹² Changes in the average productivity also affect the productivity of the permanent resident relative to that of the average temporary migrant, even though the productivity of the permanent resident is fixed (Equation 22, Appendix 1).

$$\text{WTL}_{i,r}^* = \text{WPL}_{i,r}^*$$

5.2 Allocation Methods

In this section we examine the methods for allocating temporary migrants across host regions in greater detail. Figure 1 shows that temporary migrants move from their home regions into a global pool. From the global pool they are then allocated across host regions. A number of alternative methods are available to the user for this purpose. The method selected will depend on the question being examined. The methods of allocation are implemented through a number of equations and changes in the closure can then be used to turn these methods on and off. Further details regarding the closures are provided in Appendix 1D.

Three methods of allocation are provided and can be applied to either the allocation of temporary migrants across host regions or alternatively to determining the home regions of temporary labour. The first is the case where there is an increase in temporary migrants seeking host regions. It assumes that there is an excess demand for temporary worker places and that quotas are binding. The more appropriate case for analysis is the second, where a labour importing region increases (or decreases) its quota on the number of temporary workers admitted and temporary migrants must be found to fill those positions.

a) *Exogenous Shocks Method*

This method involves applying exogenous shocks to either the number of temporary migrants leaving the home region and/or to the number of temporary workers permitted to enter the host region. The latter example is used to examine the case where the host country increases its quota on temporary workers. The first example, assumes that the additional temporary migrants will be permitted into the host country to work. This method is usually used in conjunction with one of the other methods, for example you may wish to increase the quota of skilled temporary labour in the UK by 1m and use

the shares method to determine where these 1m people came from. In this case you would exogenise and shock $\Delta QTL^*_{\text{skilled,UK}}$ by 1000 (= 1m as data are in 000's of people).

b) Shares Method

Under this method, temporary migrants are allocated across host regions or temporary workers are obtained from home regions according to certain shares. In the case of the allocation of temporary migrants across host regions, the shares of temporary labour already located in the host region are used (Equation 15). When determining where temporary labour will come from we use labour force shares (Equation 16). The use of temporary migrant shares allows some regions to supply temporary migrant labour even though the data suggested they had not done so previously (e.g. USA, UK, Germany etc).

Equation to find allocation of temporary labour across host regions

$\forall i \in \text{LAB}, \forall r \in \text{REG}$

$$\frac{\Delta QTL_{i,r}}{\Delta QTL_i} = \frac{QTL_{i,r}}{QTL_i} \quad 15$$

Equation to find home regions from which temporary migrants come from

$\forall i \in \text{LAB}, \forall r \in \text{REG}$

$$\frac{\Delta QTM_{i,r}}{\Delta QTM_i} = \frac{QO_{i,r}}{QO_i} \quad 16$$

c) Wages Method

It is generally believed that the magnitude and composition of immigrant flows are determined by the labour market opportunities¹³ in the host, relative to those in the home country (Borjas and Freeman, 1992). The wages method assumes that the home country allocates its labour to the domestic market or to the foreign market according to a Constant Elasticity of Transformation (CET) function. There are costs associated with moving, which increase as more labour is directed towards the foreign market. Suppliers of labour then maximise the income earned from labour by allocating labour across the

¹³ Including real wages, costs of migrating and uncertainty, amongst others.

domestic and foreign market according to real wages¹⁴, and subject to the increasing costs of moving¹⁵. In this model the allocation occurs at two stages: a worker in their home region must allocate labour to the foreign market (pool); and secondly, once he/she has allocated labour to the foreign market they must then be allocated across host regions. In both cases real wage differentials are used as a measure of the differences in labour market opportunities between the home and the foreign markets and between host regions. For example, temporary workers are drawn mostly from those regions (home) where real wages are lower than the average real wage obtained by a migrant worker and the migrant workers are placed in those host regions where the real wage is higher than the average real wage available to the average temporary labour.

This method can be used in conjunction with an exogenous shock to determine how a change in a quota might affect the world economy or alternatively others¹⁶ have used it to examine the impact on migration flows of various policy changes.

To use this method we first calculate an average wage for the temporary labour (Equation 17). This takes account of changes in wages and productivities for which temporary labour is compensated.

Equation to find average wage received by temporary labour

$\forall i \in \text{LAB}$

$$\text{WTL}_i^{\text{AV}} = \sum_r \frac{\text{VTL}_{i,r}}{\text{VTL}_i} \times [\text{WTL}_{i,r}^* \times \text{ATL}_{i,r}]$$

where:

WTL_i^{AV} is the average wage of temporary workers of skill level i across all host regions

$\text{VTL}_{i,r}$ is the value of labour services provided by temporary labour of skill level i in host region r .

$\text{WTL}_{i,r}^*$ is the equivalent wage received by temporary labour of skill level i in host region r . Thus $\text{WTL}_{i,r}^* \times \text{ATL}_{i,r}$ is the actual wage received.

¹⁴ It is difficult to say what prices should be considered in the decision to migrate. Faini, De Melo and Zimmermann (1999) argue that if domestic prices are used to determine real foreign and domestic wages then the decision is a temporary one, however if foreign prices are used to determine real foreign wages then the decision is more permanent. The appropriate price is most likely to be one which discounts income spent abroad by foreign prices and income spent at home (remittances) by domestic prices. The prices used are defined in Equations 30 and 31 in Appendix 1.

¹⁵ See Faini, DeMelo and Zimmerman (1999) for further explanation.

¹⁶ Faini, DeMelo and Zimmerman (1999).

A worker in the home region then chooses to allocate labour across the domestic and foreign market ($QTM_{i,r}$: Equation 18). Labour allocated to the foreign market depends on any exogenous increases in labour in the home market ($QPL^S_{i,r}$) and on the relative real wages multiplied by the elasticity of transformation (δ_{TM}). If a quota is increased, temporary migrants will flow from those regions where the real wage at home is lower than the average real wage of the temporary labour¹⁷. Where the average real wages of temporary workers, given by Equation 19, represents the real return from moving and the real wage of permanent residents, given by Equation 20, represents the real return from staying at home.

Equation to find home regions from which temporary migrants come from
 $\forall i \in LAB, \forall r \in REG$

$$\frac{QTM_{i,r}}{QPL^S_{i,r}} = \left[\frac{RWTL_i^{AV}}{RWPL_{i,r}} \right]^{\delta_{MM}} \quad 18$$

where:

$RWTL_i^{AV}$ is the real average wage of temporary workers of skill level i across all host regions.

$RWPL_{i,r}$ is the real wage of permanent workers of skill level i in region r .

δ_{TM} is the elasticity of temporary labour with respect to the difference between real wages at home and those which could be earned abroad.

Equation to find average real wage of temporary labour
 $\forall i \in LAB$

$$RWTL_i^{AV} = WTL_i^{AV} / PTL^{AV} \quad 19$$

where:

PTL^{AV} is the average price of goods purchased by temporary labour across all host regions (Equation 21).

Equation to find real wage of permanent labour
 $\forall i \in LAB, \forall r \in REG$ 20

¹⁷ In this case the user will need to ensure that the total number of temporary migrants equals the total number of temporary workers by exogoneising the slack variable in the balancing equation (Appendix 1D).

$$RWPL_{i,r} = WPL_{i,r} / P_r$$

where:

$WPL_{i,r}$ is the wage of permanent labour of skill level i in region r .

P_r is the CPI in region r and depends on the price of consumption, saving and government spending.

Equation to find average price of goods purchased by temporary labour

$\forall i \in \text{LAB}$

$$PTL_{AV} = \sum_r \frac{YTL_r}{YTL} \times P_r \quad 21$$

where:

YTL_r is the income earned by temporary labour in region r .

The allocation of temporary migrants across host regions is undertaken in a similar way (Equation 22). Temporary labour allocated to the host region ($QTL_{i,r}$) depends on the total number of temporary migrants (QTM_i) and the relative real wages multiplied by the elasticity of substitution (δ_{TL}). When deciding which regions to work in temporarily, a temporary migrant will move to those regions where the real wage ($RWTL_{i,r}$: Equation 23) is higher than the average real wage ($RWTL_i^{AV}$: Equation 19) offered in all regions.

Equation to find allocation of temporary labour across host regions

$\forall i \in \text{LAB}, \forall r \in \text{REG}$

$$\frac{QTL_{i,r}}{QTM_i} = \left[\frac{RWTL_{i,r}}{RWTL_i^{AV}} \right]^{\delta_{TL}} \quad 22$$

where:

$RWTL_i^{AV}$ is the real average wage of temporary workers of skill level i across all host regions.

$RWTL_{i,r}$ is the real wage of temporary workers of skill level i in host region r .

δ_{TL} is the elasticity of temporary labour with respect to the difference between average real wage and the real wages in a particular host region r .

Equation to find real wage of temporary labour

$\forall i \in \text{LAB}, \forall r \in \text{REG} \quad 23$

$$RWTL_{i,r} = WTL_{i,r} / P_r$$

where:

$WTL_{i,r}$ is the wage of temporary labour of skill level i in region r .

The values of δ_{TL} and δ_{TM} reflect how sensitive the allocation is to wage differentials. For example, a high δ_{TM} means that the real wage in the home region relative to the average real wage of a temporary migrant will greatly affect the workers decision to supply labour to the foreign market, while a low value of δ_{TM} means that the current shares are more appropriate. If δ_{TM} and/or δ_{TL} are zero or real wages move together, then this method is equivalent to the shares method. It is left to the user to set values for these parameters¹⁸.

5.3 Income

In this section we examine the changes to income. Separate calculations are made for income earned by permanent labour, temporary labour and temporary migrants. Total income earned in the host, by permanent and temporary labour, is also calculated for the purposes of allocating income across private and government consumption and saving to maximise utility.

In the standard GTAP model, income (Y_r) includes all factor incomes (Y_r^{land} , Y_r^{natres} , $Y_r^{capital}$, $Y_r^{skilled\ lab}$, $Y_r^{unskilled\ lab}$), net of depreciation (Y_r^{DEP}) plus taxes. In GMig, we split labour according to permanent ($YPL_{i,r}$) and temporary labour ($YTL_{i,r}$) and we must also take account of remittances received ($RR_{i,r}$) from temporary migrants and remittances paid ($RP_{i,r}$) by temporary labour. Equation 24 shows how income spent in the host region is calculated.

Equation to find income earned in region r

$\forall r \in REG$

24

¹⁸ In many models which incorporate the movement of labour, a common option is to assume that labour moves to maintain a fixed wage differential (Burfisher, Robinson and Thierfelder, 2000 and the MONASH-MRF Model: Peters, Horridge, Meagher, Naqvi and Parmenter, 1996) and/or in response to unemployment. This is the case where TMSUB and TLSUB are very large and hence the movement of labour is very sensitive to wage differentials. Faini, De Melo and Zimmermann (1999) examined the effect of varying these elasticities on the decision to migrate and found that the higher the elasticity (or the lower the costs of migrating) of migrating the more migration occurred – in this case it was return migration as they were examining the effects of trade liberalisation on migration.

$$\begin{aligned}
Y_r &= Y_r^{\text{land}} + Y_r^{\text{natres}} + Y_r^{\text{capital}} - V_r^{\text{DEP}} \\
&\quad + \sum_i [YPL_{i,r} + YTL_{i,r}] \\
&\quad - \sum_i [RP_{i,r} - RR_{i,r}] \\
&\quad + TAX_r
\end{aligned}$$

where:

Y_r is income earned in region r .

Y_r^{land} is the income earned on land.

Y_r^{natres} is the income earned on natural resources.

Y_r^{capital} is the income earned on capital.

V_r^{DEP} is depreciation on capital.

$YPL_{i,r}$ is income earned by permanent labour by skill.

$YTL_{i,r}$ is income earned by temporary labour by skill.

$RP_{i,r}$ is the value of remittances paid by temporary labour by skill.

$RR_{i,r}$ is the value of remittances received by permanent residents by temporary migrants of skill i .

TAX_r is the value of taxes received in region r .

Remittances paid by temporary labour change as a result of either: changes in the number of temporary workers ($QTL_{i,r}$ in Equation 25); or changes in the wage received by those temporary workers ($WTL_{i,r}$ in Equation 25).

Remittances received from temporary migrants change as a result of: firstly, changes in the average remittance paid by temporary labour ($RTL^{\text{AV}}_{i,r}$ in Equation 26); and secondly, changes in the number of equivalent temporary migrants ($QTM_{i,r}$ in Equation 26). The average remittance paid by temporary labour depends on the wages earned by temporary labour, and on the shares of temporary labour and of temporary migrants. The shares component takes into account two possibilities. Firstly, temporary migrants from different regions remit at different rates. For example, temporary migrants from the Philippines may remit more than those from Britain due to cultural differences or the greater necessity for assistance by families back home. Secondly, the ability to remit may also be affected by the host region of the temporary worker. For example, temporary workers in the USA may be able to remit a higher portion of their wage than

those working in Russia. Any change in either of these shares would therefore result in changes in the average level of remittances¹⁹.

Equation to find Remittances paid by temporary workers in region r

$\forall r \in \text{REG}$

$$\% \Delta \text{RP}_{i,r} = [\% \Delta \text{WTL}_{i,r} + \% \Delta \text{QTL}_{i,r}] \quad 25$$

where:

$\% \Delta$ means percentage change in the variable.

Equation to find Remittances received by permanent residents in region r

$\forall r \in \text{REG}$

$$\% \Delta \text{RR}_{i,r} = [\% \Delta \text{RTL}_i^{\text{AV}} + \% \Delta \text{QTM}_{i,r}] \quad 26$$

where:

RTL_i^{AV} is the average remittance paid by temporary labour.

Regional income is then divided into the income of temporary labour (Equation 27) and the income of permanent labour (Equation 28). The income of temporary labour is assumed to include their income from labour less remittances sent home; all other income, including income on land, capital and taxes are earned by permanent labour.

Equation to find income earned by temporary labour in region r

$\forall r \in \text{REG}$

$$\text{YTL}_r = \sum_i [\text{YTL}_{i,r}] - \sum_i [\text{RP}_{i,r}] \quad 27$$

Equation to find income earned by permanent labour in region r

$\forall r \in \text{REG}$

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¹⁹ Note that this average could be broken into two components and added to remittances in and out as appropriate. However, since this model was developed for the purposes of looking at the elimination of quotas by particular regions most of the changes in shares are expected to effect in the level of remittances paid, it was believed that it was more important to change the value of remittances received to reflect these changes than the other way around.

$$\begin{aligned}
YPL_r &= Y_r^{\text{land}} + Y_r^{\text{natres}} + Y_r^{\text{capital}} - V_r^{\text{DEP}} \\
&\quad + \sum_i [YPL_{i,r}] \\
&\quad + \sum_i [RR_{i,r}] \\
&\quad + TAX_r
\end{aligned}$$

where:

YPL_r is income earned by permanent residents in region r

The income of all temporary labour by skill and region is then added up across regions and shared out to temporary migrants according to their share of temporary migrants in the total number of temporary migrants (Equation 29). This share is also adjusted to take into account the different productivities of temporary migrants.

Equation to find income earned by temporary migrants of home region r

$\forall r \in \text{REG}$

$$YTM_r = \sum_i \frac{QTM_i^*}{QTM_i^*} \sum_r [YTL_{i,r} - RP_{i,r}] \quad 29$$

where:

YTM_r is income earned by temporary migrants of home region r

5.4 Welfare

In determining whether the world is better or worse off as a result of the movement of natural persons it is necessary to have a measure of welfare, which can be used to determine the welfare of the various agents as well as in total. In the standard GTAP model a measure of EV is obtained from income and the utility function for each of the regional households²⁰.

EV

$\forall r \in \text{REG}$

30

$$EV_r = \Delta U_r = \Delta(Y_r / P_r)$$

²⁰ Note that in GMig, the income of permanent residents and temporary workers is added together and then allocated across private and government consumption and saving. This means that the utility derived in the standard GTAP model is for a regional household, which is made up of permanent residents and temporary labour.

where:

EV_r is the Equivalent variation of the regional household n in the standard GTAP model in millions of US\$.

Y_r is the income of the regional household n in the standard GTAP model in millions of US\$.

This utility and EV can be divided into two components: the EV for permanent and temporary workers. The welfare of permanent residents is a function of the utility derived from the income of the permanent residents (Equation 30).

EV of permanent labour

$\forall r \in \text{REG}$

$$EVPL_r = \Delta(YPL_r / P_r) \quad 30$$

where:

$EVPL_r$ is the Equivalent variation of the permanent residents in region r in millions of US\$.

The welfare of temporary labour is found using a similar method (Equation 31). The total EV of all temporary workers is then equal to the sum across regions of the EV of all the temporary workers (Equation 32).

EV of permanent residents

$\forall r \in \text{REG}$

$$EVTL_r = \Delta(YTL_r / P_r) \quad 31$$

where:

$EVTL_r$ is the Equivalent variation of the temporary labour in host region r in millions of US\$.

EV of all guest workers

$$EVTL = \sum_r EVTL_r \quad 32$$

where:

$EVTL$ is the Equivalent variation of all temporary labour in millions of US\$.

This income of temporary migrants calculated in Equation 29, is then used to determine welfare of temporary migrants (Equation 33). An average price is used to determine the welfare of temporary migrants (Equation 21). This average price is the average price for goods paid by temporary labour in their host regions. Once the EV of temporary migrants is determined, the welfare of the home region, regardless of temporary residence (Equation 34), and the world EV (Equation 35) can also be calculated.

EV of temporary migrants

$\forall i \in \text{LAB}$

$$\text{EVTM}_r = \Delta(\text{YTM}_r / \text{PTL}^{\text{AV}}) \quad 33$$

where:

EVTM_r is the Equivalent variation of temporary migrants of home region r in millions of US\$.

EV of Permanent residents of region r

$\forall r \in \text{REG}$

$$\text{EV}_r^{\text{HOME}} = \text{EVPL}_r + \text{EVTM}_r ; \quad 34$$

where:

$\text{EV}_r^{\text{HOME}}$ is the Equivalent variation of permanent residents (whether temporarily residing abroad or not) in millions of US\$.

World EV

$$\text{WEV} = \sum_r \text{EV}_r^{\text{HOME}} \quad 35$$

where:

WEV is the world Equivalent variation in millions of US\$.

5.5 Sectoral Allocation

The final issue to be examined relates to what industries the temporary labour will be employed in or what sectors the temporary migrants will come from. In the standard model, labour moves across sectors to equalise the wage, thus labour moves to those sectors with the highest demand – this is also the standard closure for the GMig model.

Since particular sectors in the developed economies, e.g. the computing sector in the USA, are interested in obtaining skilled temporary workers, a user of this model may want to specify the sectors where this temporary labour is to be employed²¹. This is achieved in GMig by dividing the sectors into two groups: one group of sectors who employ temporary labour (A); and a second group of sectors who do not employ temporary labour (B). The supply of labour to the group must then equal demand (Equation 36); labour flows freely within a group of sectors but not between groups.

$$\forall i \in \text{LAB}, \forall k \in \text{PROD_GRP}, \forall r \in \text{REG}$$

$$\text{QO_GRP}_{i,k,r} = \sum_{\substack{j \in \text{industries} \\ \text{in } k}} \text{QFE}_{i,j,r}$$

36

where:

QO_GRP is the quantity of labour supplied to each group of sectors
QFE is the quantity of labour demanded by each sector

To fix the quantity of labour supplied to a particular group of sectors, the price of labour to those sectors needs to be able to move independently of the price of labour in the other sectors. This is achieved by including a variable, which allows prices of labour to differ by group (TFG_{i,k,r} in Equation 37).

$$\forall i \in \text{LAB}, \forall j \in \text{SECTOR}, \forall r \in \text{REG}$$

$$\text{TF}_{i,j,r} = \text{TFE}_{i,j,r} \times \text{TFG}_{i,k,r}$$

where:

TF_{i,j,r} is the power of the tax rate on labour of skill i, purchased by sector j in region r.

TFE_{i,j,r} is the component of the power of the tax rate which differs by industry.

TFG_{i,k,r} is the component of the power of the tax rate which differs by industry group.

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Fixing labour supply within a group of sectors also has important implications for permanent labour. All labour within the group, both permanent and temporary, is restricted to the sectors within that group. Hence permanent labour cannot flow out of these sectors (e.g. services) in response to new temporary workers. For example, an

²¹ Or the sectors where the temporary migrants come from.

increase in intra-company transfers into the host region does not lead to a decrease in local workers employed in the sector. In this case, labour is not perfectly mobile, except within sectors of the same group. In research undertaken by Borjas and Freeman (1992) in the United States on permanent migration, they found that permanent residents did move out of areas in which there was an influx of foreign workers, leaving the total labour force unchanged. As a result restricting the movement of labour in this way should be considered carefully.

6. Conclusion

Restriction of the movement of natural persons is increasingly gaining recognition as a severe impediment to trade, particularly in services. Removal of these restrictions could result in important benefits to the world as a whole and in particular to the suppliers of this labour. In this paper we have attempted to develop a model, which could be used to analyse the effect of removing these restrictions on the movement of labour.

The model takes into account a number of important issues related to the movement of labour including:

- a) differences in the productivities of temporary and permanent labour;
- b) the importance of remittances on home country income;
- c) income and welfare of permanent and temporary labour; and
- d) the movement of labour into particular sectors in the host region.

In this paper the temporary movement of natural persons is treated as an export of labour services to the host regions. Although this is not a migration issue, the temporary movement of persons involves the movement of intra-company transferees, executives and other specialists to the host region for unspecified periods of time, anywhere from less than a month to 3 or more years. These temporary workers produce, earn wages²², pay taxes and consume in the host country, as well as send remittances back to their home countries. By treating the movement of natural persons as the export and import of

²² We have assumed that the host country pays the wages of the temporary labour, however there are some cases where the home region pays the salary of an intra-company transferee.

labour the model can to properly take account of the productivity, wages, taxes and consumption of the temporary workers.

Alternatively the temporary movement of natural persons could also be considered as a movement of natural persons who supply a service on behalf of their home region. In this case a service is exported which involves the temporary movement of a person. The removal of restrictions on the movement of natural persons would then reduce the cost of exporting this service. This could be incorporated into the model as a reduction in the cost of exporting services, however, further modifications would then be required to distinguish the effects of the movement of persons on productivity, wages and consumption. This has not been undertaken in this paper, instead the labour itself has been treated as the export.

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8. Appendices

Appendix 1A: The GMig Extension in Gempack notation – Equations

Definitions

Equations linking change and Percentage changes

(all,r,REG) pop(r)=(100/POPNO(r)) * d_pop(r) ;	1
(all,i, LAB)(all,r,REG) qotlp(i,r) = (100/TLNO(i,r)) * d_qotlp(i,r) ;	2
(all,i, LAB)(all,r,REG) qopl(i,r) = (100/PLNO(i,r)) * d_qopl(i,r) ;	3
(all,i, LAB)(all,r,REG) qotmp(i,r) = (100/TMNO(i,r)) * d_qotmp(i,r) ;	4
(all,i, LAB)(all,r,REG) qotm(i,r) = (100/(TMNO(i,r) * PRDUCTVTY(i,r))) * d_qotm(i,r) ;	5
(all,r,REG) poppl(r)=(100/POPPLNO(r)) * d_poppl(r);	6
(all,r,REG) poptl(r)=(100/sum(i, LAB, TLNO(i,r))) * d_poptl(r);	7
(all,r,REG) poptm(r)=(100/sum(i, LAB, TMNO(i,r))) * d_poptm(r) ;	8

Equations to find Totals

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{tottlp(i) = (100/(sum(s, REG, TLNO(i,s)))) * d_tottlp(i) ;} \end{array} \quad 9$$

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{tottmp(i) = (100/(sum(s, REG, TMNO(i,s)))) * d_tottmp(i) ;} \end{array} \quad 10$$

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{tottm(i) = sum(r, REG, TMNO(i,r) * PRDUCTVTY(i,r)/} \\ \text{sum(k, REG, TMNO(i,k) * PRDUCTVTY(i,k)) * qotm(i,r)) ;} \end{array} \quad 11$$

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{d_tottmp(i) = sum(r, REG, d_qotmp(i,r)) ;} \end{array} \quad 12$$

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{d_tottlp(i) = sum(r, REG, d_qotlp(i,r)) ;} \end{array} \quad 13$$

$$\begin{array}{l} \text{(all,i,LAB)} \\ \text{d_gwslackp(i) = d_tottlp(i) - d_tottmp(i) ;} \end{array} \quad 14$$

Equation to find Permanent Labour force

$$\begin{array}{l} \text{(all,i, LAB)(all,r,REG)} \\ \text{d_qopl(i,r) = - d_qotmp(i,r) + d_qoplshift(i,r);} \end{array} \quad 15$$

Equations to find Populations

$$\begin{array}{l} \text{(all,r,REG)} \\ \text{d_pop(r) = sum(i, LAB, d_qopl(i,r) + d_qotlp(i,r)) ;} \end{array} \quad 16$$

$$\begin{array}{l} \text{(all,r,REG)} \\ \text{d_poppl(r) = sum(i, LAB, d_qopl(i,r)) ;} \end{array} \quad 17$$

$$\begin{array}{l} \text{(all,r,REG)} \\ \text{d_poptl(r) = sum(i, LAB, d_qotlp(i,r)) ;} \end{array} \quad 18$$

$$\begin{array}{l} \text{(all,r,REG)} \\ \text{d_poptm(r) = sum(i, LAB, d_qotmp(i,r)) ;} \end{array} \quad 19$$

Equations finding productivity equivalents

$$(all,i, LAB)(all,r,REG) \\ d_qotm(i,r) = PRDUCTVTY(i,r) * d_qotmp(i,r) ; \quad 20$$

$$(all,i, LAB) \\ AVPRDTVTY(i) * avprod(i) = sum(r, REG, (TMNO(i,r)/ sum(k, REG, TMNO(i,k)) * PRDUCTVTY(i,r)) * (qotmp(i,r) - tottmp(i))) ; \quad 21$$

$$(all,i, LAB)(all,r,REG) \\ productivity(i,r) = -avprod(i) ; \quad 22$$

$$(all,i, LAB)(all,r,REG) \\ prodtl(i,r) = PROPORTION * AVPRDTVTY(i)/PRDUCTVTYTL(i,r) * avprod(i) ; \quad 23$$

$$(all,i, LAB)(all,r,REG) \\ qotl(i,r) = prodtl(i,r) + qotlp(i,r) ; \quad 24$$

Methods of Allocation

Shares Method

$$(all,i,LAB)(all,r,REG) \\ d_qotlp(i,r) = TLNO(i,r)/sum(s, IMPREG, TLNO(i,s)) * d_tottmp(i) + shifttlshp(i,r) ; \quad 25$$

$$(all,i,LAB)(all,r,REG) \\ d_qotmp(i,r) = LFNO(i,r)/sum(s, EXPREG, LFNO(i,s)) * d_tottlp(i) + shifttmshp(i,r) ; \quad 26$$

Wages Method

$$(all,i,LAB) \\ avps(i) = sum(r, REG, VOATL(i,r)/sum(s, REG, VOATL(i,s)) * (ps(i,r) + prodtl(i,r))) ; \quad 27$$

$$(all,i,LAB)(all,r,REG) \\ qotmp(i,r) = qoplshift(i,r) + TMSUB(i,r) * ((avps(i) - ptlav) - (ps(i,r) - p(r))) + shifteq(i) + shiftmwp(i,r) ; \quad 28$$

$$(all,i,LAB)(all,r,REG) \\ qotlp(i,r) = tottmp(i) + TLSUB(i,r) * ((ps(i,r) + prodtl(i,r) - p(r)) - (avps(i) - pav) + shifttlwp(I,r) ; \quad 29$$

Income

$$\begin{aligned} &(\text{all}, r, \text{REG}) \\ & \text{FY}(r) * \text{fincome}(r) \\ & = \text{sum}(i, \text{ENDW_COMM}, \text{VOM}(i, r) * [\text{pm}(i, r) + \text{qo}(i, r)]) \\ & - \text{VDEP}(r) * [\text{pcgds}(r) + \text{kb}(r)] \\ & - \text{sum}(i, \text{LAB}, \text{REMOUT}(i, r) * [\text{ps}(i, r) + \text{qotl}(i, r)]) \\ & + \text{sum}(i, \text{LAB}, \text{REMIN}(i, r) * [\text{avpsrem}(i) + \text{qotm}(i, r) \\ & + \text{avremit}(i)]) ; \end{aligned} \quad 30$$

$$\begin{aligned} &(\text{all}, i, \text{LAB}) \\ & \text{avremit}(i) = -[\text{sum}(r, \text{REG}, \text{REMIN}(i, r) / \text{sum}(k, \text{REG}, \text{REMIN}(i, k)) * \\ & \text{qotm}(i, r)) - \text{sum}(r, \text{REG}, \text{REMOUT}(i, r) / \text{sum}(k, \text{REG}, \text{REMOUT}(i, k)) * \\ & \text{qotl}(i, r))] ; \end{aligned} \quad 31$$

$$\begin{aligned} &(\text{all}, i, \text{LAB}) \\ & \text{avpsrem}(i) = \text{sum}(r, \text{REG}, \text{REMOUT}(i, r) / \text{sum}(s, \text{REG}, \text{REMOUT}(i, s)) * \\ & \text{ps}(i, r)) ; \end{aligned} \quad 32$$

$$\begin{aligned} &(\text{all}, r, \text{REG}) \\ & \text{INCOMETL}(r) * \text{ytl}(r) = \text{sum}(i, \text{LAB}, \text{VOMTL}(i, r) * [\text{pm}(i, r) + \text{qotl}(i, r)]) \\ & - \text{sum}(i, \text{LAB}, \text{REMOUT}(i, r) * [\text{ps}(i, r) + \text{qotl}(i, r)]) \\ & + \text{INCOMETL}(r) * \text{incslacktl}(r) ; \end{aligned} \quad 33$$

$$\begin{aligned} &(\text{all}, r, \text{REG}) \\ & \text{INCOMEPL}(r) * \text{ypl}(r) \\ & = \text{sum}(i, \text{NLAB}, \text{VOM}(i, r) * [\text{pm}(i, r) + \text{qo}(i, r)]) \\ & + \text{sum}(i, \text{LAB}, \text{VOMPL}(i, r) * [\text{pm}(i, r) + \text{qopl}(i, r)]) \\ & - \text{VDEP}(r) * [\text{pcgds}(r) + \text{kb}(r)] \\ & + \text{sum}(i, \text{LAB}, \text{REMIN}(i, r) * [\text{avpsrem}(i) + \text{qotm}(i, r) + \text{avremit}(i)]) \\ & + 100.0 * \text{INCOME}(r) * \text{DTAXR}(r) \\ & + \text{TOTTAX}(r) * \text{y}(r) \\ & + \text{INCOME}(r) * \text{incslackpl}(r) ; \end{aligned} \quad 34$$

Welfare

1. EV of permanent Labour

$$\begin{aligned} &(\text{all}, r, \text{REG}) \\ & \text{upl}(r) = [1.0 / \text{UTILELAS}(r)] * [\text{ypl}(r) - \text{poppl}(r) - \text{p}(r)] ; \end{aligned} \quad 35$$

$$\begin{aligned} &(\text{all}, r, \text{REG}) \\ & \text{upl}(r) = [1.0 / \text{UTILELASEV}(r)] * [\text{yplev}(r) - \text{poppl}(r)] ; \end{aligned} \quad 36$$

$$(\text{all}, r, \text{REG}) \quad 37$$

$$EVPL(r) = [INCOMEEVPL(r)/100]*yplev(r);$$

2. EV of permanent residents

$$(all,r,REG) \quad utl(r) = [1.0/UTILELAS(r)]*[ytl(r) - popl(r) - p(r)]; \quad 38$$

$$(all,r,REG) \quad utl(r) = [1.0/UTILELASEV(r)]*[ytlev(r) - popl(r)]; \quad 39$$

$$(all,r,REG) \quad EVTL(r) = [INCOMEEVTL(r)/100]*ytlev(r); \quad 40$$

$$EVALLGW = \text{sum}(r, REG, EVTL(r)) ; \quad 41$$

3. EV of temporary migrants

$$(all,i,LAB) \quad \begin{aligned} &(\text{sum}(h, REG, INCTLSK(i,h))) * ytm\text{tot}(i) = \\ &\quad \text{sum}(k, REG, VOMTL(i,k) * (pm(i,k) + qotl(i,k)) \\ &\quad - REMOUT(i,k) * (ps(i,k) + qotl(i,k))) ; \end{aligned} \quad 42$$

$$(all,r,REG) \quad \begin{aligned} &INCOMETM(r) * ytm(r) = \\ &\quad \text{sum}(i, LAB, SHRTM(i,r) * \text{sum}(h, REG, INCTLSK(i,h)) \\ &\quad * [qotm(i,r) - tottm(i) + ytm\text{tot}(i)]); \end{aligned} \quad 43$$

$$pav = \text{sum}(r, REG, INCOMETL(r)/\text{sum}(k, REG, INCOMETL(k)) * p(r)) ; \quad 44$$

$$(all,r,REG) \quad utm(r) = [1.0/UTILELASGW]*[ytm(r) - pop\text{tm}(r) - pav]; \quad 45$$

$$(all,r,REG) \quad utm(r) = [1.0/UTILELASEVGW]*[ytmev(r) - pop\text{tm}(r)]; \quad 46$$

$$(all,r,REG) \quad EVTM(r) = [INCOMETM(r)/100] * ytmev(r) ; \quad 47$$

$$(all,r,REG) \quad EVPR(r) = EVPL(r) + EVTM(r) ; \quad 48$$

$$WEVPR = \text{sum}\{r, REG, EVPR(r)\}; \quad 49$$

Sector Allocation

$$\begin{aligned}
& (all,i,LAB)(all,k,PROD_GRP)(all,r,REG) \\
& \quad qo_grp(i,k,r) \\
& \quad = \text{sum}(j, PROD_COMM: MAPPROD(j) = k, SHREM(i,j,r) * qfe(i,j,r)) \quad 50 \\
& \quad + grpslack(i,k,r) ;
\end{aligned}$$

$$\begin{aligned}
& (all,i,LAB) (all,k,PROD_COMM) (all,r,REG) \\
& \quad tf(i,j,r) \quad 51 \\
& \quad = tfe(i,j,r) + tfg(i,MAPPROD(j),r) ;
\end{aligned}$$

Appendix 1B: The GMig Extension – Sets and Variables

Sets

LAB is the set of Labour types
LAB is subset of ENDWM_COMM

NLABM is the set of Mobile Non Labour types
= ENDWM_COMM – LAB

NLAB is the set of Non Labour types
= ENDW_COMM – LAB

IMPREG is the set of labour importing regions
IMPREG is subset of REG

EXPREG is the set of labour exporting regions
= REG – EXPREG

PROD_GRP is the set of sectors groups to which international labour migrants move.
There is a mapping between these sectors and the GTAP sectors (MAPPROD)

Variables

d_pop(r)	(change)(all,r,REG)	Change in regional population
pop(r)	(all,r,REG)	% change in regional population
qotlp(i,c)	(all,i,LAB)(all, c, REG)	% change in temporary labour in region r (Number of people)
d_qotlp(i,r)	(change) (all,i,LAB)(all,r,REG)	change in temp labour (Number of people)
qotl(i,c)	(all,i,LAB)(all, c, REG)	% change in temporary labour in region r (productivity equivalents)
qopl(i,c)	(all,i,LAB)(all, c, REG)	% change in permanent labour in region r
d_qopl(i,c)	(change) (all,i,LAB)	Change in permanent labour in region r

	(all, c, REG)	
qotmp(i,c)	(all,i,LAB)(all, c, REG)	% change in perm residents of r living abroad (Number of people)
d_qotmp(i,c)	(change) (all,i,LAB)(all, c, REG)	Change in perm residents of r living abroad (Number of people)
qotm(i,c)	(all,i,LAB)(all, c, REG)	% change in perm residents of r living abroad (productivity equivalents)
d_qotm(i,c)	(change) (all,i,LAB)(all, c, REG)	Change in perm residents of r living abroad (productivity equivalents)
d_qoplshift(i,c)	(all,i,LAB)(all, c, REG)	Shift to allow for exogenous changes in permanent Labour Force
d_tottmp(i)	(change) (all,i,LAB)	Number of temporary migrants (no. of people)
d_tottlp(i)	(change) (all,i,LAB)	Total number of temporary labour of skill level i (people)
d_gwslackp(i)	(change) (all,i,LAB)	Slack on total number of guest workers - equal zero
tottlp(i)	(all,i,LAB)	Total number of temporary workers
tottmp(i)	(all,i,LAB)	Total number of temporary migrants
avprod(i)	(all,i,LAB)	% change in average productivity
productivity(i,r)	(all,i,LAB)(all,r,REG)	% change in productivity of permanent labour in region r relative to migrant labour.
prodtl(i,r)	(all,i,LAB)(all,r,REG)	% change in productivity of temporary labour.
avremit(i)	(all,i,LAB)	% change in average Remittance
avpsrem(i)	(all,i,LAB)	% change in average remittance due to change in wages
fincome(r)	(all,r,REG)	% change in factor income in r net of depreciation
incslacktl(r)	(all,r,REG)	slack variable in income of temp labour
incslackpl(r)	(all,r,REG)	slack variable in the expression for income of perm lab
ytl(r)	(all,r,REG)	% change in income of temporary labour in region r
ypl(r)	(all,r,REG)	% change in income of permanent labour
shifttlshp(i,r)	(all,i,LAB)(all,r,REG)	Shift to turn on/off shares method
shifttmshp(i,r)	(all,i,LAB)(all,r,REG)	Shift to turn on/off shares method

avps(i)	(all,i,LAB)	% change in average wage of temp labour
shifftlwp(i,r)	(all,i,LAB)(all,r,REG)	Shift to turn on/off wages method
shifftmwp(i,r)	(all,i,LAB)(all,r,REG)	Shift to turn on/off wages method
shifteq(i)	(all,i,LAB)	Shift to ensure equality if required
ylev(r)	(all,r,REG)	% change in Income of perm labour for EV
d_poppl(r)	(change)(all,r,REG)	change in population of perm residents
poppl(r)	(all,r,REG)	% change in perm population
upl(r)	(all,r,REG)	% change in utility of perm population
EVPL(r)	(change)(all,r,REG)	EV of permanent Labour
ytlev(r)	(all,r,REG)	Income of Temporary Labour for EV calc
d_poptl(r)	(change)(all,r,REG)	Change in population of temp labour
poptl(r)	(all,r,REG)	% Change in population of temp labour
utl(r)	(all,r,REG)	% change in utility of temp labour
EVTl(r)	(change)(all,r,REG)	EV of temporary labour
yltot		% change in Total income of temp labour
EVALLGW	(change)	EV of all temporary labour
tottm(i)	(all,i,LAB)	% change in total temp migrant
ytmtot(i)	(all,i,LAB)	% change in income of all temp migrant
ytm(r)	(all,r,REG)	% change in income of temp migrants
d_poptm(r)	(change)(all,r,REG)	Change in population of temp migrants
poptm(r)	(all,r,REG)	% change in population of temp migrants
pav		Average price index for disposition of income by regional household
utm(r)	(all,r,REG)	% change in Utility of temp migrants
ytmev(r)	(all,r,REG)	% change in Income of temp migrants, for

EVTM(r)	(change)(all,r,REG)	EV calc EV of temp migrants
EVPR(r)	(change)(all,r,REG)	EV of permanent residents
WEVPR		WEV of permanent residents
qo_grp(i,k,r)	(all,i,LAB)(all,k,PROD _GRP) (all,r,REG)	slack variable in endowment market clearing condition
grpslack(i,k,r)	(all,i,LAB)(all,k,PROD _GRP)(all,r,REG)	Slack variable in endowment market clearing condition.

Appendix 1C: The GMig Extension – Coefficients

POPNO(c)	(all,r,REG)	Population data
LFNO(i,c)	(all,i,LAB)(all,r,REG)	Labour force data by labour type
TLNO(i,c)	(all,i,LAB)(all,r,REG)	Number of Temporary workers by labour type located in country c
PLNO(i,c)	(all,i,LAB)(all,r,REG)	Number of Permanent workers by labour type located in country c
TMNO(i,c)	(all,i,LAB)(all,r,REG)	Number of Permanent resident of c who work abroad by labour type
PRDUCTVTY(i,r)	(all,i,LAB)(all,r,REG)	Productivity of worker relative to migrant worker
AVPRDTVTY(i)	(all,i,LAB)	Average productivity of migrant labour
PROPORTION		Proportion of productivity gained by temporary labour entering region
PRDUCTVTYTL(i,r)	(all,i,LAB)(all,r,REG)	Productivity of temporary worker in region r.
VOATL(i,c)	(all,i,LAB)(all,r,REG)	Value of Labour of Temp Labour
VOAPL(i,c)	(all,i,LAB)(all,r,REG)	Value of Labour of permanent labour
VOMPL(i,r)	(all,i,LAB)(all,r,REG)	value of commodity i output in region r at market prices
VOMTL(i,r)	(all,i,LAB)(all,r,REG)	value of commodity i output in region r at market prices
REMIN(i,c)	(all,i,LAB)(all,r,REG)	Remittances received from temporary Migrant living abroad
REMOUT(i,c)	(all,i,LAB)(all,r,REG)	Remittances paid by Temporary Labour in region c

FY(r)	(all,r,REG)	primary factor income in r net of depreciation
INCOMETL(r)	(all,r,REG)	Income of temporary labour
INCOMEPL(r)	(all,r,REG)	Income of Permanent labour
TMSUB(i,r)	(all,i,LAB)(all,r,REG)	Elasticity on the worker's decision to become a temporary migrant
TLSUB(i,r)	(all,i,LAB)(all,r,REG)	Elasticity on the migrant's decision of where to reside temporarily
INCOMEEVPL(r)	(all,r,REG)	regional income of permanent residents, for EV calc
POPPLNO(r)	(all,r,REG)	Perm population, working in region, for EV calc
INCOMEEVTL(r)	(all,r,REG)	income of temporary labour, for EV calc
INCTLSK(i,r)	(all,i,LAB)(all,r,REG)	Income of temporary labour by labour type
SHRTM(i,r)	(all,i,LAB)(all,r,REG)	Share of temporary migrants in total (incl. Productivity)
INCOMETM(r)	(all,r,REG)	Income of temporary migrant
UTILELASGW		Average elasticity of cost of utility wrt utility
UTILELASEVGW		Average elasticity of cost of utility wrt utility, for EV calc.
SHREMG(i,j,r)	(all,i,LAB)(all,j,PROD_GRP) (all,r,REG)	share of labour i used by group j at market prices

Appendix 1D: The GMig Extension – Closure

Additions to the GTAP Standard Closure

exogenous

tfg tfe ! Replaces tf
qo(NLAB,REG)
d_qotmp
d_qotlp
d_qoplshift
shifteq
incslackpl
incslacktl
endwdemslk
endwslack
grpslack

Changes in Closure to incorporate various methods of allocation

Two special sets are used to assist with the allocation of temporary migrants. These are:

- a) The set IMPREG, which is the set of labour importing regions
- b) The set EXPREG, which is the set of labour exporting regions

1. Exogenous Temporary Migrants

- a) X temporary migrants from one home region EXPREG go to a single host region IMPREG.

swap d_qotlp(LAB,IMPREG) = d_gwslackp(LAB)

shock d_qotmp(LAB,EXPREG) = X

- b) X temporary migrants from a set of home regions EXPREG go to a set of regions IMPREG - allocated exogenously.

No swaps – shock relevant quantities. Must check d_gwslackp to make sure it is zero.

- c) X temporary migrants from home regions EXPREG go to a set of host regions EXPREG - allocated according to shares.

swap d_qotlp(LAB,IMPREG) = d_shifttlshp(LAB,IMPREG)

shock d_qotmp(LAB,EXPREG)

- d) X temporary migrants from home regions EXPREG go to a set of host regions EXPREG - allocated according to wages.

swap d_qotlp(LAB,IMPREG) = shifttlwp(LAB,IMPREG)

shock d_qotmp(LAB,EXPREG)
set value for TLSUB

2. *Exogenous Temporary Labour*

- a) Single host region IMPREG changes quota on temporary labour which come from a single region EXPREG.

swap d_qotmp(LAB,EXPREG) = d_gwslackp(LAB)
shock d_qotlp(LAB,IMPREG) = quota

- b) Set of host regions IMPREG change quotas on temporary labour which come from a set of regions EXPREG - allocated exogenously.
No swaps. Must check d_gwslackp to make sure it is zero.

- c) Set of host regions IMPREG change quotas on temporary labour which come from a set of regions EXPREG - allocated according to shares.

swap d_qotmp(LAB,EXPREG) = d_shifttmshp(LAB,EXPREG)
shock d_qotlp(LAB,IMPREG) = quota

- d) Set of host regions IMPREG change quotas on temporary labour which come from a set of regions EXPREG - allocated according to wages.

swap d_qotmp(LAB,EXPREG) = shifttmwp(LAB,EXPREG)
swap shifteq(LAB) = d_gwslackp(LAB)
shock d_qotlp(LAB,IMPREG) = quota
set value for TMSUB

Changes in Closure to allow temporary Labour to work in special sectors

1. *Standard Closure*

In this case all temporary labour can migrate to any sector.

Exogenise tfg
Exogenise endwslack
Exogenise grpslack
Endogenise qo_grp

2. *Two Groups*

In this case sectors are split into two groups: Group A which employs the new labour and group B, where labour supply is fixed²³.

²³ This method cannot accommodate more than one group which employs labour, although there can be more than one group where labour is fixed.

Swap $qo_grp(LAB, B, REG) = tfg(LAB, B, REG)$

Note:

- 1) $qo_grp(LAB, B, REG)$ is fixed as the temporary labour does not flow into this group of sectors.
- 2) You do not have to do these swaps for all LAB and all REG, only those that are relevant to your analysis.