Construction of the Database for OMAGE (Oman Applied General Equilibrium) Model

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Abstract

This paper describes in detail the process to create the database for OMAGE - a Dynamic Applied General Equilibrium model for Oman with labour market detail. It starts with an overview of the model theoretical structure, which consists of a CGE core model and a labour supply module. Then it specifies the coefficients and parameters required for the model database, which provides an initial solution to the model. All data sources and procedures to create the database are then discussed in detail.

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1 INTRODUCTION

This working paper describes the construction of the database for the OMAGE (Oman Applied General Equilibrium) model for the year 2012. In the remainder of this section we first provide an overview of the model theory, before turning to a discussion of the data required by the model. In Section 2 we explain the process by which we turn the format of the supplied data into that required by the model. In Section 3 we present a summary of the input/output data for 2012 in terms of industry cost and sales shares. Data on employment by industry and occupation are also tabled. References are in Section 4.

1.1 Overview of OMAGE theoretical structure

OMAGE has two distinct theoretical parts: (i) the modelling of the economy and its demand for labour by occupation, nationality and skill, hereafter called the core CGE model; and (ii) the modelling of supply of labour by skill, occupation and nationality, hereafter called the labour supply module. Our discussions below focus on these two parts.

1.1.1 Core CGE model

The core CGE structure of OMAGE consists of equations describing: demands for produced inputs and primary factors for current production purposes; commodity supplies by individual industries; industry-specific demands for inputs to capital formation; household commodity demands; export demands distinguished by commodity; government demands distinguished by commodity; the relationship of basic values to production costs and to purchasers' prices; market-clearing conditions for commodities and primary factors; and numerous macroeconomic variables, such as balance of trade, government budget, foreign liabilities and assets.

In OMAGE each industry is assumed to minimise unit costs subject to given input prices and a nested constant returns to scale production function. Three primary factors are identified (labour, capital and land) with labour further distinguished by occupation, nationality and skill. Capital is assumed to be sector-specific, while occupation-specific labour is perfectly mobile across industries. Households are modelled as constrained maximisers of utility functions. Units of new industry-specific capital are cost-minimising combinations of local and foreign commodities. For all commodity users, imperfect substitutability between imported and local varieties of each commodity is assumed. The export demand for any given Omani commodity is inversely related to its foreign-currency price. The model recognises consumption of commodities by government and the details of taxation instruments. It is assumed that all sectors are competitive and all goods markets clear. Purchasers’ prices differ from producer prices by the value of indirect taxes and trade and transport margins. All agents are assumed to be price-takers, with producers operating in competitive markets which prevent the earning of pure profits.

OMAGE is dynamic. The dynamic mechanisms in OMAGE’s core CGE structure include:

- stock/flow accounting for the accumulation of capital stocks via investment and depreciation;

- accounting for changes in net foreign liabilities via changes in investment and saving; and
- lagged adjustment mechanisms in the labour market.

Capital accumulation is industry-specific, and linked to industry-specific net investment. Annual changes in the net liability position of the economy are related to the annual investment/savings imbalance. In policy simulations, the model provides the option of allowing the labour market to follow a lagged adjustment path. With this option activated, short-run real consumer wages are sticky. Hence short-run labour market pressures mostly manifest as changes in employment. In the long-run, employment returns to baseline, with labour market pressures reflected in changes in real wages.

The theory of the CGE core of OMAGE is based on that of the MONASH model, hence, for details of the full equation system underlying the CGE core of OMAGE, see Dixon and Rimmer (2002).

1.1.2 Labour supply module

The labour supply module contains the mechanism for stock/flow accounting for skill accumulation in the working age population. It starts with the stock of the working age population (WAP) in year 2011 (year t-1 in OMAGE), distinguished by skill, age, gender and citizenship. The WAP in year t is defined as:

$$WAP_{s,c}^{a,g} = \sum_{aa \in AGE, ss \in SKILL} \left(WAP_{ss,c,t-1}^{aa,g} \times T_{(ss,s),c}^{(aa,a),g} \right) + NEW_{s,c}^{a,g} \qquad (1)$$

where:

$WAP_{a,g}^{s,c}$ is working age population by age (a), gender (g), citizenship (c), holding skill (s) in year *t*;

$WAP_{aa,g}^{(t-1)ss,c}$ is working age population of (g,c), having age (aa) and skill (ss) in year *t-1*;

$NEW_{a,g}^{s,c}$ is the net number of persons by (a,g,c and s) entering the labour market at the beginning of year t, mainly consisting of people already in Oman turning 15 year of age in *t*, and net additions of new foreign workers; and

$T_{(aa,a),g}^{(ss,s),c}$ is a transition matrix showing the rates at which persons (classified by gender and citizenship) move between age categories (movements from age category (aa) to (a)) and skill categories (movements from skill category (ss) to (s)) between years t-1 and t.

The age transition probabilities are calculated based on the number of years in each age group[2], and average death rates by age category. The initial qualification transition rates are estimated using educational data on the probability of a group of people by age, gender and citizenship staying within the same qualification or acquiring a different qualification between years *t-1* and *t*. We expect that the skill dimension of the transition matrix is strongly diagonal, especially for

[2] OMAGE uses 5-year age groups.

older age groups.

The qualification transition matrix is not static, but has the potential to change from year to year based on changes in relative wage rates between qualifications according to the following equation:

$$T_{(aa,a),g}^{(ss,s),c} = AT_{(aa,a),g}^{(ss,s),c} \times \left(\frac{W_c^s}{W^{ss}} \right)^{\alpha_{a,g,c}} \quad (2)$$

where:

$AT_{(aa,a),g}^{(ss,s),c}$ provides for autonomous shifts in qualification transition rates, allowing for changes in the probability of people changing skill types (qualification fields and/or qualification levels) due to reasons other than changes in the relative wage rates between skills;

W_c^{ss} is the average wage rate for persons holding skill (ss);

$\alpha_{a,g,c}$ are age-, gender- and citizenship-specific elasticities of qualification transformation with respect to movements in relative wage rates by skill.

Once the stock of working age population by skill is determined, labour supply by skill ($LS_{a,g}^{s,c}$) in year *t* is determined as:

$$LS_{a,g}^{s,c} = WAP_{a,g}^{s,c} \times PR_{a,g}^{s,c} \times ER_{a,g}^{s,c} \quad (3)$$

where

$PR_{a,g}^{s,c}$ is the labour force participation rate, classified by age, gender, skill and citizenship; and

$ER_{a,g}^{s,c}$ is the employment rate, classified by age, gender, skill and citizenship. This rate can be determined endogenously under a closure in which wages are determined by another process, or determined exogenously under a closure in which wages are determined endogenously.

The supply of labour distinguished by skill and nationality across occupations is guided by movements in occupation-and-nationality specific wage rates. We assume that workers of nationality *c* holding skill *s* allocate labour across occupations so as to maximise a utility function in which the arguments are wage-weighted allocations of labour across occupations and preference variables. The utility maximising solution to this problem, converted to percentage change form, is:[3]

$$x_{o,s,c} = x_{s,c} + \phi_{o,s,c}\left(w_{o,s,c} - w_{s,c}\right) \quad (4)$$

where:

- $x_{o,s,c}$ and $w_{o,s,c}$ are the percentage changes in labour supply and wage rates classified by occupation (o), skill (s) and citizenship (c);
- $x_{s,c}$ and $w_{s,c}$ are percentage changes in labour supply and a measure of average wage classified by skill and citizenship; and

[3] See Dixon et al. (2011) for the derivation of this equation.

- $\phi_{o,s,c}$ is the elasticity of labour supply to occupation *o* by citizen type *c* with skill *s* with respect to movements in the wage available in occupation *o* relative to other occupations on average.

1.1.3 Linking the core CGE model (Labour demand) and labour supply

OMAGE allows the user to link the core CGE model and the labour supply module via labour markets distinguished by skill, occupation and nationality. On the demand side, industries first chose labour inputs by occupation and nationality based on their demand for primary factors, which, in turn, are based on their level of activity. They then chose a combination of skills to minimise the cost of compiling a unit of labour by occupation and nationality. On the supply side, workers with a given qualification and nationality supply their labour to occupations to maximise a utility function which has hourly wage rates as an argument. Together, labour demand and labour supply in occupation-, qualification- and citizenship-specific labour markets are then reconciled via endogenous movements in wage rates.

The integration of labour demand and labour supply allows endogenous adjustment in the labour market. For example, if a policy change or an economic shock causes a shortage of a particular occupation, the wage of the occupation will rise relative to that of other occupations. This will cause, on the demand side, a relative decline in demand for that occupation from industries compared to other occupations. On the supply side, the rise in the occupation wage rates cause more people to offer to work in the occupation. This, in turn, encourages more people to enroll in qualifications used intensively in that occupation. These adjustments occur until a new equilibrium is established. The integration of labour demand and supply also facilitates the analysis of the economic effects of skill shortages.

However, the model also allows the user to decouple the supply and demand sides, configuring the model as a traditional demand-side forecasting model. This is useful in applications in which we wish to uncover future workforce needs, because it is important that short-run supply-side constraints do not exert an influence on forecast labour needs.

1.2 Overview of the structure of the OMAGE database

The OMAGE model is a system of simultaneous equations, the initial solution to which is provided by the model's database. The database for OMAGE consists of three main parts:

(1) Input-output (IO) data for the base year;

(2) Behavioural parameters, which govern matters such as how economic agents substitute their input or consumption mix to solve their objective functions when relative prices change; and

(3) Ancillary base year data, relating to industry capital stocks, government accounts, interest rates and the net foreign liability positions of the household and public sectors.

The structure of the database is presented in Figure 1 through to Figure 6.

1.3 The OMAGE Input – Output database (Figure 1)

Figure 1 sets out the structure of the OMAGE input-output database in three parts: an absorption matrix, a production matrix, and a tariff matrix.

Figure 1 The OMAGE core input-output database

(Adapted from Horridge 2000)

			Absorption Matrix					
			1	2	3	4	5	6
			Producers	Investors	Household	Export	Government	Change in Inventories
		Size	← I →	← I →	← H →	← 11 →	← 1 →	← 1 →
1	Basic Flows	↑ C×S ↓	V1BAS	V2BAS	V3BAS	V4BAS	V5BAS	V6BAS
2	Margins	↑ C×S×M ↓	V1MAR	V2MAR	V3MAR	V4MAR	V5MAR	n/a
3	Commodity Taxes	↑ C×S ↓	V1TAX	V2TAX	V3TAX	V4TAX	V5TAX	n/a
4	Labour	↑ O×L ↓	V1LAB					
5	Capital	↑ 1 ↓	V1CAP					
6	Land	↑ 1 ↓	V1LND					
7	Production Tax	↑ 1 ↓	V1PTX					
8	Other Costs	↑ 1 ↓	V1OCT					

C = Number of commodities (51)
I = Number of industries (51)
H = Number of households (1)
S = Sources (domestic and imported)
O = Number of labour occupations (98)
M = Number of commodities used as margins (5)
L = Number of labour categories by nationality (2)

	Production Matrix
Size	← I →
↑ C ↓	MAKE

	Tariff
Size	← 1 →
↑ C ↓	V0TAR

The column headings in the absorption matrix identify the following users:

(1) Domestic producers divided into I industries;
(2) Investors divided into I industries;
(3) A representative household;
(4) Foreign purchasers of exports divided into major trading partners;
(5) One government representing all levels of government.

(6) Changes in inventories.

The first row in the absorption matrix (the "BAS matrices": V1BAS,…,V6BAS) shows flows in year *t* of commodities to all users. Each of these matrices has CxS rows, one for each of C commodities from S sources. The flows are valued at basic prices. The basic price of a domestically produced good is the price received by the producer (that is, the price paid by users excluding sales taxes, transport costs and other margin costs). The basic price of an imported good is the landed-duty-paid price, *i.e*. the price at the port of entry after the commodity has cleared customs.

The second row (the "MAR matrices": V1MAR,…,V5MAR) shows the values of margin services used to facilitate the flows of commodities identified in the BAS matrices. The commodities used as margins are domestically produced trade, road transport, rail transport, water transport, air transport services, and insurance. Imports are not used as margins services. Each of the margin matrices has CxSxM rows. These correspond to the use of M margin commodities in facilitating flows of C commodities from S sources. We assume that inventories (column 6) comprise mainly of unsold products, and therefore do not bear margins. As with the BAS matrices, all the flows in the MAR matrices are valued at basic prices. Consistent with the UN convention (UN 1999:33), we assume that there are no margins on services.

The third row (the "TAX matrices": V1TAX,, V5TAX) shows sales taxes on flows to different users. Again, we assume that there are no sales taxes on inventories. The tax rates can differ between users and between sources. For example, tax rates on a commodity used as an intermediate input to producers can be lower than that on household consumption of the same commodity.

Besides intermediate inputs, current production requires inputs of primary factors: labour (divided into occupations and nationality), fixed capital, and land. These are shown in rows 4, 5 and 6. Industries also have to pay production taxes (row 7). Production taxes consist mainly of taxes on the ownership or use of factors of production (UN 1999:26). Examples are fees on licences and permits.

The final two data items in Figure 1 are the MAKE and TARIFF matrices. MAKE is a CxI matrix showing the value of commodity c∈COM produced by industry i∈IND. The TARIFF matrix includes a vector of import duties by import commodity. They are used to calculate the tariff rates in the base year as the ratios between the tariff revenues and the relevant basic flows of imports on which the tariffs are levied.

1.4 Sign and balancing conditions for an input-output database

There are four basic sign and balancing conditions that the database must satisfy.

1. First, excepting matrices relating to taxes and changes in inventories (VTAXs and V6BAS), matrices should not contain negative numbers.

2. Second, the value of output by each industry must equal the total of production costs. That is, the column sums of the MAKE matrix must equal the sums of the corresponding producers' columns in the Absorption matrix. This follows from the fact that the current production columns of the Absorption matrix recognise all input costs that form part of production costs at basic prices. This includes the profits earned by owners of the fixed factors employed in each industry.
3. Third, the value of output of domestically produced commodities must equal the total of the value of demands for them. That is, for non-margin commodities, the row sums of the MAKE matrix must equal the sums of the corresponding BAS rows in the Absorption matrix. For margin commodities, their row sums in the MAKE matrix must equal the sum of all direct usage of m (BAS matrix) plus the sum of all usage of m as a margin (MAR matrix). This reflects two features of the database: the valuation basis of the MAKE matrix and absorption matrices are the same, namely, basic prices; and, the columns of the absorption matrix identify all possible uses of domestically produced goods.
4. Finally, by definition, total value added plus indirect taxes (GDP on the income side) must equal the value of final outputs at market prices (GDP on the expenditure side).

1.5 Behavioral parameters (Figure 2)

Figure 2 lists the various parameters that govern the behaviour of economic agents. In the notation, subscript *c* indicates commodity ($c \in COM$) and subscript *i* indicates industry ($i \in IND$).

The first three parameters are elasticities which govern the substitutability between factors of production. The first parameter ($\sigma prim_{i}^{(1)}$) is a vector of elasticities of substitution between labour, capital and land. The second parameter ($\sigma lab_{i}^{(1)}$) is a vector of elasticities of substitution between different occupations. The parameter $\sigma citiz_{i,o}^{(1)}$ is a matrix of elasticities of substitution between citizens and non-citizens within each occupation and each industry.

The next three parameters $\sigma_c^{(1)}$, $\sigma_c^{(2)}$ and $\sigma_c^{(3)}$ are vectors of Armington elasticities[4] which govern commodity-specific domestic/foreign substitution possibilities faced by producers, investors and households respectively.

Parameter $\varepsilon_{c,t}$ is a vector of foreign demand elasticities for Omani exports by commodity.

Figure 2. ELASTICITIES AND OTHER PARAMETERS

Elasticity of substitution between primary factors	$\sigma prim_{i}^{(1)}$
Elasticity of substitution between labour occupations	$\sigma lab_{i}^{(1)}$
Elasticity of substitution between domestic and foreign labour	$\sigma citiz_{i,o}^{(1)}$
Elasticity of substitution between domestic and imported intermediate inputs	$\sigma_c^{(1)}$
Elasticity of substitution between domestic and imported inputs to capital formation	$\sigma_c^{(2)}$

[4] Elasticities of substitution between domestic and imported goods, named after Armington (1969 and 1970) who pioneered the treatment of imports as imperfect substitutes for domestic goods.

Elasticity of substitution between domestic and imported commodities – household consumption	$\sigma_c^{(3)}$
Export demand elasticities, by commodity	$\varepsilon_{c,t}$
Household expenditure elasticities	EPS_c
Frisch parameter	F

The last two parameters relate to household consumption: EPS_c is the vector of household expenditure elasticities; while the Frisch parameter F shows the ratio of households' total expenditure to their supernumerary expenditure in the Klein-Rubin utility function. The Frisch parameter is used in evaluating household own and cross-price elasticities of demand and in calculating the change in the subsistence component of household consumption.

1.6 Ancillary data (Figure 3 to Figure 6)

1.6.1 Data and parameters for investment and the capital accumulation process

The matrices listed in Figure 3 contain the parameters and data required to operationalise the rate of return and capital accumulation theory in the model. They include capital stocks K_i, depreciation rates D_i, and historical normal capital growth rates $Kgr_{trend,i}$. Other parameters and data include the difference between trend capital growth rates and maximum capital growth rates (coefficient *DIFF*); the reciprocal of the slope of the economy-wide capital supply function C_i in the vicinity of $Kgr_i = Kgr_{trend,i}$, the real interest rate (R) and the inflation rate. The inflation rate is calculated from the levels of the national CPI in years t and t-1 (CPI_{t-1} and CPI_t).

Figure 3. INVESTMENT AND CAPITAL	
Value of capital in the base year	K_i
Depreciation rates	D_i
Trend growth rates of capital	$Kgr_{trend,i}$
Difference between max. and trend growth rates of capital	DIFF
Average sensitivity of capital growth to variations in expected rates of return	C_i
Level of the CPI – lagged	CPI_{t-1}
Level of the CPI	CPI_t
Real interest rate	R

1.6.2 Data and parameters for the labour market

The matrices listed in Figure 4 contain additional data relating to the labour market. The wage rate matrix by industry, occupation and nationality $W_{i,occ,citizenship}$ is used for the calculation of the number of workers in the economy. The latter is calculated by dividing the labour payment matrix V1LAB by industry, occupation and nationality (Figure 1) by their associated wage rates stored in the matrix $W_{i,occ,citizenship}$. The remaining coefficients are needed for the labour market adjustment process. They include the real national consumer pre-tax wage index W_b, the national aggregate employment index E_t, and the value of the parameter α_1, which governs the speed with which aggregate employment in the policy deviation run returns to its forecast value.

Figure 4 LABOUR MARKET	
Wages in the base year by industry, occupation, and nationality	$W_{i,occ,citizenship}$
Index of CPI deflated wages	W_b
Index of aggregate employment	E_t
Parameter governing duration of non-zero employment deviations	α_1

1.6.3 Government accounts

Figure 5 lists the data needed for the government accounts. They include aggregate items for government revenues and expenditures, as well as the government debt. Revenues include tax and non-tax sources. The direct taxes include taxes on labour, capital and land incomes (*TAX_LAB, TAX_CAP and TAX_LND*). These taxes are used for calculating tax rates on factors of production, by dividing tax revenues by the relevant factor income base. Note that indirect taxes are already included in Figure 1. Government non-tax revenues include government oil revenues, and government services and investment revenues. Government expenditure include government current expenditure, government social welfare paid to households (*BENEFITS*), net interest paid by government on public debt (*NETINT_G*), and government investment by industry ($V^{(2)}_{g,i}$). The net interest paid by government on public debt is calculated using the value of government debt stock at the start of the base year (PSD_{start}) and the rate of interest on public debt (R_{PSD}). With these data, the model can trace the government account balance during simulations.

Figure 5 GOVERNMENT ACCOUNTS	
(a) Government tax revenues	
Corporate income tax	*TAX_CAP*
Labour income tax	*TAX_LAB*
Land income tax	*TAX_LND*
Taxes on goods and services (VTAX matrices in Figure 1)	
(b) Government non-tax revenues	
Government oil revenues and non-tax revenue from industries	$V^{(GOS)}_{g,i}$
Government other revenues	*G_OTHREV*
(c) Government expenditures	
Government current expenditure (V5BAS + V5MAR + V5TAX)	
Government social benefits paid to households	*BENEFITS*
Net interest paid by government on public debts	*NETINT_G*
Government investment	$V^{(2)}_{g,i}$
(d) Other data	
Stock of public debt	PSD_{start}
Interest rate on public debt	R_{PSD}

1.6.4 Accounts with the rest of the world

Figure 6 lists additional data needed to calculate accounts with the rest of the world. They include stocks of net foreign liabilities in the base year (FDATT), rates of interest on those liabilities (ROIFOREIGN), and grants and remittances from Rest of World to Oman (GRANTS, FPTRANS).

Figure 6 ACCOUNTS WITH THE REST OF THE WORLD	
Net foreign liabilities in the base year	*FDATT*
Rate of interest on net foreign liabilities	*ROIFOREIGN*
Grants from foreigners	*GRANTS*
Remittances from Rest of Word	*FPTRANS*

2 THE DATABASE FOR THE CORE OMAGE MODEL

Our aim is to build a model which represents the Oman economy in 2012, the latest year for which key economic data required for the model are publicly available at the time of this database construction.

Sources for the data items discussed in the previous section include:

- Oman input-output data for the year 2007 and elasticities in the GTAP 8.0 database (Narayanan et al. 2012). This database is a global database describing bilateral trade patterns, production, consumption and intermediate use of commodities and services for just under 130 countries/regions in the World. More discussion about this Oman database can be found in Section 2.1.
- Oman Statistical yearbooks for the years 2010-2013 (NCSI 2011, 2012, 2013a, 2013b), which contain statistics on national accounts and sectoral variables, such as gross output, gross value added and payment to labour for the period 1998 - 2012. These data are used to (i) split the GTAP database into more relevant sectors for Oman (e.g. one sector in GTAP includes public administration, education and healthcare. We wanted to model each of these activities separately); and (ii) to update the database from 2007 to 2012. The Yearbooks also contains data on government and foreign accounts required for data items in Figures 5 and 6 above. More discussions on these procedures are included in Section 2.2.
- Oman Census 2010 data (NCSI 2013c), which contain data on the number of employed persons by industry, occupation, age, gender, nationality (Omani/NonOmani), qualification level and qualification fields. This data is used to compile the employment matrix by industry, occupation and nationality.
- Oman Labour force survey 2008 data (NCSI 2014), which contain data on salary ranges for workers classified by industry, occupation, age, gender, nationality, qualification level and qualification fields. This data is used to compile the wage rate matrix by industry,

occupation and nationality. These wage rates are used together with the number of workers from Census to compile the wage bill matrix V1LAB in Figure 1.

The input-output database for OMAGE was compiled in 12 steps as illustrated in Figure 7 below. To promote transparency and assist trouble shooting, we automated the process of generating the OMAGE database by using GEMPACK (Harrison and Pearson 1996).[5] Much of our initial input data was provided to us in Excel format. We converted this to GEMPACK's Header Array format using ViewHAR (Horridge 2014). For each step of the database creation process, we wrote a TABLO program to conduct the necessary calculations and manipulations. They are listed in rectangular boxes in Figure 7. An important part of each TABLO program at each step is a series of checks to ensure that the data meet necessary balance and other conditions at each stage of the data creation process (see Section 1.4). Batch files automate the execution of the series of TABLO-generated programs. We think our approach has a number of advantages, particularly relative to the common alternative of doing large numbers of sequential data manipulations using a spreadsheet program like Excel. First, it is transparent. TABLO input files are text files written in an easy to master language. As such, each TABLO program represents transparent documentation of the data manipulation processes that we have implemented at each stage of the database creation process. Second, automation enables timely generation of an updated database, as required.

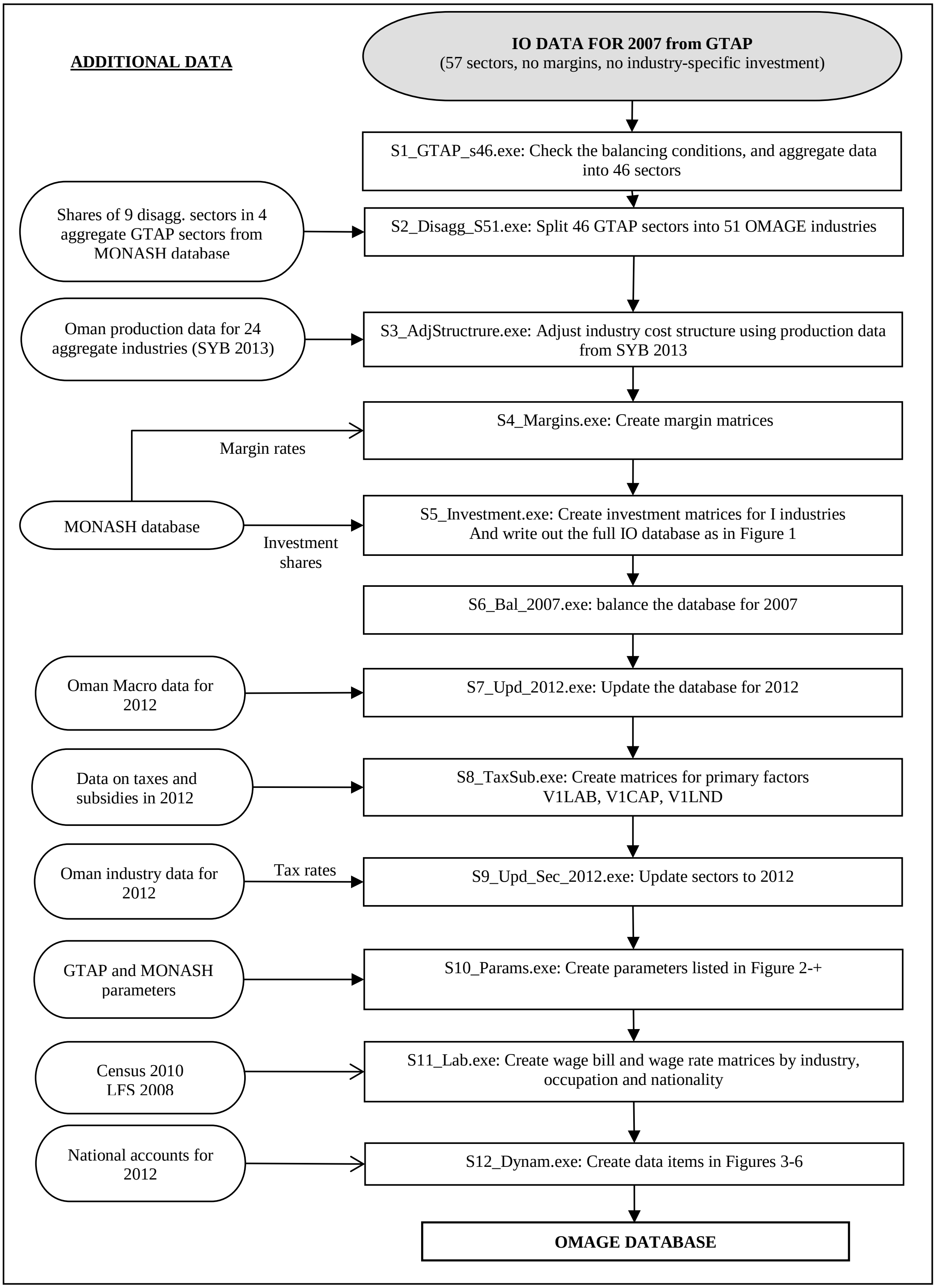
2.1 Step 1: Checking the GTAP data for Oman and aggregating it to 46 sectors

Our starting point for the database is Oman data in the GTAP database for the year 2007, denominated in million US dollars. In this first step we first checked the GTAP data to see whether they satisfy the balancing and sign conditions, and then checked whether the GTAP data set contains all the matrices required for the OMAGE model as specified in Figure 1. We found that the GTAP data satisfy the sign and the balancing conditions. However, the data set itself does not distinguish all the detail required. In particular:

1. It does not distinguish trade and transport margins on commodity flows from producers to users of commodities. That is, it does not have the matrices V1MAR – V5MAR listed in Figure 1. Distinguishing margins is important for properly accounting for the contributors to market prices, and hence better assessment of impacts of policy changes. We, therefore, will need to create these margin matrices.

[5] GEMPACK was created at, and is maintained by, the Centre of Policy Studies. It is designed specifically for CGE modelling. Key components of GEMPACK include: Header Array files that can accommodate very large data sets, and the Header Array reader ViewHAR; and the TABLO programming language for coding model equations, formulas, etc.

Figure 7. Steps in creating the database for the core OMAGE model, data sources, and execution programs



2. It does not distinguish investment by industry. That is, it does not have the matrices V2BAS, V2MAR and V2TAX as listed in Figure 1. There is only one investment column showing the use of commodities for investment purposes. In addition, the column seems to contain goods used for investment (i.e. fixed capital formation) and goods going into inventories. For example, the investment column contains non-zero values for pure consumer goods such as meat, dairy, rice, beverages and tobacco products. We will need to split the "Investment" column into the 51 columns representing the investment activity of each of the industries in OMAGE.

Importantly, the sectoral disaggregation of the GTAP database is not entirely suitable for the Omani economy. For example, out of its 57 sectors, GTAP data distinguish 14 agricultural, forestry and fishery industries, which are of relatively little importance to Oman. On the other hand, GTAP data have a higher level of aggregation for services sectors than what is desirable for Oman. For example, public administration, education and health are represented by only one sector, whereas it is desirable that these sectors are treated separately. Hence, as can be seen from Table 1 below, we created for OMAGE a database with 51 sectors, where there are fewer agricultural and food processing sectors but more services sectors than that in GTAP.
In the first step (Step 1), we aggregated the more detailed agricultural, mining and food processing sectors in GTAP into the level of aggregation adopted in the final OMAGE database (see the first half of Table 1). After this step, the database contained 46 sectors. In the next step (Step 2), some services sectors are disaggregated (see the second half of Table 1).

At this point we converted the database from USD million into Omani Rials million, using the exchange rate of 0.386 OMR/USD. This exchange rate was calculated as the ratio of the GDP for Oman in 2007 measured in OMR to that measured in USD as published in the World Development Indicators database (World Bank 2013).

Table 1. Concordance between sectors in GTAP data, Omani production account data, and the adopted sectors for the OMAGE database

A. GTAP sectors	B. Sectors with data from NCSI	C. Adopted sectors
1. Paddy rice	1.Agriculture	1.Cereals
2.Wheat		
3.Cereal grains n.e.c.[6]		
4.Vegetable, fruits, nuts		2.Fruits and vegetables
5.Oil seeds		3.Other crops
6.Sugar cane, sugar beet		
7.Plant-based fibers		
8.Crops n.e.c.		
9.Forestry		
10.Bovine cattle, sheep and goats, horses		4.Live stock

[6] "n.e.c" stands for "Not elsewhere classified".

A. GTAP sectors	B. Sectors with data from NCSI	C. Adopted sectors
11.Animal products n.e.c.		
12.Raw milk		
13.Wool, silk-worm cocoons		
14.Fishing	2.Fishing	5.Fishing
15.Coal	3.Mining of non-ferrous metal ores	6.Coal
16.Oil 17.Gas extraction	4.Extraction of crude petroleum 5.Extraction of natural gas 6.Services incidental to oil and gas[7]	7.Oil 8.GasExtract
18.Minerals n.e.c.	7.Other mining and quarrying	9.Minerals n.e.c.
19.Bovine meat.	8.Other manufacturing	10.Meat products
20.Meat product n.e.c		11.Meat products
21.Vegetable oils and fats		12.Vegetable oils and fats
22.Dairy products		13.Dairy products
23.Processed rice		14.Processed rice
24.Sugar		15.Sugar
25.Food products n.e.c.		16.Food products n.e.c.
26.Beverages and tobacco products		17.Beverages and tobacco products
27.Textiles		18.Textiles
28.Wearing apparel		19.Wearing apparel
29.Leather products		20.Leather products
30.Wood products		21.Wood products
31.Paper products, publishing		22.Paper products, publishing
32.Petroleum, coal products	9.Manufacturing of refined petroleum products	23.Petroleum, coal products
33.Chemical, rubber, plastic products	10.Manufacturing of chemicals	24.Chemical, rubber, plastic products
34.Mineral products n.e.c.		25.Mineral products n.e.c.
35.Ferrous metals		26.Ferrous metals
36.Metals n.e.c.		27.NonFeMetals
37.Metal products		28.Metal products
38.Motor vehicles and parts		29.Motor vehicles and parts
39.Transport equipment n.e.c.		30.Transport equipment n.e.c.
40.Electronic equipment		31.Electronic equipment
41.Machinery and equipment n.e.c.		32.Machinery and equipment n.e.c.
42.Manufactures n.e.c.		33.Manufactures n.e.c.
43.Electricity	11.Electricity and water supply	34.Electricity
44.Gas		35.Gas
45.Water		36.Water

[7] Although the SYB provides data on output and value added for this "Services incidental to oil and gas" sector, we do not distinguish it separately in our final database. It is because we have no sales and costs structures for this sector. We also cannot borrow these structures from any other databases that we know of.

A. GTAP sectors	B. Sectors with data from NCSI	C. Adopted sectors
46.Construction	12.Building and construction	37.Construction
47.Trade	13.Wholesale and retail trade	38.Wholesale and retail trade
	14.Hotels and restaurants	39.Hotels and restaurants
48.Transport n.e.c.	15.Land transport	40.Land transport
	16.Supporting and auxiliary transport activities	41.Transport n.e.c.
49.Water transport		42.Water transport
50.Air transport	17.Air transport	43.Air transport
51.Communication	18.Post and telecommunication	44.Communication
52.Financial services n.e.c.	19.Financial intermediation, except insurance	45.Financial services n.e.c.
53.Insurance	20.Insurance and pension trust	46.Insurance
54.Business services n.e.c.	21.Real Estate	47.Real Estate
	22.Business activities	48.Business services n.e.c.
55.Recreational and other services	23.Other community, social and personal services	49.Recreational and other services
	24.Private household with employed persons	
56.Public Administration, Defense, Education, Health	25.Public administration and defence	50.Public administration and defence
	26.Education	51.Education
	27.Health	52.Health
57.Dwellings		53.Dwellings

2.2 Step 2: Disaggregating 46 GTAP sectors into 51 sectors

In this step we conducted the following disaggregations:

1. The Trade, Hotel and Restaurant sector was disaggregated into two separate industries – Trade, and Hotels and restaurants;

2. The Other Transport sector was disaggregated into two industries - Land transport, and Transport services;

3. The Other Business services sector was disaggregated into two industries - Real estate, and Other business services; and

4. The Government, Education and Health sector was disaggregated into three industries - Public administration, Education, and Health.

The disaggregation required us to know the cost and sale structures of the new sectors. We borrowed these structures from the MONASH database for the Australian economy. We then used the RAS procedure to scale the data so that the newly created sectors summed to their original sectors.[8] After this step, the database contained 51 sectors as described in Column (c), Table 1 above.

[8] RAS is a method in which a bi-proportional technique is used to scale a matrix to specified targets, often the row and column targets. For information on RAS, see United Nations (1999); Lahr and Mesnard (2004).

2.3 Step 3: Adjusting sectoral structure

Statistical Yearbook 2013 (NCSI 2013b) provides data for output and broad production cost categories for 27 sectors in the economy for the period 2007 -2012. We aggregated the 27 sectors to 24 sectors to which OMAGE 51 sectors can map, and then calculated the average shares of different cost categories for the period to get a representative cost structure for the sectors, as reported in Table 2. We then adjusted the GTAP database to reflect these structures.

Table 2. Cost structure for 24 aggregate sectors

Sector	Share of cost categories in total cost (%)			
	Intermediate inputs	Compensation of employees	Gross operating surplus[9]	Total
Agriculture	35.6	10.2	54.2	100.0
Fishing	9.7	3.6	86.7	100.0
Crude oil	6.5	3.5	90.0	100.0
Natural gas	4.4	3.0	92.7	100.0
Other mining and quarrying	36.6	12.4	51.0	100.0
Refined petroleum	95.0	1.3	3.7	100.0
Chemicals	42.7	1.8	55.5	100.0
Other manufacturing	59.9	9.1	31.0	100.0
Electricity and water supply	66.4	6.7	27.0	100.0
Construction	63.0	19.5	17.6	100.0
Trade	30.4	30.7	38.9	100.0
Hotels and restaurants	46.2	22.4	31.4	100.0
Land transport	33.8	4.0	62.2	100.0
Air transport	58.8	28.3	13.0	100.0
Supporting and auxiliary transport	19.1	26.5	54.4	100.0
Post and telecommunication	31.6	12.9	55.5	100.0
Financial services	58.6	22.6	18.7	100.0
Insurance and pension	38.9	8.0	53.2	100.0
Rea estate	19.0	6.7	74.3	100.0
Business activities	30.7	45.7	23.7	100.0
Public administration and defence	34.4	57.2	8.4	100.0
Education	13.2	75.2	11.6	100.0
Health	27.1	65.1	7.8	100.0
Other community, social and personal services	31.1	55.9	13.0	100.0
Total	33.8	16.6	49.6	100.0

(Source: Calculated for the period 2007-2012 from NCSI 2013a, "Production account by kind of economic activity at current prices")

2.4 Step 4: Creating margin matrices

In this step we created the margin matrices. This involved two steps. First, we distinguished between direct and margin usage of a margin commodity. Then we allocated the margin usage

[9] Calculated as the difference between Gross Value Added and Compensation of Employees.

to different commodity flows to different users.

Margin commodities (such as road transport) can be used either directly, or as a margin service. Margin services facilitate the flows of goods from producer to user, while direct purchases are valued in their own right. For example, consider road transport services. Purchase of a taxi ride by a banker to get from one office to another is a direct intermediate input of road transport services to the banking industry. Purchase of truck delivery service to deliver furniture from a shop to a bank office is a purchase of a road transport margin service by the banking industry.

The GTAP database contains five margin commodities (namely Trade, Land transport, Water transport, Air transport, and Supporting and auxiliary transport). However, it does not distinguish direct and margin uses of these commodities. It also does not contain information on the margin rates on each commodity flow. We borrowed this information from the MONASH database. First, we calculated the direct use of margin commodities by assuming that, for each margin commodity, the share of direct use in total use of the commodity by each user is the same as that in the MONASH database. For example, the direct use of margin commodities by households is 20% for trade, 41% for land transport, 96% for water transport, 97% for air transport, and 92% for supporting and auxiliary transport services. For each margin commodity, the margin use is the difference between total use and direct use. We then calculated the margin matrices with the assumption that for each commodity, all the margin rates are the same on intermediate inputs and investment for all producers, and the margin rates are also the same for commodities used by other final consumption categories. We calculated these rates from the MONASH database. Then we multiplied the rates with the USE matrix to get the initial margin values. The initial margin values were then scaled so that they sum up to the margin use of each margin commodity.

2.5 Step 5: Creating investment matrices

The OMAGE model requires each industry to be an investor. The investor buys commodities to construct capital units specific to their industry. However, in the original GTAP database there is only a single investor for the whole economy, represented in a single column. In this step, we split that column into 51 columns, as required in Column 2, Figure 1.

This task involved two main stages. In the first stage, we calculated the amount of total investment undertaken by each industry in the base year. The sum of investment across industries must equal the GDP (expenditure side) estimate of economy-wide investment. In the second stage, we calculated the commodity-composition of each industry's investment. The total use of each commodity for investment purposes across all industries must be the same as the value of that commodity in the single investment column in IO table. In the section below we describe the procedure in more detail.

2.5.1 Stage 1: Estimating industry investment and capital stock

There are two pieces of data on investment in Oman in 2007, available from national accounts (NCSI 2013b):

1. Aggregate gross fixed capital formation, valued at RO 4,638.6 million.
2. Investment by 16 aggregate sectors, as reported in Table 3 below.

Table 3. Sectoral investment in 2007 (RO mil)

Sector	Value	Corresponding OMAGE industries[10]
Agriculture and fisheries	12.2	Cereals, VegFruits, OthCrops, Livestock, Fishing
Crude oil	1,210.6	CrudeOil
Natural gas	381.9	NatGas
Other mining and quarrying	9.9	OthMining
Manufacturing	1,060.3	Meat, OilFats, Dairy, Rice, Sugar, OthFood, BevTobacco, Textile, Clothing, LeatherProd, WoodProd, PaperPublish, PetrolCoke, ChemRubPlast, NMetalProd, FeMetal, NFeMetals, MetalProds, MotorVehicle, OthTransEq, ElectronicEq, OthMachEq, OthManuf
Electricity and water supply	163.4	Electricity, Gas, Water
Construction	172.5	Construction
Wholesale and retail trade	97.0	Trade
Hotels and restaurants	53.4	HotelsRest
Transport, storage and communication	254.8	LandTrans, WaterTrans, AirTrans, OthTrans, Communicatn
Financial intermediation	56.9	FinanceServ, Insurance
Real estate, renting and business activities	367.8	RealEstate, OthBusServ
Public administration and defence	513.8	PublicAdmin
Education	99.8	Education
Health	25.0	Health
Other community, social and personal services	159.1	RecrOthServ
Total	4638.6	

(Source: NCSI 2013a, Table 17-14, adjusted to meet the value of aggregate Gross Fixed Capital Formation in National Account).

We first allocated the value of investment by 16 aggregate sectors to more disaggregated industries within each sector (see column 3, Table 3) in proportion to industry shares in capital rentals of the aggregated sector. We then checked to see if these initial estimates are plausible by calculating industry rates of return based on the following equation: for each industry,

$$R = \frac{GOS(k + D)}{I} - D \tag{5}$$

where R is the net rate of return on an industry's capital stock (e.g. a number like 0.05), I is industry investment, GOS is gross operating surplus, k is the industry's capital growth rate, defined as $k = \frac{K_1}{K_0} - 1$ (e.g. a number like 0.01), and D is the industry's depreciation rate (e.g. a number like 0.07). Equation (5) is derived from the following equations:

[10] Due to space limit, industries are listed with their short names here. See Appendix 1 of this document to see their corresponding long names.

1) The capital accumulation formula:

$$K_1 = K_0(1 - D) + I \tag{6}$$

where K_0 and K_1 are the industry's capital stock at the beginning and the end of the year; D is the industry's depreciation rate; and I is the value of investment in the industry during the year; and

2) The equation for calculating net rate of return on industry capital stock:

$$R_1 = \frac{GOS}{K_0} - D \tag{7}$$

where R_1 is the net rate of return on the industry's capital in the period, defined as the ratio of capital rental in the industry (GOS) to the value of its capital stock (K_0), less depreciation rate (D).

To implement (5), we already have GOS from the database. We adopted industry depreciation rate D from BEA (2013) estimates for American industries for the year 2012. The rates range from 0.033 for real estate to 0.17 for the manufacturing of electronic equipment. The economy-wide average depreciation rate is 0.082. As for industry capital growth rates (k), we assumed that capital stock grew at the same rates as industry real value added over the period 2007-2012. We calculated these real growth rates of value added from national accounts data (NCSI 2013a). On average, the growth rate is 0.052 (or 5.2%). With the initial estimates for I discussed earlier, we calculated the initial values of R based on equation (5). These initial values for R vary substantially between industries, from 0.39 for agriculture to negative 0.11 for public administration and defence. We do not believe this wide dispersion of R, and hence we adjusted R according to the following formula:

$$R_1 = R_{ave}^{\alpha} R_0^{1-\alpha} \tag{8}$$

where R_0 and R_1 are industry initial and adjusted rates of return respectively; α is the weight with which we weigh industry rate of return and economy-wide average rate of return R_{ave}. We adopted the value of 0.8 for α, and the value of 0.0286 for economy-wide average rate of return on capital. The latter value (2.86 %) is the average lending rate over the period 2003-2012 in Oman (World Bank 2013).

After calculating R1, we recalculated industry investment value (I) using equation (5), and then scaled them so as they sum to economy-wide aggregate capital formation values as reported in the national accounts. We then calculated industry capital stocks using the following formula that is derived from equation (6) above:

$$K = \frac{I}{k + D} \tag{9}$$

2.5.2 Stage 2: Calculating the composition of investment

After estimating the value of investment by industry, we estimated the commodity input requirements for each industry's investment. Industry-specific capital input requirements are mainly governed by the nature of the industry. For example, we would expect investment in transport service sectors to be comprised mainly of transport equipment. Similarly, we might expect units of new capital in agricultural sectors to have a high requirement for inputs of agricultural machinery. We formed an initial guess at industry-specific input requirements to capital formation using shares from Australian data. These shares can be replaced in the data creation algorithm at a later date if specific information on the composition of investment by industry in Oman becomes available.

We first multiplied the total value of investment in each industry (calculated in Stage 1) by our initial estimate of shares of source-specific commodity inputs to each industry's capital formation. This produced an initial estimate of the basic value of each source-specific commodity flow to the capital creation activity of each industry. We then applied tax and margin rates from the IO table output from the previous step to produce the tax and margin flows on these commodities. Finally, we applied the RAS procedure to the investment matrices so that (i) the commodity, tax and margin row sum to their values in the investment columns for basic, tax and margins in the previous step; and (ii) the columns sums to the value of industry investment.

2.6 Step 6: Balancing the database

In this step we balanced the database and target some macro variables using the Adjuster program developed by Horridge (2009). This program provides a better approach than simple RAS or similar iterative methods, in which each scale factor is adjusted to meet one constraint only. In the Adjuster program, all coefficients in the IO database and macroeconomic variables are simultaneously connected via equations describing the balancing conditions in the database and the macroeconomic relationships in the model. The equations include scaling variables which allow the coefficients to adjust so as to meet exogenously determined targets. The targets may include balancing constraints, such as the zero-pure profit conditions, or the values of GDP and its components as available from the national accounts.

Specifically, in this step the following targets were set. First, we imposed the market clearing condition; that is, commodity demand equals commodity supply. Second, we imposed the zero-pure-profit condition; that is, production costs equal production revenues. Finally, we imposed the GDP expenditure values for 2007 as reported in column 1, Table 4.

Table 4. GDP components in 2007 and 2012, RO mil

GDP components	2007	2012
Household consumption	4,955.5	8,782.1
Government consumption	3,043.9	5,718.1
Gross capital formation	5,513.70	7,336.60
Exports	9,139.8	18,667.0
Imports	6,471.0	10,706.0
GDP	16,181.8	29,797.7

(Source: NCSI 2013b, Section 14 – National Accounts)

2.7 Step 7: Updating the database to 2012 at the macro level

We used the Adjuster program (Horridge 2009) to update the database from 2007 to 2012, using the values of macro variables as reported in column 2, Table 4. This scaled the whole database proportionately so as to achieve these values. However, during the period 2007-2012 different sectors may have developed differently. These differences in sectoral development are taken into account in Step 9. In Step 8 below, we recalculate taxes and subsidies in the database.

2.8 Step 8: Recreating matrices of indirect taxes

There are two main types of indirect tax in OMAGE: taxes and subsidies on products (hereafter commodity taxes) and other taxes and subsidies on production (hereafter production taxes). In the original and updated GTAP data, total net (taxes less subsidies) indirect tax revenues are positive. However, the Omani national accounts show that the total net indirect tax revenues become negative in 2012. One of the causes of this is the addition of subsidies on oil product in 2012, which did not exist in 2007 (see Table 2-15 in Chapter 15 "Public Finance" in NCSI (2011, 2013b)). Therefore, there is a need to recalculate the net indirect tax matrices V1TAX - V5TAX and PTAX in the model. Table 5 reports the values and our assumptions about the incidence of the taxes/subsidies that were used to create the net tax matrices in OMAGE.

Table 5. Indirect taxes and subsidies in 2012 (RO mil)

Items	Value	Assumed tax incidence for tax allocation
(a) Taxes	**349.6**	
Business and professional Licences	9.2	Production tax on all industries, except Agriculture, Public administration, and Dwellings services
Vehicle licences	39.3	Tax on the use of Motor vehicles by all users
Hotels & entertainments taxes	19.1	Tax on the use of Hotels, restaurants and Recreation services by all users
Taxes on concessionary use of airports & seaports	18.5	Tax on the use of Water transport and Air transport by all users
Taxes on building permits	1.6	Production tax on the Construction industry
Miscellaneous taxes	11.8	Tax on all commodities from both sources, by all users
Communication services-licensing fees	0.0	Production tax on the Communication industry
Customs duties	250.1	Tariff on all imported products
(b) Subsidies	**1,260.3**	
Electricity sector	252.6	Subsidy on the use of Electricity by all users

Oil products	1,007.7	Subsidy on the use of refined petroleum by all users
Net indirect taxes	**-910.7**	

(Source: NCSI 2013a, Section 15 – Public Finance)[11]

For each of the taxes/subsidies in Table 5, except for Custom duties, we allocated the tax/subsidy revenue proportionately to the values of commodity flows or production listed in the Incidence column. For Custom duties, we scaled the existing tariff revenues in the database to the value reported in Table 5.

2.9 Step 9: Updating the database to 2012 at the sectoral level

In this step we used the Adjuster program (Horridge 2009) to update not only macro, but also selected sectoral variables for the year 2012. Specifically, we targeted the gross outputs and compensation of employees for selected sectors in the 24 aggregate sectors as published in NCSI (2013a), and reported in Table 6.

Table 6. Sectoral gross output and Compensation of employees in 2012 (RO mil)

Sector	Gross output	Compensation of employees
Agriculture	332.5	35.9
Fishing	151.0	4.1
Cruide oil	15,129.4	507.7
Other mining and quarrying	159.5	21.1
Natural gas	1,217.6	27.6
Refined petroleum	3,052.1	40.3
Chemicals	3,464.9	60.2
Other manufacturing	2,800.8	255.0
Electricity and water supply	1,024.3	77.2
Construction	4,056.9	877.4
Trade	3,165.4	888.2
Hotels and restaurants	375.2	84.1
Land transport	945.0	32.1
Air transport	347.8	107.8
Supporting and auxiliary transport	374.1	87.2
Post and telecommunication	630.9	91.1
Financial services	979.3	234.5
Insurance and pension	459.2	28.6
Rea estate	749.7	49.1
Business activities	664.1	334.9
Public administration and defence	3,686.6	2,193.0
Education	1,353.6	994.6
Health	627.3	394.4
Other community, social and personal services	558.2	297.6

[11] Note that the net indirect tax revenues calculated in this Table is slightly higher than the value of -1,001.4 reported in the national accounts (Ch. 14, NCSI 2013a). We could not find the source of the discrepancy. In Step 9, we simply scale the tax matrices so as to meet the national account value.

Sector	Gross output	Compensation of employees
Total	46,305.4	7,723.7

(Source: NCSI 2013a, Production account by kind of economic activity at current prices)

We also targeted export values of important products, such as oil, chemicals, foods and beverages, and other goods and services for which data are available for 2012.

2.10 Step 10: Compilation of parameters

In this step we compiled the parameters described in Figures 2. As there are no parameter estimates for Oman, we adopted them from the GTAP database and/or from the MONASH model. The values of the industry or commodity parameters are reported in Table 7. We discuss them below.

Table 7. Industry/commodity parameters for OMAGE

Sector	(1) $\sigma prim_i$	(2) σlab_i	(3) $\sigma citiz_{i,o}$	(4) $\sigma_c^{(1)}$	(5) $\sigma_c^{(2)}$	(6) $\sigma_c^{(3)}$	(7) $\varepsilon_{c,t}$	(8) EPS_c
1. Cereals	0.25	0.35	2	3.98	3.57	3.57	-3.30	0.17
2. Fruits and vegetables	0.25	0.35	2	1.85	1.85	1.85	-2.17	0.17
3. Other crops	0.25	0.35	2	2.99	3.24	3.24	-3.77	0.18
4. Livestock	0.25	0.35	2	2.57	1.65	1.59	-3.30	0.67
5. Fishing and hunting	0.20	0.35	2	1.25	1.25	1.25	-1.61	0.67
6. Crude oil extraction	0.20	0.35	2	5.20	5.20	5.20	-7.38	0.86
7. Natural gas extraction	0.20	0.35	2	17.20	17.20	17.20	-23.80	1.04
8. Other mining	0.20	0.35	2	0.90	0.90	0.95	-1.64	1.07
9. Meat products	1.12	0.35	2	4.05	4.20	4.20	-5.80	0.67
10. Oils and fats	1.12	0.35	2	3.30	3.30	3.30	-4.53	0.69
11. Dairy products	1.12	0.35	2	3.65	3.65	3.65	-5.15	0.67
12. Rice and rice products	1.12	0.35	2	2.60	2.60	2.60	-3.30	0.17
13. Sugar and sugar products	1.12	0.35	2	2.70	2.70	2.70	-3.50	0.69
14. Other food products	1.12	0.35	2	2.00	2.00	2.00	-2.81	0.69
15. Beverages	1.12	0.35	2	1.15	1.15	1.15	-1.60	0.69
16. Textiles	1.26	0.35	2	3.75	3.75	3.75	-5.27	0.89
17. Clothing	1.26	0.35	2	3.70	3.70	3.70	-3.30	0.89
18. Leather products	1.26	0.35	2	4.05	4.05	4.05	-3.30	0.89
19. Wood products	1.26	0.35	2	3.40	3.40	3.40	-4.45	1.07
20. Paper products	1.26	0.35	2	2.95	2.95	2.95	-3.30	1.07
21. Oil Refinery	1.26	0.35	2	2.10	2.10	2.10	-2.98	0.95
22. Other chemicals	1.26	0.35	2	3.30	3.30	3.30	-4.63	1.07
23. Non-metallic mineral products	1.26	0.35	2	2.90	2.90	2.90	-3.69	1.07
24. Ferrous metal	1.26	0.35	2	2.95	2.95	2.95	-4.10	1.07
25. Non-ferrous metals	1.26	0.35	2	4.20	4.20	4.20	-6.15	1.07
26. Metal products	1.26	0.35	2	3.75	3.75	3.75	-5.24	1.07
27. Motor vehicles and parts	1.26	0.35	2	2.80	2.80	2.80	-4.13	1.07
28. Other transport equipment	1.26	0.35	2	4.30	4.30	4.30	-6.15	0.95

Sector	(1) $\sigma prim_i$	(2) σlab_i	(3) $\sigma citiz_{i,o}$	(4) $\sigma_c^{(1)}$	(5) $\sigma_c^{(2)}$	(6) $\sigma_c^{(3)}$	(7) $\varepsilon_{c,t}$	(8) EPS_c
29. Electronic equipment	1.26	0.35	2	4.40	4.40	4.40	-6.50	1.07
30. Other machinery and equipment	1.26	0.35	2	4.05	4.05	4.05	-5.88	1.07
31. Other manufacturing	1.26	0.35	2	3.75	3.75	3.75	-5.51	1.07
32. Electricity	1.26	0.35	2	2.80	2.80	2.80	-3.30	1.04
33. Gas distribution	1.26	0.35	2	2.80	2.80	2.80	-4.19	1.04
34. Water, sewerage and drainage	1.26	0.35	2	2.80	2.80	2.80	-3.30	1.04
35. Construction services	1.40	0.35	2	1.90	1.90	1.90	-3.30	1.04
36. Wholesale and retail trade services	1.68	0.35	2	1.90	1.90	1.90	-3.30	1.11
37. Accommodation and restaurants	1.68	0.35	2	1.90	1.90	1.90	-2.85	1.11
38. Land transport services	1.68	0.35	2	1.90	1.90	1.90	-2.85	0.95
39. Water transport services	1.68	0.35	2	1.90	1.90	1.90	-2.85	0.95
40. Air transport services	1.68	0.35	2	1.90	1.90	1.90	-2.85	0.95
41. Other transport services	1.68	0.35	2	1.90	1.90	1.90	-2.85	0.95
42. Communications	1.26	0.35	2	1.90	1.90	1.90	-2.85	0.95
43. Financial services	1.26	0.35	2	1.90	1.90	1.90	-2.85	1.25
44. Insurance services	1.26	0.35	2	1.90	1.90	1.90	-2.85	1.04
45. Real estate services	1.26	0.35	2	1.90	1.90	1.90	-3.30	1.25
46. Other business services	1.26	0.35	2	1.90	1.90	1.90	-2.85	1.25
47. Public administration and defence	1.26	0.35	2	1.90	1.90	1.90	-3.30	1.07
48. Education	1.26	0.35	2	1.90	1.90	1.90	-2.85	1.07
49. Health	1.26	0.35	2	1.90	1.90	1.90	-3.30	1.07
50. Recreational, personal and community services	1.26	0.35	2	1.90	1.90	1.90	-2.85	1.07
51. Dwelling services	1.26	0.35	2	1.90	1.90	1.90	-3.30	1.07

2.10.1 Substitution elasticities between primary factors

For substitution elasticities between primary factors (labour, capital and land), we adopted GTAP values, which range from 0.25 for agriculture, 0.2 for mining, to 1.68 for transport services, as reported in Column 1, Table 7.

As for the elasticities of substitution between labour of different occupations (Column 2, Table 7), we use the MONASH value of 0.35 for all industries. For more discussion on this latter set of substitution parameters, see Dixon et al. (1982).

For the elasticities of substitution between domestic and foreign labour within the same occupation (Column 3, Table 7), we have adopted the value of 2 for all industries. This value is higher than that for the elasticities of substitution between occuaptions, because we think the level of substitutability of workers within the same occupation tends to be higher than that between workers from different occupations. For more discussion on this parameter, see Dixon et al. (2011).

2.10.2 Armington substitution elasticities between domestic and foreign sources of supply

OMAGE treats domestic and imported products as imperfect substitutes, with the degree of substitutability governed by Armington elasticities. These elasticities are important for determining the behaviour of trade flows. However, they are very difficult to estimate, and the available estimates vary widely due to the availability and quality of data for their estimation, as well as the differences in the econometric models used to estimate them (McDaniel and Balistreri 2003, Hertel et al. 2004). Due to the lack of any estimate of these elasticities of substitution between domestic and foreign sources of supply for Oman, we adopted the elasticities from the latest GTAP 8.0 database (Narayanan et al. 2012). These elasticities are the results of an extensive econometric estimation by Hertel et al. (2004).

We assume that the commodity-specific Armington elasticities are the same for the three users in OMAGE who undertake price-responsive import/domestic substitution: producers, investors, and households. The Armington elasticities for services are generally lower than for agricultural and manufacturing products. There are two reasons for this. Firstly, there is a higher degree of heterogeneity of services across sources. Secondly, services trade is often tied to trade of goods and services. For example, imports of transport services are often closely related to the imports of goods. Hence the responsiveness of demand for transport services to changes in own price would be lower than if they were demanded in their own right, rather than as a margin service.

2.10.3 Export demand elasticities

Export demand elasticities are crucial in determining the effects of changes in the volume of exports on the terms of trade and hence aggregate economic welfare. However, estimates of export demand elasticities are difficult to obtain, and often differ between studies and models. To date, there have been no estimates for export demand elasticities for Oman at the commodity level. This section describes how we have adopted or calculated the export demand elasticities for commodities in OMAGE.

OMAGE distinguishes three groups of exports: (1) individual exports, which comprise the bulk of exports; (2) tourism-related services, such as travel and hospitality services; and (3) collective exports, for which exports comprise a small proportion of sales (e.g. less than 20 per cent). For each category, the model requires export demand elasticties.

2.10.3.1 Export demand elasticities for individual exports

For the individual exports, we calculate export demand elasticities using GTAP model estimates of elasticities of substitution between different sources of imports (Hertel et al. 2004), and theory suggested by Dixon and Rimmer (2002:222-225).

Foreign importers are assumed to be profit-maximisers, who consider imports from different sources as imperfect substitutes. Thus, they choose imports from different sources to minimise the costs of producing a unit of imports subject to the CES production function. From that optimisation problem, Oman's export demand elasticity for commodity *i* with regard to its f.o.b.

export price can be calculated as[12]:

$$\varepsilon_i = [\eta_i S_{M,i} - \phi_i(1 - S_{M,i})]S_{fob,i} \quad (10)$$

That is, export demand elasticity ε_i for good *i* is positively related to the price elasticity η_i of world demand for good *i* and the share $S_{M,i}$ of Oman in the rest-of-world's imports of good *i*, and negatively related to foreign importers' elasticity of substitution ϕ_i between alternative sources of supply. It also depends on the proportion $S_{fob,i}$ of the f.o.b. price of good *i* from Oman in the purchasers' price of *i* in foreign countries.

As can be seen from the above formula, if Oman is very small in international trade (i.e. $S_{M,i} \approx 0$), and if there is no difference between f.o.b. price and purchasers' price of *i* (i.e. $S_{fob,i} = 1$), then the export demand elasticity ε_i would equal the negative of the foreigners' Armington elasticity of substitution between alternative imports ϕ_i. However, Oman is likely to have non-trivial shares of the foreign markets for many of its exports (ie $S_{M,i} > 0$), and thus we use the above equation with appropriate values for $S_{M,i}$ and $S_{fob,i}$ to calculate Oman's export demand elasticities.

The elasticities were calculated first for 57 GTAP commodities using the values of ϕ_i from Hertel et al. (2004) and data from the GTAP 6.0 database on world imports and Oman's imports and exports of goods. Oman's share in world imports was calculated as:

$S_{M,i}$ = Oman's Exports of i /[World Imports of i – Oman's Imports of i]

The GTAP 8.0 database provides data on world imports and exports for the year 2007. We also adopted the price elasticity $\eta(i) = -0.5$, the share of f.o.b. price in the importers' purchasers' price $S_{fob,i} = 0.8$ for all merchandise goods as in Dixon and Rimmer (2002:224), and $S_{fob,i}=1$ for all services. The elasticities were then mapped to the 51 OMAGE commodities. They range from -1.6 for Beverage and tobacco products, to -7.38 for crude oil and -23.8 for natural gas. The export-weighted average is -7.2.

2.10.3.2 Export demand elasticities for tourism and collective export bundles

For the tourism and collective export bundles, we calculated the export demand elasticities as a weighted average of the elasticities of commodities in their respective bundle. The resulting average elasticity for tourism and collective export bundles are -2.85 and -3.3 respectively.

2.10.4 Household expenditure elasticities and the Frisch parameter

Household expenditure elasticities (Column 8, Table 7) are adopted from the GTAP database.

The Frisch parameter is the negative of the ratio between total final household expenditure and

[12] See the derivation of this formula in Dixon and Rimmer (2002:222-225).

household supernumerary expenditure. The Engel law states that as income increases, the proportion of income spent on food falls. Similarly, we can expect that as income increases, the proportion of income spent on subsistence items will fall. That is, the supernumerary proportion of household consumption should rise as income rises. As a result, we expect that the Frisch parameter for low-income countries will generally be higher than that for high-income countries. We adopted the value for the Frisch parameter from GTAP database, which is -3.1 for Oman.

2.11 Step 11: Create wage bill and wage rate matrices

In this step we split each industry's wage bill across occupation and nationality (Omani and Non-Omani). We also created the wage rate matrix by industry, occupation and nationality (the first item in Figure 4). As employment data on the demand side must be consistent with employment data on the supply side, we compiled these data together. We will discuss sources and the procedure to compile these data in Section 3.

2.12 Step 12: Ancilliary data and parameters

2.12.1 Parameters for the capital accumulation process

In this section we discuss how we adopted the values for parameters listed in Figure 3 but have not been dealt with in previous steps. They include the difference between maximum and trend growth rates of capital, the average sensitivity of capital growth to variations in expected rates of return on capital, industry asset price of capital, the level of the CPI, and the real interest rate.

In the absence of Oman-specific information on the value of the difference between the maximum and trend growth rates of capital for industries, we set the value of this parameter to 20 percentage points for all industries. We set the average sensitivity of capital growth to variations in expected rates of return at 1.0, the same as its value in the Australian MONASH database. This value, in turn, was obtained from the investment functions in Australian macro models (Dixon and Rimmer 2002:192-193).

The price of capital assets for all industries were normalised at 1 in the base year. The values for the CPI - lagged and CPI were adopted from Oman data for 2011 and 2012, which are 1.392 and 1.432 respectively relative to the base year 2000 =1 (NCSI 2013a, Chapter 17 "Price index").

The real interest rate was calculated based on Oman average lending interest rate of 5.6% (World Bank 2013), deflated by the inflation rate of 2.87% (calculated from the CPI and CPI lagged above). The result is a real interest rate of 2.7%.

2.12.2 Government revenues and expenditures

This section discusses the values for the coefficients listed in Figure 5.

Data on government revenue and expenditure for the base year 2012 are available from SYB 2013 (NCSI 2013b). The data are quite detailed. In OMAGE, we group them into broad revenue and expenditure items, as listed in Table 8 below. Table 8 also reports how these revenue and expenditure items are modelled in OMAGE. Note that Oman does not have personal income tax (Government of Oman 2009).

With regard to government debt and the associated rate of interest , according to IMF (2013), the ratio of government debt to GDP is 0.06. Multiplying this ratio with the value of GDP for 2012 gives the value of the stock of government debt in 2012, which is 1,788 RO mil. The average interest rate on this debt is derived by dividing the interest payment on government debt (see Table 8) on the government debt stock. The resulting interest rate is 2.53%.

Table 8. Government revenues and expenditures in 2012 (RO mil)

Item	Value	Components and modelling
(a) Revenues		
Revenues from oil, gas and public enterprises	11,941.0	Include government oil revenues, services revenues, and investment revenues in various sectors. Modelled as revenues from government shares in gross operating surplus of oil, gas and other industries.
Income tax	396.6	Tax on companies and establishment profits + Tax on property. Modelled as tax on capital and land income.
Net Indirect taxes	-1,001.4	Taxes on domestic and imported goods and services. Modelled as commodity and production taxes on good flows and production.
Other revenues	305.6	Miscellaneous revenues, sales of buildings and land, instalment in repayment loans. Modelled as moving with nominal GDP
(b) Expenditure		
Government current expenditure	5,718.1	Government final consumption (from National Account data), modelled as V5TOT in the model.
Government investment expenditure	2,886.5	Government investment in various sectors. Modelled as the share of government investment in industry total investment.
Government transfers to household	1,145.3	Includes government subsidies and other current transfers, and government support to international, regional and local organisations. Modelled as moving with the population and the CPI.
Interest payment on government debt	45.3	Interest on loans. Modelled as the product of stock of government debt and interest rate on government debt.
Other expenditure	1,766.1	Other expenditures. Modelled as moving with nominal GDP.
Government budget balance	-80.6	= Total revenues – Total expenditures

(Source: Compiled from Chapter 15: "Public Finance", NCSI (2013a))

2.12.3 Accounts with the rest of the world

This section discusses the values for the coefficients listed in Figure 6.
Table 9 reports data sources and the calculation of the key items in the current account, net foreign liabilities and rate of interest on net foreign liabilities.

Table 9. Current account, GNI, GNDI and net foreign liabilities

	Item	Value	Source
A.	Current account		
(1)	Export	18,667.0	National Accounts for 2012 (NCSI 2013a, Section 14)
(2)	Imports	10,706.0	National Accounts for 2012 (NCSI 2013a, Section 14)
(3)	Balance of trade	7,961.0	Balance of Payment (NCSI 2013a, Section 11)
(4)	Net primary income from abroad	-1,721.0	Balance of Payment (NCSI 2013a, Section 11)

	Item	Value	Source
(5)	*Compensation of Employees*	15.0	Balance of Payment (NCSI 2013a, Section 11)
(6)	*Other investment income*	-1,736.0	Balance of Payment (NCSI 2013a, Section 11)
(7)	Net current transfers from abroad	-3,171.2	Balance of Payment (NCSI 2013a, Section 11)
	Total CAB	3,068.8	
B.	**National Income Account**		
(8)	GDP	29,797.7	National Accounts for 2012 (NCSI 2013a, Section 14)
(10)	GNI	28,076.7	= (8) + (4)
(12)	Gross national disposable income	24,905.5	= (10) + (7)
C.	**Net foreign liabilities**		
(13)	Ratio of foreign debt to GDP	12.5%	IMF (2013)
(14)	Inferred stock of foreign debt	3,724.7	= (8) * (13)
(15)	Stock of foreign investment	15,070.2	NCSI (2013b), which contain stock of foreign direct and portfolio investment for 2011. We add to that stock the amount of net capital inflows of 2,353 RO mil for 2012 from NCSI (2013a, Section 11)
(16)	Net foreign liabilities	18,794.9	= (14) + (15)
(17)	Implied rate of interest on NFL	9.2%	= (6)/(16)

This concludes the discussions on the compilation procedure for the core CGE model. After this step, we have a correctly balanced and complete database for OMAGE for the year 2012.

3 DATA FOR THE LABOUR SUPPLY MODULE

This section discusses the creation of the coefficients required to implement the labour demand and labour supply modules described in Section 1.1.2.

3.1 Required data

The required coefficients are matrices listed in Table 10. Note that the dimensions of the matrices are denoted by letters, such as s,o,i,a,g,c . The associations between these letters and their sets are: s∈SKILL, o∈OCC, i∈IND, a∈AGE, g∈GENDER, and c∈CITIZ. These sets are listed in Appendix 1. For skills and ages, double letter indices (ss and aa) denote the skill and age in year t-1, whereas single letter indices (s and a) denote the skill and age in year t.

Note also that except for the lagged WAP matrix ($WAP_{a,g}^{(t-1)ss,c}$), which is for the year 2011, all matrices are for the base year 2012.

Table 10. Labour market coefficients and parameters

Coefficient	Description
$WAP_{a,g}^{(t-1)ss,c}$	The *lagged working age population* for year *t-1*, by skill, age, gender, and nationality. Our database starts from 2012, hence this coefficient is for the working age population in year 2011.

$T_{(aa,a),g}^{(ss,s),c}$	The *transition matrix*. This matrix shows the probability of a person of a certain gender and nationality moving from skill type *ss* to *s* and from age *aa* to *a* from year *t-1* to year *t*.
$NEW_{a,g}^{s,c}$	The *number of new entrants* into the working age population at the beginning of each year, by skill, age, gender and nationality.
$PR_{a,g}^{s,c}$	*Labour force participation rates*, by skill, age, gender and nationality in year t.
$ER_{a,g}^{s,c}$	*Employment rates*, by skill, age, gender and nationality in year t.
$LS_{a,g,c}^{s}$	*Labour supply, hours,* by skill, age, gender and nationality in year *t*.
$\phi_{o,s,c}$	The *elasticity of labour supply* to occupation *o* by skill *s* and nationality c with respect to movements in the relative wage of occupation *o*.
$\alpha_{a,g,c}$	The *elasticity of skill acquisition* to relative skill-specific wage rates by people with (a,g,c) characteristics.
$W_{i,o,c}$	Wage rates, by industry, occupation and nationality.
$V1LAB_{i,o,c}$	The wage bill matrix, by industry, occupation and nationality.

3.2 Data sources

Data for the coefficients listed in Table 10 come from the following sources:

1. *Census 2010*, which contain data on the number of workers by 58 industries, 98 occupations, 11 age groups, gender, nationality, 7 qualification levels, and 37 qualification fields.[13]. This is the main data source for the compilation of employment matrices. We also have published Census 2010 results, which contain:
   - i. Data on the labour force status (namely, employed, unemployed, and not in the labour force) of the working age population, by age, gender and nationality. These data were used in conjunction with employment data to calculate labour force participation rates and employment rates, by age, gender and nationality;
   - ii. Data for employment number by one-digit occupations. This data were used to map the 98 three-digit occupations to one-digit occupations;
   - iii. Data on employment status (namely, employer, own-account workers, paid employees and unpaid worker), by gender and nationality. These data were used to adjust the number of registered workers published in statistical yearbooks.[14]

[13] In this list we take into account only "real" categories, that is, the categories which exist in official classifications. The Census and LFS data also contain supplementary categories, such as "Don't know", "Not stated", "Blank". These supplementary categories are allocated proportionately to the "real" categories.

[14] According to the table on p.7, Chapter 4, SYB 2013, the employment indicators only include people in civil service, royal court, public corporations, Omanis registered with the public authority for social insurance, and expatriate workers with valid work permit. As at 2012, social insurance in Oman excludes foreign workers, household workers and self-employed persons

2. *Labour Force Survey* (LFS) 2008, which contains data on the number of workers by 152 industries, 92 occupations, 11 age groups, gender, nationality, 92 skills, and 7 salary ranges.
3. *Statistical year books* (SYB) for 2011 and 2012 (NCSI 2012, 2013a), from which the following data were used:
   i. Working age population, by age, gender and nationality in 2011 (hereafter referred to as $WAP_{a,g}^{(2011)c}$). This is used to create $WAP_{a,g}^{(2011)ss,c}$.
   ii. The numbers of Omani and Expatriate workers in government and private sectors for the years 2011 and 2012. These data were used as controls in updating employment data from 2010 to 2012;
   iii. The wage bill for 24 aggregate sectors for 2010-2012, as reported in Table 6. These data were used in updating industry employment from 2010 to 2012;
   iv. Data on basic wages for Omanis working in the private sector in 2009, by 10 age groups and 11 salary ranges, from Statistical Yearbook for 2010 (NCSI 2011). These data were used for the better estimation of wage rates. As will be discussed later, there is one large category in LFS with the wage range of RO 450 and above. SYB data were used to split this wage range into 7 ranges (451-600, 601-700, 701-800, 801-900, 901-1000, 1001-2000 and Over 2000);
   v. Data on the number of students and the number of graduates from different school systems, colleges and universities in the academic year 2011/12. These data were used to combine education data for reallocation of some "Unknown" skill data in Census 2006 to the relevant skill categories, and to compile the skill transition matrix.
4. *OMAGE wage bill by industry* in OMAGE input-output database.

Note that our core data sources for employment numbers and wage rates are for the year 2010 and 2008. And the data for PR, ER and WAP do not have the same dimensionality as required, namely, they do not contain the skill dimension. We also do not have any data on skill transition. Therefore, our major tasks involve:

a) Creating the additional skill dimension for PR, ER and WAP;
b) Updating WAP data to 2011 and all other data to 2012;
c) Creating the transition matrix;
d) Creating the wage rate and wage bill matrices.

There are many issues with the available labour market data, such as: (i) inconsistencies in employment numbers from difference sources; (ii) differences in classifications between databases; and (iii) lack of many important data items. We will discuss these issues and how we deal with them during the discussion of our data processing procedure below.

3.3 Data compilation procedure

3.3.1 Compilation of the lagged working age population matrix, participation rates and employment rates

In this section we discuss the compilation of the lagged working age population matrix, participation rates and employment rates by skill, age, gender and nationality ($WAP_{a,g}^{(2011)ss,c}$, $PR_{a,g}^{s,c}$, $ER_{a,g}^{s,c}$, $LS_{a,g,c}^{s}$).

These coefficients need to be compiled together because they must be consistent with one another and consistent with available data on employment.

3.3.1.1 Initial estimates of WAP, PR and ER by (a,g,c) for 2010

Our starting point for calculating these coefficients was data from Census for $WAP_{a,g}^{(2010)c}$, labour force by (a,g,c) and employment (EMP) by (i,o,a,g,c). The data are reported in Table 11. We then calculated participation rates and employment rates, $PR_{a,g}^{(2010),c}$ as the ratio of labour force to working age population, and $ER_{a,g}^{(2010)c}$ as the ratio of employment to the labour force. The resulting rates are reported in Table 12. Note that at this point these coefficients do not have the skill dimension, and are for the year 2010, not 2011.

Table 11. Data on WAP, LF and EMP from Census 2010

(Persons, unless otherwise indicated)

	Omani			NonOmani			Grand total
Age	Male	Female	Total	Male	Female	Total	
(1) Working age population ($WAP_{a,g}^{(2010)c}$)							
1 A15_19	125,124	118,824	243,948	7,282	6,392	13,674	257,622
2 A20_24	123,221	117,271	240,492	66,738	16,165	82,903	323,395
3 A25_29	103,502	102,679	206,181	137,291	29,462	166,753	372,934
4 A30_34	76,105	76,737	152,842	108,729	32,241	140,970	293,812
5 A35_39	51,365	50,068	101,433	89,294	27,808	117,102	218,535
6 A40_44	36,547	36,467	73,014	69,186	18,285	87,471	160,485
7 A45_49	29,226	30,082	59,308	44,602	11,108	55,710	115,018
8 A50_54	24,580	27,539	52,119	32,554	6,634	39,188	91,307
9 A55_59	17,176	18,977	36,153	15,448	3,312	18,760	54,913
10 A60_64	16,345	16,119	32,464	5,532	1,812	7,344	39,808
11 A65Plus	35,132	33,549	68,681	3,078	2,054	5,132	73,813
Total	638,323	628,312	1,266,635	579,734	155,273	735,007	2,001,642
Nationality share			63.3%			36.7%	100.0%
(2) Labour force ($LF_{a,g}^{(2010)c}$)							
1 A15_19	25,312	12,724	38,036	1,127	652	1,779	39,815
2 A20_24	91,843	43,176	135,019	64,226	9,686	73,912	208,931
3 A25_29	98,902	47,342	146,244	136,032	18,160	154,192	300,436

Age	Omani Male	Omani Female	Omani Total	NonOmani Male	NonOmani Female	NonOmani Total	Grand total
4 A30_34	73,852	29,092	102,944	107,942	20,331	128,273	231,217
5 A35_39	48,970	13,812	62,782	88,596	18,085	106,681	169,463
6 A40_44	33,397	6,222	39,619	68,573	11,362	79,935	119,554
7 A45_49	23,586	2,960	26,546	44,098	6,388	50,486	77,032
8 A50_54	16,798	1,693	18,491	32,062	3,359	35,421	53,912
9 A55_59	9,154	812	9,966	15,037	1,266	16,303	26,269
10 A60_64	5,258	416	5,674	5,011	457	5,468	11,142
11 A65Plus	5,176	361	5,537	2,012	253	2,265	7,802
Total	432,248	158,610	590,858	564,716	89,999	654,715	1,245,573
Nationality share			47.4%			52.6%	100.0%
(3) Employment ($EMP_{a,g,c}^{(2010)s}$)							
1 A15_19	6,472	1,440	7,912	930	589	1,519	9,431
2 A20_24	57,096	15,956	73,053	63,773	9,468	73,241	146,294
3 A25_29	82,694	31,077	113,771	135,631	17,904	153,535	267,306
4 A30_34	67,534	23,790	91,323	107,697	20,174	127,870	219,194
5 A35_39	46,746	13,163	59,910	88,452	18,016	106,469	166,378
6 A40_44	31,763	6,039	37,802	68,474	11,337	79,811	117,613
7 A45_49	22,506	2,902	25,408	44,033	6,370	50,403	75,811
8 A50_54	15,931	1,664	17,595	32,009	3,356	35,365	52,960
9 A55_59	8,662	805	9,467	15,022	1,260	16,282	25,750
10 A60_64	4,836	408	5,244	4,998	457	5,455	10,699
11 A65Plus	5,129	359	5,488	2,011	252	2,263	7,751
Total	349,370	97,604	446,974	563,030	89,184	652,214	1,099,188
Nationality share			40.7%			59.3%	100.0%

(Source: Census 2010)

Table 12. Participation rates and employment rates for 2010 (%)

Age	Omani Male	Omani Female	Omani Average	NonOmani Male	NonOmani Female	NonOmani Average	Grand Average
(1) Labour force participation rate							
1 A15_19	20.2	10.7	15.6	15.5	10.2	13.0	15.5
2 A20_24	74.5	36.8	56.1	96.2	59.9	89.2	64.6
3 A25_29	95.6	46.1	70.9	99.1	61.6	92.5	80.6
4 A30_34	97.0	37.9	67.4	99.3	63.1	91.0	78.7
5 A35_39	95.3	27.6	61.9	99.2	65.0	91.1	77.5
6 A40_44	91.4	17.1	54.3	99.1	62.1	91.4	74.5
7 A45_49	80.7	9.8	44.8	98.9	57.5	90.6	67.0
8 A50_54	68.3	6.1	35.5	98.5	50.6	90.4	59.0
9 A55_59	53.3	4.3	27.6	97.3	38.2	86.9	47.8
10 A60_64	32.2	2.6	17.5	90.6	25.2	74.5	28.0
11 A65Plus	14.7	1.1	8.1	65.4	12.3	44.1	10.6
Average	67.7	25.2	46.6	97.4	58.0	89.1	62.2
(2) Employment rate							
1 A15_19	25.6	11.3	20.8	82.5	90.3	85.4	23.7
2 A20_24	62.2	37.0	54.1	99.3	97.8	99.1	70.0

	Omani			NonOmani			Grand
Age	Male	Female	Average	Male	Female	Average	Average
3 A25_29	83.6	65.6	77.8	99.7	98.6	99.6	89.0
4 A30_34	91.4	81.8	88.7	99.8	99.2	99.7	94.8
5 A35_39	95.5	95.3	95.4	99.8	99.6	99.8	98.2
6 A40_44	95.1	97.1	95.4	99.9	99.8	99.8	98.4
7 A45_49	95.4	98.0	95.7	99.9	99.7	99.8	98.4
8 A50_54	94.8	98.3	95.2	99.8	99.9	99.8	98.2
9 A55_59	94.6	99.1	95.0	99.9	99.5	99.9	98.0
10 A60_64	92.0	98.1	92.4	99.7	100.0	99.8	96.0
11 A65Plus	99.1	99.4	99.1	100.0	99.6	99.9	99.3
Average	80.8	61.5	75.6	99.7	99.1	99.6	88.2

(Source: Authors' calculations from data in Table 11).

The data show that Non-Omanis constitute only over a third of the working age population, but they contribute to almost two third of employment numbers. This is because, except for the PR for age 15-19, Non-Omanis have higher participation rates and employment rates than those of Omanis across all age and gender groups.

3.3.1.2 Updating WAP, PR, ER and EMP by (a,g,c) to 2011

To update WAP PR, ER and EMP by (a,g,c) from 2010 to 2011, we use WAP for 2011 by (a,g,c), as reported in Table 13, and aggregate employment by government/private jobs, gender and nationality from Statistical Yearbook 2012 (NCSI 2013a) as reported in Panel A, Table 14 below.

Table 13. WAP for 2011 (Persons, unless otherwise indicated)

	Omani			NonOmani			Grand
	Male	Female	Total	Male	Female	Total	Total
Age							
1 A15_19	120,900	113,185	234,085	7,970	6,624	14,594	248,679
2 A20_24	124,754	120,173	244,927	104,105	17,312	121,417	366,344
3 A25_29	111,900	108,890	220,790	263,402	36,645	300,047	520,837
4 A30_34	84,628	83,655	168,283	197,220	37,786	235,006	403,289
5 A35_39	57,720	54,140	111,860	150,552	32,925	183,477	295,337
6 A40_44	39,043	37,642	76,685	120,448	21,018	141,466	218,151
7 A45_49	32,735	32,412	65,147	81,260	13,189	94,449	159,596
8 A50_54	27,342	29,644	56,986	60,127	8,072	68,199	125,185
9 A55_59	20,308	22,844	43,152	30,906	3,930	34,836	77,988
10 A60_64	17,421	18,001	35,422	8,926	1,731	10,657	46,079
11 A65Plus	47,896	41,497	89,393	2,782	1,613	4,395	93,788
Total	684,647	662,083	1,346,730	1,027,698	180,845	1,208,543	2,555,273
Nationality share			52.7%			47.3%	100.0%
Growth rate from 2010	7.3%	5.4%	6.3%	77.3%	16.5%	64.4%	27.7%

Source: Statistical Yearbook 2012 (NCSI 2013a);

Table 14. Calculation of employment for 2011 (Persons, unless otherwise indicated)

	Omani			NonOmani			Grand
Sector	Male	Female	Total	Male	Female	Total	Total
(A) Original employment data in SYB 2012[(a)]							
1 Government sector	88,313	61,895	150,208	15,778	6,988	22,766	172,974
2 Private sector	146,204	37,287	183,491	1,007,523	109,483	1,117,006	1,300,497
Total	234,517	99,182	333,699	1,023,301	116,471	1,139,772	1,473,471
Nationality share			22.6%			77.4%	100.0%
Growth rate from 2010	-32.9%	1.6%	-25.3%	81.7%	30.6%	74.8%	34.1%
(B) Share of missing employment categories in total employment[(b)]							
Share of self-employed and unpaid family workers	8.9%	10.0%		0.7%[(c)]	0.5%[(c)]		
Share of the armed forces in total government job	42.1%	3.7%		8.2%[(c)]	3.1%[(c)]		
(C) Adjusted employment numbers							
1 Government sector	152,522	64,298	216,819	15,778	6,988	22,766	239,585
2 Private sector	160,500	41,436	201,936	1,007,523	109,483	1,117,006	1,318,942
Total	313,021	105,734	418,755	1,023,301	116,471	1,139,772	1,558,527
Nationality share			26.9%			73.1%	100.0%

Notes: (a) Statistical Yearbook 2012 (NCSI 2013a); (b) Calculated from Census 2010 (NCSI 2013c); (c) These shares are not used in our adjustment.

Examination of the data for 2011 and close reading of the SYB publication have lead us to the conclusion that employment data in SYB do not fully capture employment numbers. The reasons are as follows:

1. SYB (NCSI 2013a) states that the employment data only include Omanis who have registered for social security. To our knowledge, this excludes self-employed persons and unpaid family workers.[15] Moreover, the data on the government sector only record civil servants, and hence likely do not include the armed forces.[16] This means the number of employed Omanis is understated.
2. The above point is supported by the observation that the employment share of Non-Omanis in 2011 is significantly higher than that in Census 2010 (77.4% vs. 59.3%, see the last row of Panel A,Table 14, and the last row of Table 11). This could partly be due to the higher growth rates of Non-Omanis in WAP than those of Omanis (see the last row, Table 13). However, the growth rate of Non-Omanis in WAP cannot fully explain the increase in the share of Non-Omanis in employment, because the Non-Omani WAP growth rate between 2010 and 2011 was only 64.4%, whereas that in employment was 74.8% (The last row, Panel A, Table 14). The increase in the share of Non-Omanis in employment can hardly be explained by the increase in their participation rates and/or employment rates, because these rates are generally already very high, close to 1 for the age 20-59 year old groups (see Table 12).

Therefore, we have made adjustment to Omanis' employment to account for self-employed,

[15] See information in Social Security Administration - USA (2012).
[16] See p.7, Chapter 4, NISC 2013a.

unpaid family workers and armed forces (see Panels B and C, Table 14). We have made the decision not to adjust the numbers for Non-Omanis, because the SYB records all Non-Omanis with valid work permits, and hence self-employed, unpaid family workers and armed forces are more likely to have already been counted. In addition, the shares of these categories are very small for Non-Omanis.

After re-estimating employment numbers, we summed them across the two private and government sectors to get aggregate employment numbers by gender and nationality (g,c), denoted as $AdjEMP_{g}^{c}$. We then allocate them to different ages according to the following procedure:

- First, we estimated the initial employment numbers by (a,g,c), based on $WAP_{a,g}^{(2011)c}$ as reported in Table 15 and the $PR_{a,g}^{c}$ and $ER_{a,g}^{c}$ by (a,g,c) as reported in Table 12. Let's denote these numbers $InitEMP_{a,g}^{c}$.
- We then used the age shares in $InitEMP_{a,g}^{c}$ to allocate $AdjEMP_{g}^{c}$ to different age groups. The results were $EMP_{a,g}^{c}$ which were the same as $AdjEMP_{g}^{c}$ but with the age dimension added.
- We then used an iterative procedure to adjust $EMP_{a,g}^{c}$ and $PR_{a,g}^{c}$ and $ER_{a,g}^{c}$ so that (i) $PR_{a,g}^{c}$ and $ER_{a,g}^{c}$ did not exceed unity; (ii) $EMP_{a,g}^{c}$ summed to $AdjEMP_{g}^{c}$; and (iii) $WAP_{a,g}^{(2011)c}$ was preserved.

At the end of this procedure, we have WAP, PR, ER and EMP for 2011, by (a,g,c). In the next step we will add the skill dimension to these matrices.

a) Adding the skill dimension to WAP, PR, ER and EMP by (a,g,c) for 2011

There are no data on the skill composition of WAP, PR or ER from any of the data sources available to us. We only have the skill information from employment data in Census 2010. To create the skill dimension for WAP, PR and ER, one solution could be to assume that all skills have the same PR and ER. Then WAP could be reconstructed from EMP. However, there is evidence from the Australian data that people with higher skills tend to have higher PR, especially for the youngest and oldest age groups (the 15-19 year-olds and those over 65). The differences are smaller for ER, but they still tend to be higher for higher skill groups.

Therefore, we borrowed the relative PR and ER by skill level in Australian data for Oman in adding the skill dimension to these coefficients. We do that by multiplying $PR_{a,g}^{c}$ and $ER_{a,g}^{c}$ calculated earlier with the Australian relative ratio of different PR and ER by skill. The result was the initial PR and ER by (s,a,g,c), denoted as $InitPR_{a,g}^{s,c}$ and $InitER_{a,g}^{s,c}$. These initial rates exceed unity for many age groups for Non-Omanis, because the initial $PR_{a,g}^{c}$ and $ER_{a,g}^{c}$ were already close to or equal to unity.

We then simultaneously and iteratively calculate the required matrices $WAP_{a,g}^{(2011)s,c}$, $PR_{a,g}^{s,c}$, $ER_{a,g}^{s,c}$ and $EMP_{a,g}^{s,c}$, which are linked via the formula:

$$EMP_{a,g}^{(2011)s,c} = WAP_{a,g}^{(2011)s,c} * PR_{a,g}^{s,c} ER_{a,g}^{s,c}$$

so as to satisfy the following conditions:

1. PR and ER should not exceed unity;
2. Sum of WAP over skill should be the same as that in SYB 2012 for (a,g,c);
3. Sum of EMP over skill should be the same as that in SYB 2012 for (a,g,c) and for government and private sectors;

3.3.2 Compilation of new entrants in 2012

The main data source used to compile the matrix $NEW_{a,g}^{s,c}$, showing the number of new entrants in the base year, was the WAP data for 2011 and 2012, by age, gender and nationality (NCSI 2013d, 2013e), as reported in Table 15.

Table 15. Working age population in 2011, 2012 and changes between them

Age	Number of persons in 2011			Number of persons in Year 2012			Growth rate (%)		
	Omani	Non-Omani	Total	Omani	Non-Omani	Total	Omani	Non-Omani	Total
1 A00_04	273,971	26,611	300,582	291,441	31,400	322,841	6.4	18.0	7.4
2 A05_09	210,098	26,530	236,628	225,063	34,641	259,704	7.1	30.6	9.8
3 A10_14	182,359	20,456	202,815	188,652	27,936	216,588	3.5	36.6	6.8
4 A15_19	234,085	14,594	248,679	230,206	17,980	248,186	-1.7	23.2	-0.2
5 A20_24	244,927	121,417	366,344	247,826	161,860	409,686	1.2	33.3	11.8
6 A25_29	220,790	300,047	520,837	228,782	370,623	599,405	3.6	23.5	15.1
7 A30_34	168,283	235,006	403,289	179,438	286,907	466,345	6.6	22.1	15.6
8 A35_39	111,860	183,477	295,337	121,669	208,986	330,655	8.8	13.9	12.0
9 A40_44	76,685	141,466	218,151	81,909	158,563	240,472	6.8	12.1	10.2
10 A45_49	65,147	94,449	159,596	65,927	103,888	169,815	1.2	10.0	6.4
11 A50_54	56,986	68,199	125,185	59,730	69,789	129,519	4.8	2.3	3.5
12 A55_59	43,152	34,836	77,988	44,812	40,016	84,828	3.8	14.9	8.8
13 A60_64	35,422	10,657	46,079	36,398	12,569	48,967	2.8	17.9	6.3
14 A65Plus	89,393	4,395	93,788	90,707	5,283	95,990	1.5	20.2	2.3
Total	2,013,158	1,282,140	3,295,298	2,092,560	1,530,441	3,623,001	3.9	19.4	9.9
WAP	1,346,730	1,208,543	2,555,273	1,387,404	1,436,464	2,823,868	3.0	18.9	10.5

In principle, the difference between the two WAPs is the number of new entrants to the labour market at the beginning of 2012. However, there are some issues with these data.

- First, we would expect that changes in WAP for Omanis are due to the young people turning 15 only, but the data include changes for Omanis across all ages, albeit at much smaller rates than those for Non-Omanis. We could not find any information to explain this phenomenon.

- Second, the growth rate of 10.5% for aggregate WAP between 2011 and 2012 (last row of Table 15) seem too high, given that the real GDP increases by only 5.8% between the two years. Unless there have been significant decline in PR and/or ER, the high growth rate for WAP means a high growth rate for EMP, and hence a very low or even negative growth rate for technology. But we have not found any information to suggest that PR and/or ER have fallen much during that period. The high WAP growth rate is mainly due to the growth rate of Non-Omanis (19.3% in 2012), we conjecture that the number for Non-Omanis may include temporary short-term foreign workers. This category should not be included in our annual model.

Therefore, we have decided to adopt the following calculations for the new entrants:

1. We first adopted the aggregate number of new entrants consistent with a growth rate in WAP of 3.5% - the average population growth rate for Oman during the last decade, as reported in Table 16 below.[17]

Table 16. Population data, 2000-2012

Year	Number ('000 person)			Growth rates (%)		
	Omani	Non-Omani	Total	Omani	Non-Omani	Total
2000	1,778	624	2,402			
2001	1,826	652	2,478	2.7	4.5	3.2
2002	1,870	668	2,538	2.4	2.5	2.4
2003	1,782	559	2,341	-4.7	-16.3	-7.8
2004	1,803	613	2,416	1.2	9.7	3.2
2005	1,843	666	2,509	2.2	8.6	3.8
2006	1,884	693	2,577	2.2	4.1	2.7
2007	1,923	820	2,743	2.1	18.3	6.4
2008	1,967	900	2,867	2.3	9.8	4.5
2009	2,018	1156	3,174	2.6	28.4	10.7
2010	1,957	816	2,773	-3.0	-29.4	-12.6
2011	2,013	1282	3,295	2.9	57.1	18.8
2012	2,093	1530	3,623	4.0	19.3	10.0
Average annual growth rates 2001-2012				1.2	8.1	3.5

Source: Statistical Yearbook 2013.

2. For Omanis, we assumed that all new entrants are people turning 15 years old in 2012. We calculated the number as 20% of the age 10-14 group in 2011 (see Table 15). This results in 36,472 new entrants, or an increase of 2.7% in WAP 2011. We assume that

[17] If the number of short-term foreign workers were known, we could have excluded them from the published WAP to calculate the number of new entrants. However, this information is not available, and hence we had to adopt this average growth rate approach.

all the new entrants belong to the age group 15-19, and all have the qualification "Unknown/Not applicable".[18]

3. For Non-Omanis, we also assumed that the new entrants for the A15-19 groups are 20% of Non-Omanis in the age group 10-14 in WAP 2011 (Table 15). New entrants into other age groups are the difference between the aggregate number of new entrants calculated in step 1 above, the number of new Omanis calculated in step 2 above, and the number of Non-Omanis aged 15-19. The new Non-Omanis are assumed to have the same age distribution as that in the difference between WAP 2011 and WAP 2012, and have the same skill distribution for their relative age and gender groups as in EMP 2011.

3.3.3 Compilation of the transition matrix

The transition matrix $T_{(aa,a),g}^{(ss,s)c}$ matrix shows the probability of a person of a certain gender and nationality moving from skill type *ss* to *s* and from age *aa* to *a* from year *t-1* to year *t*. It can be calculated as:

$$T_{(aa,a),g}^{(ss,s),c} = T\_age_{(aa,a),g}^{c} \times T\_Q_{aa,g}^{(ss,s),c}$$

where $T\_age_{(aa,a),g}^{c}$ is the probability of a person of gender g and nationality c moving from age aa to age a between year *t-1* and year *t*;
$T\_Q_{aa,g}^{(ss,s),c}$ is the probability of a person aged aa, with gender g and nationality c, changing their skill type from *ss* to *s* between year *t-1* and year *t.*

1.1.1.1 Age transition ($T\_age_{(aa,a),g}^{c}$)

The age transition matrix shows the combined probabilities of people moving from one age group to another. Thus, it is a product of the pure age transition rate and the death rate.

(a) Pure age transition ($PAGE_{(aa,a),g}^{c}$)

Our model contains 5-year age groups. Therefore, we assume that 80 per cent of each age cohort stays in the same age group, while 20 per cent progress to the next age cohort. An exception is the age group 65 and over, where people within this group are assumed to stay until they die. We further assume that this setting is uniform over skill type, gender and nationality.

(b) Death rate ($DRATE_{(aa),g}^{c}$)

Age-specific death rates were calculated by dividing the number of deaths by the number of

[18] Education data in SYB 2013 shows that in academic year 2011-2012 the great majority (96.3%) of students studying in Grades 11 and 12, i.e. students having completed Grade 10, or Preparatory skill level in OMAGE, are aged 16 and above. Out of 97,894 students in this group, there are only 20 are 15 years old.

population for 2012 (NCSI 2013e). As can be expected, the death rates are highest for the 65+ age group, at 3.72% for male Omanis. The rates are lowest among the 20-39 age bracket. Except for the age 15-19, NonOmanis tend to have lower death rates than those for Omanis. We assume that the death rates are uniform across skill levels.

(c) Final age transition matrix

The final age transition matrix is calculated as a product of the pure age transition matrix and the death rate. That is:

$$T\_age^{c}_{(aa,a),g} = PAGE^{c}_{(aa,a),g} * [1 - DRATE^{c}_{aa,g}]$$

3.3.3.1 Skill transition ($T\_Q^{(ss,s)}_{aa,g}$)

The skill transition matrix was calculated using the following data sources:

1. Graduation data for the year 2011-12 for schools and higher education institutions (NCSI 2013e), by gender, nationality, qualification level and study field.
2. Stock of university students, by age and qualification level. This data was provided by the Sultan Qaboos University. This data was used to create the age distribution for the graduation data.
3. WAP for 2011, calculated in previous steps.

In compiling $T\_Q^{(ss,s)}_{aa,g}$, we first create a matrix showing the number of people moving from one skill level to another with the following assumptions:

- As there is no information on the proportion of people changing their field of study, we assume that people only move from a lower level to a higher level, but remain in the same field;
- Within each field, due to lack of information on the level of enrolment of different qualifications, it is assumed that 80% of new PhDs come from people with Masters degrees, and 20% come from people with Bachelor degrees. All new Masters come from people with Bachelor degrees. New Bachelors come from people with Diplomas and Secondary Certificates in the proportions of the latter in WAP. All new Diplomas come from people with Secondary Certificates. All new Secondary Certificates come from people with Preparatory certificates, and all new Preparatory Certificates come from the Unknown/Not applicable category.

Then the skill transition matrix is the ratio of the transition numbers from skill (ss) to skill (s) to WAP, by (a,g,c). Note that this skill transition matrix can be changed in the year-on-year dynamic simulation if we have information on the number of graduates by level and field on enrolment and on graduation for each of the years.

3.3.4 Creating the wage bill and wage rate matrices

These matrices are required for the demand side of the labour market in OMAGE. The input-output data for OMAGE contain data for the wage bill by industry. Our task is to split each industry's wage bill across occupations and nationality (Omani and Non-Omani).

We have already calculated the number of employed persons, by industry, occupation and nationality, from the previous step. The remaining task is to calculate the wage rates for these categories.

First, we used the LFS data and the wage data in SYB 2010 to create the matrix of average wage rates for LFS 51 industries, 98 occupations, 11 age groups, gender, and nationality. The reason we used SYB 2010 data is that it contained more information for wage rates over 450 RO/person/month. As can be seen from Table 17, LFS 2008 contains fewer salary ranges than SYB 2010. In particular, a fifth of the workforce belongs to the salary range of "Over 450". It is not easy to adopt a point estimate for this salary range. We would also expect that the wage rates vary a lot among this group. Indeed, this can be seen from the SYB data (Panel B, Table 17). Therefore, we used the share of the number of different salary ranges higher than 500 (Final column, Panel B, Table 17) to split the number of people earning over 450RO/month in LFS into different salary brackets. Note that while Table 17 shows the shares for aggregate numbers of workers, in the SYB2010 data the wage ranges are available by age and gender. We used that information in processing the LFS data as well. The final salary ranges are those as listed in the first column of Panel C, Table 17.

For calculating average wage rates, we needed to adopt a salary value for each salary range. As can be seen from the second column, Panel C, Table 17:

- The adopted wage rates for all salary ranges (except the first and last) are the midpoints of the ranges.
- For the group "below 100", we tried to find the minimum wage information for Oman. According to the USA Department of State (2009), the minimum wage for citizens was 140 RO/month, but there was no minimum wage reported for foreign workers. As a result, we did not adopt the midpoint, but the wage rate of RO 80/month, for this salary range.
- For the group "Over 2000", we calculated the wage rate that this group should have in order for the wage bill calculated from the LFS number of workers and the adopted wage rates to sum to the aggregate wage bill available for 2008 in SYB 2010. The wage rates was a little over RO 3,000/person/month. We adopted the rate of RO 3,000/person/month.

Table 17. Information on average salary rates

A. LFS 2008			B. SYB 2010				C. Adopted salary rate	
Salary range[a]	No of workers	Share (%)	Salary range[b]	No of workers[c]	Share (%)	Share of workers with salary over 500RO	Salary range	Salary rate[d]
Below 100	463,906	38.4	Up to 120	47,202	29.8		Below 100	80

A. LFS 2008			B. SYB 2010				C. Adopted salary rate	
Salary range[a]	No of workers	Share (%)	Salary range[b]	No of workers[c]	Share (%)	Share of workers with salary over 500RO	Salary range	Salary rate[d]
101 - 150	169,156	14.0	120-140	21,317	13.5		101 - 150	125
151-200	95,481	7.9	141-200	48,454	30.6		151-200	175
201-250	77,510	6.4	201-300	18,061	11.4		201-250	225
251-350	94,128	7.8	301-400	8,063	5.1		251-350	275
351-450	68,634	5.7	401-500	4,825	3.0		351-450	400
Over 450	238,727	19.8	501-600	2,763	1.7	26.6	451-600	525
			601-700	1,730	1.1	16.6	601-700	650
			701-800	1,223	0.8	11.8	701-800	750
			801-900	931	0.6	9.0	801-900	850
			901-1000	749	0.5	7.2	901-1000	950
			1001-2000	2,273	1.4	21.9	1001-2000	1,500
			Over 2000	724	0.5	7.0	Over 2000	3,000
Total	1,207,542	100.0	Total	158,315	100.0	100.0		

Sources: Calculated from NCSI (2013g, 2014).
Note: (a) Monthly salary, RO; (b) Monthly salary, RO. The range "141-200" are actually broken down in more detail ranges, namely 141-160, 161-180, 181-200, but we aggregate them away to roughly match the salary range 151-200 in LFS data; (c) Omani workers only; (d) see discussions in the text.

We then applied the average wage rates from LFS for industries, occupations, age groups, gender and nationality to the number of employed persons calculated in Section 3.3.1.2. We then aggregated the wage bill to 51 industries, 98 occupations and 2 nationality types (Omanis/Non-Omanis) to get the initial wage bill by (i,o,c).

Next, we scaled the initial wage bill to OMAGE wage bill for 51 industries available from OMAGE input-output data. This resulted in the required wage bill matrix $V1LAB_{i,o,c}$.

Finally, we calculated the average wage rates matrix $WAGE_{i,o,c}$ by dividing the scaled wage bill $V1LAB_{i,o,c}$ to the number of workers of the same dimensions.

3.3.5 Parameters

The labour supply module requires two parameters, namely the *elasticity of labour supply* to occupation *o* by skill *s* with nationality *c* with respect to movements in the relative wage of occupation *o*, denoted $\phi_{o,s,c}$; and the *elasticity of skill acquisition* to relative skill wage rates by people with (a,g,c) characteristics, denoted $\alpha_{a,g,c}$. Due to lack of estimates for Oman, we have borrowed the elasticities of labour supply from Giesecke et al. (2013) for $\phi_{o,s,c}$, which is 2 for all categories. As for the elasticity of skill acquisition, we conjectured that the elasticity is likely to be low, because it takes time and resources for people to acquire a new skill. We have adopted the value of 0.25 for $\alpha_{a,g,c}$ for the moment. These elasticities can be adjusted later if estimates for them become available for Oman.

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5 APPENDIX: SETS AND MAPPINGS

(a) Overview

In OMAGE there are 51 industries and commodities, 98 occupations, 55 skills, 11 age groups, 2 genders and 2 nationalities.

The AGE set includes 5-year age groups for the population 15 years of age and over, namely 15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49, 50-54, 55-59, 60-64 and 65+.

The GENDER set includes: Male, Female.

The CITIZ set for Nationality includes: Omani, Non-Omani.

Below are the descriptions of the longer sets for industries/commodities, occupations and skills, together with their short names which are used in the model. For reporting purposes, these sets are sometimes aggregated. For examples, industries/commodities are aggregated to 26 and 6 sectors, occupations are aggregated to 10 major groups, and skills are aggregated to 7 qualification levels and 13 broad study fields. Mappings between these sectors are also provided below.

(b) Industries/Commodities

In OMAGE there is a one-to-one correspondence between the 51 industries and 51 commodities. Their names, and their concordance to the 23 sector aggregations are reported in Table A1.1 below.

Table A1.1: Industry/commodity names and their concordance with aggregated 23 sectors

Ind/Com short name	Ind/Com long name	Concordance with 23 sectors
1. Cereals	1. Cereals	1.Agriculture
2. VegFruits	2. Fruits and vegetables	
3. OthCrops	3. Other crops	
4. Livestock	4. Livestock	
5. Fishing	5. Fishing and hunting	
6. CrudeOil	6. Crude oil extraction	2.Crude Oil
7. NatGas	7. Natural gas extraction	3.Natural Gas
8. OthMining	8. Other mining	4.Other Mining
9. Meat	9. Meat products	7.Other manufacturing
10. OilFats	10. Oils and fats	
11. Dairy	11. Dairy products	
12. Rice	12. Rice and rice products	
13. Sugar	13. Sugar and sugar products	
14. OthFood	14. Other food products	
15. BevTobacco	15. Beverages	
16. Textile	16. Textiles	
17. Clothing	17. Clothing	
18. LeatherProd	18. Leather products	
19. WoodProd	19. Wood products	
20. PaperPublish	20. Paper products	
21. PetrolCoke	21. Oil Refinery	5.Oil Refinery
22. ChemRubPlast	22. Other chemicals	6.Chemistry, rubber and plastic
23. NMetalProd	23. Non-metallic mineral products	7.Other manufacturing
24. FeMetal	24. Ferrous metal	
25. NFeMetals	25. Non-ferrous metals	
26. MetalProds	26. Metal products	

27. MotorVehicle	27. Motor vehicles and parts	
28. OthTransEq	28. Other transport equipment	
29. ElectronicEq	29. Electronic equipment	
30. OthMachEq	30. Other machinery and equipment	
31. OthManuf	31. Other manufacturing	
32. Electricity 33. Gas 34. Water	32. Electricity 33. Gas distribution 34. Water, sewerage and drainage	8.Electricity, gas and water
35. Construction	35. Construction services	9.Construction
36. Trade	36. Wholesale and retail trade services	10.Trade
37. HotelsRest	37. Accommodation and restaurants	11.Accommodation and food services
38. LandTrans	38. Land transport services	12.Land transport
39. WaterTrans	39. Water transport services	14.Other transport services
40. AirTrans	40. Air transport services	13.Air transport
41. OthTrans	41. Other transport services	14.Other transport services
42. Communicatn	42. Post and communications	15.Post and communication
43. FinanceServ	43. Financial services	16.Finance and insurance services
44. Insurance	44. Insurance services	17.Insurance
45. RealEstate	45. Real estate services	18.Real estate services
46. OthBusServ	46. Other business services	19.Other business services
47. PublicAdmin	47. Public administration and defence	20.Public administration and defence
48. Education	48. Education	21.Education
49. Health	49. Health	22.Health
50. RecrOthServ	50. Recreational, personal and community services	23.Recreational and other services
51. Dwellings	51. Dwelling services	18.Real estate services

(c) Occupations

Table A1.2 shows the short and long names of the 98 labour market occupations in OMAGE. Except for the last occupation (the Armed forces), each of the short names has a prefix that identifies the broader 9 category classification to which they belong. The prefixes are:

1. M Administration directors, managers and working investors
2. P Scientific, technical and human matters specialists
3. T Scientific, technical and human subjects technicians
4. CL Clerical occupations
5. SL Sales occupations
6. SV Services occupations
7. Ag Agriculture, stock-breeding, aviculture and hunting occupations
8. I Industrial, chemical and food industries occupations
9. E Principal and auxiliary engineering occupations

The mappings between the 98 occupations and the 10 major occupations are not listed in Table A1.2 because they are based on the 9 categories listed above, plus the Armed forces, and hence can be readily understood from the short occupation names.

Table A1.2: Occupation names – short and long

Occupation short name	Occupation long name
1 M_AdminDir	1 Administration directors, managers and working investors
2 M_CntrAdmDir	2 Central administration directors

Occupation short name	Occupation long name
3 M_IndAgComFT	3 Industrial, agricultural, commercial, financial and tourism managers
4 M_LocAdmSrv	4 Local administration and services directors
5 M_SocialServ	5 Social services directors
6 M_WrkgInvest	6 Working investor
7 P_AccFinIns	7 Professionals in finance, accounting and insurance sciences
8 P_AgricLvstk	8 Professionals in agriculture and stock, poultry and aquatic animals breeding
9 P_AirSeaNav	9 Professionals in air and sea navigation
10 P_ArtSport	10 Professionals in plastic arts, aesthetics, acting & sports
11 P_Biologists	11 Biologists
12 P_CultInfo	12 Professionals in culture and information
13 P_DeputyDir	13 Deputy directors
14 P_Education	14 Professionals in education
15 P_Engineer	15 Professionals in engineering
16 P_Experts	16 Experts
17 P_MedSci	17 Professionals in medical sciences
18 P_PharmaSci	18 Professionals in pharmacology
19 P_PhysicSci	19 Professionals in physical sciences
20 P_PolFinIns	20 Professionals in political, financial and insurance sciences
21 P_PsySocio	21 Professionals in psychology and sociology
22 P_ReligLegal	22 Professionals in religious and legal affairs
23 P_StatMath	23 Professionals in statistics, mathematics and system analysis
24 T_AccountSci	24 Accounting sciences technicians
25 T_Agric	25 Agricultural and stock ,poultry and aquatic animals breeding technicians
26 T_AirSeaNav	26 Air and sea navigation technicians
27 T_CircSport	27 Circus and sports technicians
28 T_CulturInfo	28 Cultural and information technicians
29 T_Design	29 Designers technicians
30 T_EconFin	30 Economic and financial affairs
31 T_Education	31 Educational technicians
32 T_EngSciTec	32 Engineering sciences technicians
33 T_LifeSci	33 Life sciences technicians
34 T_management	34 Management technicians
35 T_MedPharm	35 Medical and pharmacology
36 T_Pharma	36 Pharmacology technicians
37 T_PhysSci	37 Physical sciences technicians
38 T_SaleSuperv	38 Sales supervisors
39 T_Secretary	39 Secretaries and short-hand clerks
40 T_SocialSci	40 Social sciences technicians
41 T_StatInfo	41 Statistics and information systems technicians
42 CL_AccFin	42 Accounting and finance clerks
43 CL_Admin	43 Administrative affairs clerks
44 CL_Govt	44 Government clerical occupations
45 CL_RecInfo	45 Reception, information, and dispatching clerks
46 CL_TourTravl	46 Tourism and travel clerks
47 SL_CnstrMatS	47 Construction materials and supplies
48 SL_ConsGood	48 Consumer goods salesmen
49 SL_ConstTrnM	49 Road and construction machinery and transport means selling occupations

Occupation short name	Occupation long name
50 SL_CultSport	50 Books, periodicals, musical equipments and sport goods salesmen
51 SL_IndAgFuel	51 Industrial agricultural and fuel, equipments selling occupations
52 SL_InsShipng	52 Insurance, shipping clearance mediation occupations
53 SL_Luxury	53 Luxury goods and articles salesmen
54 SL_Mediate	54 Sales and purchasing mediation occupations
55 SL_OSciMedEq	55 Occupations involved in the selling of office, scientific and medical equipment?s
56 SL_Supermrkt	56 Workers in supermarkets exclude salesmen
57 SV_AirServ	57 Air services occupations
58 Sv_CarePers	58 Care attention and personal service workers
59 SV_Cleaners	59 Cloth cleaning and general cleaning occupations
60 SV_FoodDrink	60 Food and drinks services occupations
61 SV_HairBeaut	61 Hairdressers and beauticians
62 SV_LoadingOc	62 Loading and unloading occupations
63 SV_Maritime	63 Maritime services occupations
64 SV_Packaging	64 Packing and packaging works
65 SV_Religion	65 Religious services occupations
66 SV_RescGardM	66 Rescue, guarding and messengers occupations
67 SV_TradMed	67 Practitioners of traditional medicine
68 Ag_AgriOccs	68 Agricultural occupations
69 Ag_animbreed	69 Aquatic animals breeding occupations
70 Ag_Fishing	70 Fishing occupations
71 Ag_LivstkPlt	71 Livestock and poultry farmers
72 I_ChemOper	72 Chemical operations occupations
73 I_CnstMatM	73 Construction materials manufacturing occupations
74 I_FoodProc	74 Cereals milling, bakery, confectionery and sugar production occupations
75 I_LeatherOc	75 Leather industries occupations
76 I_MeatDairy	76 Meat & dairy products manufacturing occupations
77 I_MiningOcc	77 Mining, quarrying, oil and natural gas extraction occupations
78 I_PetrochemM	78 Process manufacturing &equipment petrochemical
79 I_Printing	79 Printing occupations
80 I_TextileOc	80 Textile occupations
81 I_TobTeaPro	81 Tobacco, tea and salt production occupations
82 I_VegFruit	82 Vegetable and fruit processing occupations
83 I_WoodPaper	83 Wood and paper industries occupations
84 E_AirconSan	84 Air-conditioning and sanitary equipment occupations
85 E_AssmMaint	85 Industrial and office equipments installation and maintenance occupations
86 E_Building	86 Building construction occupations
87 E_Decoratn	87 Decoration occupations
88 E_Drivers	88 Transport and road vehicles driving occupations
89 E_ElecEqAss	89 Electrical equipments and instruments assembly occupations
90 E_Electricl	90 Electrical occupations
91 E_Electronic	91 Electronic equipments and instruments assemblers
92 E_ElectronO	92 Electronic occupations
93 E_MechAssem	93 Mechanical machines and instruments assembly occupations
94 E_MetalProd	94 Metal production and moulding mechanical occupations
95 E_RoadRail	95 Road and railway construction occupations
96 E_VehRepair	96 Transport road & agricultural vehicles repair occupations

Occupation short name	Occupation long name
97 E_Woodwrk	97 woodworkers occupations
98 ArmedForces	98 Armed forces

(d) Skills

There are 55 skill categories in OMAGE, whose short and long names are reported in Table A1.4. As evident from the names, the first 52 skills are the combinations of the four post-secondary study levels (namely PhD, Masters, Bachelor and Diploma) and 13 broad study fields. The last three skill categories are secondary, preparatory and unknown/not applicable categories, which are assumed to be associated with only one of the study fields, and hence are listed by themselves. The secondary and preparatory levels are obviously associated with education; and due to the unknown nature of the Unknown/Not applicable level, we assume that it is associated with the "Others" study field.

Table A1.4 Skills – short and long names

Skill short name	Skill long name
PhD_NatPhSci	PhD_Natural and Physical Sciences
PhD_IT	PhD_Information technology
PhD_EngTech	PhD_Engineering and related technologies
PhD_ArchBlg	PhD_Architecture and building
PhD_AgriEnv	PhD_Agricuture, environment studies
PhD_Health	PhD_Health
PhD_Edu	PhD_Education
PhD_MngComm	PhD_Management and Commerce
PhD_SocCult	PhD_Society and Culture
PhD_ReligPhl	PhD_Religion and Philosophy
PhD_CreatArt	PhD_Creative Arts
PhD_PerServ	PhD_Personal Services
PhD_Others	PhD_Combined Broad Fields
Mas_NatPhSci	Masters_Natural and Physical Sciences
Mas_IT	Masters_Information technology
Mas_EngTech	Masters_Engineering and related technologies
Mas_ArchBlg	Masters_Architecture and building
Mas_AgriEnv	Masters_Agricuture, environment studies
Mas_Health	Masters_Health
Mas_Edu	Masters_Education
Mas_MngComm	Masters_Management and Commerce
Mas_SocCult	Masters_Society and Culture
Mas_ReligPhl	Masters_Religion and Philosophy
Mas_CreatArt	Masters_Creative Arts
Mas_PerServ	Masters_Personal Services
Mas_Others	Masters_Combined Broad Fields
Bch_NatPhSci	Bachelor_Natural and Physical Sciences
Bch_IT	Bachelor_Information technology
Bch_EngTech	Bachelor_Engineering and related technologies
Bch_ArchBlg	Bachelor_Architecture and building
Bch_AgriEnv	Bachelor_Agricuture, environment studies
Bch_Health	Bachelor_Health
Bch_Edu	Bachelor_Education

Skill short name	Skill long name
Bch_MngComm	Bachelor_Management and Commerce
Bch_SocCult	Bachelor_Society and Culture
Bch_ReligPhl	Bachelor_Religion and Philosophy
Bch_CreatArt	Bachelor_Creative Arts
Bch_PerServ	Bachelor_Personal Services
Bch_Others	Bachelor_Combined Broad Fields
Dip_NatPhSci	Diploma_Natural and Physical Sciences
Dip_IT	Diploma_Information technology
Dip_EngTech	Diploma_Engineering and related technologies
Dip_ArchBlg	Diploma_Architecture and building
Dip_AgriEnv	Diploma_Agricuture, environment studies
Dip_Health	Diploma_Health
Dip_Edu	Diploma_Education
Dip_MngComm	Diploma_Management and Commerce
Dip_SocCult	Diploma_Society and Culture
Dip_ReligPhl	Diploma_Religion and Philosophy
Dip_CreatArt	Diploma_Creative Arts
Dip_PerServ	Diploma_Personal Services
Dip_Others	Diploma_Combined Broad Fields
Secondary	Secondary
Preparatory	Preparatory
UnkNApp	Unknown/Not Applicable