Centro de Estudos de Economia Aplicada do Atlântico

WORKING PAPER SERIES

CEEAplA WP No. 10/2006

Impacts of Closure of a Military Base on a Small Island Open Economy

Mário Fortuna
Ali Bayar
Suat Sisik
Cristina Mohora
Sameer Rege

July 2006

Universidade dos Açores
Universidade da Madeira

Impacts of Closure of a Military Base on a Small Island Open Economy

Mário Fortuna
Universidade dos Açores (DEG)
e CEEAplA

Ali Bayar
Universite Libre de Bruxelles
Departement D'Economie Appliquee
EcoMod

Suat Sisik
Universite Libre de Bruxelles
Departement D'Economie Appliquee
EcoMod

Cristina Mohora
Universite Libre de Bruxelles
Departement D'Economie Appliquee
EcoMod

Sameer Rege
Universidade dos Açores (DEG)
e CEEAplA

Working Paper n.º 10/2006
Julho de 2006

CEEAplA Working Paper n.º 10/2006
Julho de 2006

RESUMO/ABSTRACT

Impacts of Closure of a Military Base on a Small Island Open Economy

Military bases are commonplace in many countries. Their economic impact on the neighbouring communities depends on their location and the level of integration of their activities on the local economies. Base closures or base activity reductions are also frequent as a consequence of military strategy alterations. The current paper seeks to analyse the economic impact of a US base located in the island of Terceira in the Azores. The base has been an important element of economic life in this island since the end of WWII. The changing geo-strategic map of the world has, along the second half of the twentieth century, led to changing roles of this base and consequent changes in the intensity of its activity. On the other hand discussions over the importance of the base for the local economy are recurrent in an attempt, on the part of the participants, to set forth arguments in favour or against the presence of military forces in the location. The current paper tries to contribute with a quantification of the economic impact of the base using a dynamic CGE model of the Azorean economy. A closure scenario is created and the impacts traced through various economic indicators including some sector detail. Estimates are made for the overall impact and for the impact on the island that houses the base.

Mário Fortuna
Departamento de Economia e Gestão
Universidade dos Açores
Rua da Mãe de Deus, 58
9501-801 Ponta Delgada

Ali Bayar
Universite Libre de Bruxelles
Departement D'Economie Appliquee
Avenue Paul Heger 2
B-1000 Bruxelles

Suat Sisik
Universite Libre de Bruxelles
Departement D'Economie Appliquee
Avenue Paul Heger 2
B-1000 Bruxelles

Cristina Mohora
Universite Libre de Bruxelles
Departement D'Economie Appliquee
Avenue Paul Heger 2
B-1000 Bruxelles

Sameer Rege
Departamento de Economia e Gestão
Universidade dos Açores
Rua da Mãe de Deus, 58
9501-801 Ponta Delgada

IMPACTS OF CLOSURE OF A MILITARY BASE ON A SMALL ISLAND OPEN ECONOMY

Mário Fortuna*
Ali Bayar**
Suat Sisik**
Cristina Mohora**
Sameer Rege*

Abstract

Military bases are commonplace in many countries. Their economic impact on the neighbouring communities depends on their location and the level of integration of their activities on the local economies. Base closures or base activity reductions are also frequent as a consequence of military strategy alterations. The current paper seeks to analyse the economic impact of a US base located in the island of Terceira in the Azores. The base has been an important element of economic life in this island since the end of WWII. The changing geo-strategic map of the world has, along the second half of the twentieth century, led to changing roles of this base and consequent changes in the intensity of its activity. On the other hand discussions over the importance of the base for the local economy are recurrent in an attempt, on the part of the participants, to set forth arguments in favour or against the presence of military forces in the location. The current paper tries to contribute with a quantification of the economic impact of the base using a dynamic CGE model of the Azorean economy. A closure scenario is created and the impacts traced through various economic indicators including some sector detail. Estimates are made for the overall impact and for the impact on the island that houses the base.

* CEEAplA, University of the Azores
** ECOMOD, ULB

1. Introduction

Military bases are commonplace in many countries. Their location has important economic impacts on the neighbouring communities and depends on the level of integration of their activities with the local economies. Base closures or base activity reductions are also frequent as a consequence of military strategy alterations. The current paper seeks to analyse the economic impact of a US base located in the island of Terceira in the Azores. The base has been an important element of economic life on this island since the end of WWII. The activity of the base reflects the changing geo-political situation in the second half of the twentieth century.

The improvements in defence technology coupled with a new equilibrium in global power politics have impacted the American strategy and perhaps their perception of the Lajes air base. This is reflected in the strength of the military personnel on the base and their approach to integration in the local community. Housing problems in the past were solved via rentals of the local housing but in the recent times there has been a shift to housing in the air base, this reducing the dependence on the local economy.

During the 1980's, in addition to the direct impact of the base's activity, its presence justified aid given to the regional government and other given directly to the national authorities. The monetary compensation for the use of the base is immediately quantified. Not so obvious are the impacts on local economic activity that results from the presence of the base.

Discussions over the importance and the impact of the base for the local economy are recurrent in an attempt, on the part of the participants, to advance arguments in favour or against its presence. The current paper tries to contribute with a quantification of the economic impact of the base using a dynamic CGE model of the Azorean economy. A closure scenario is created and the impacts traced through various economic indicators including some sector detail. Estimates are made for the overall impact and for the impact on the island that houses the base.

In what follows section 2 reviews the body of the literature on base closures using CGE models. Section 3 presents the main variables that characterize the impact of the base on the local economy. Section 4 reviews the main characteristics of a CGE model of the Azores. Section 5 reviews the results of calibration of the model and the results of the closure scenario developed. Section 6 presents some of the main conclusions that can be drawn from application of the model.

2. Analysing Base Closures with CGE Models

Sandra Hoffmann, Sherman Robinson, & Shankar Subramanian (1996) analyze the impact of defense cuts on the economy in California using a computable general equilibrium (CGE) model. Their focus is on the migration of factors from California to other states and the impact of this migration on the economy. CGE models are better suited to analyze the economy wide impact of these defense cuts and their study shows that the impacts are highly sensitive to the assumption of inter-state mobility.

Other studies have taken a less elaborate approach looking mostly at lost direct expenditures and jobs on an accounting approach and looking other social and environmental impacts.

The current research paper can be classified as a cut in defence expenditure and is more focussed on base closure on an island economy where the economic conditions are not very conducive to factor mobility, especially labour migration.

3. The Military Base in Terceira/Azores

The base in Terceira/Azores houses both US and Portuguese military activities. It comprises an airport adequate for landing any known type of aircraft, fuel storage tanks and port facilities. This base has been extensively used in various international conflicts, namely those that have occurred in the last half century and in the Middle East during recent times.

The impact of the American component of the base can be simulated by the model using data on the main variables. In the simulation undertaken here the relevant data collected characterizes expenditures on construction works and repair, employment and private consumption by the US military, servicemen and civilians.

Access of locals to purchases in the base's stores can also be taken into consideration. It is common for some locals to make their purchases in the base stores at prices that are lower than those practiced in the local stores, for a wider variety of products. There are no good estimates for the total value of the purchases made in these stores, which is equivalent to purchasing the goods abroad. Given that there are no good estimates of the values involved, two scenarios will be created to test the impact of these "imports": one where the import effect is zero, the reference scenario and one in which 50% of the income is spent on these "foreign" stores.

The main elements of the date on the activity of the US military are summarized in tables 1 and 2. Table 1 provides an estimate of the value (in US Dollars) of the construction works and repair commissioned by the Lajes Field Base for 2004 and for 2005.

Table 1 Construction works and repair commissioned by the Lajes Field base

		US$
Projects	**2004**	**2005**
Repair breakwater	14.400.000	7.000.000
Construct housing, phase 3	13.392.000	0
Add/renovate fitness center	4.086.000	5.689.000
Community Improvements	3.865.644	7.644.000
Airfield improvements	407.592	150.000
Housing improvements	833.241	663.550
Fuel Sustem improvements	556.046	4.010.000
DoDDS improvements	568.117	615.000
	38.110.644	25.771.550

Source: U.S. Air force

An evaluation of the local consumption expenditure by the US base staff in Azores is given in Table 2.

To estimate the local impact of the Lajes Field Base two scenarios are created. On the first scenario it is assumed that 30 per cent of the payroll of active duty personnel living on base is spent outside the base. For the active duty personnel living off base this figure is estimated at 50 per cent, and for US civilians living it is assumed at 55%. For the Portuguese civilians working on base, two scenarios are considered: one in which they spend 100 per cent of their income off base and one in which they spend only 50 per cent off base. This second scenario tries to take into account the mentioned fact that many civilians purchase goods in the base stores supplied by the US military.

Table 2 Annual payroll and estimates regarding the loss in terms of private consumption

	Annual Payroll		Impact Factor	Local Impact	
	2004	**2005**		**2004**	**2005**
Reference Scenario	**57.509.059**	**61.247.015**		**34.710.940**	**37.311.796**
Active duty on base	19,814.147	19,287.261	0.30	5,944.244	5,786.178
Active duty off base	13,209.431	12,858.174	0.50	6,604.716	6,429.087
US civilians	5,163.335	8,900.109	0.55	2,839.834	4,895.060
Portuguese civilians	19,322.146	20,201.471	1.00	19,322.146	20,201.471

Source: U.S. Air force

The closure of the US component of the Lajes Field base would have direct and indirect impacts on the economy of the Azores through the following four channels:

- The reduction in the demand for construction works and repair;
- The employment loss of the Portuguese civilians working on the base, which leads to a loss in the labour income and consumption demand both domestic and foreign, namely the demand of goods from the base's stores;
- The loss in the consumption demand from the US active duty personnel living on base and off base;
- The loss of the rents of local lodging contracted quarters.

The difference of financial impact between the two scenarios is about US$10million, a variation of about 28%.

4. A CGE Model of a Small Island Economy

4.1 Model Description

The model is a static multi-sector computable general equilibrium model (CGE), which incorporates the economic behaviour of four economic agents: firms, households, government and the rest of the world. All economic agents are assumed to adopt an optimizing behaviour under relevant budget constraints and all markets operate under the perfect competition assumption. The goods-producing sectors, consisting of both public and private enterprises, are disaggregated into 16 sectors[1]. The model distinguishes 16 types of commodities, such that each sector produces one homogenous commodity. With regard to the rest of the world the economy is treated as a small open economy with no influence on (given) world market prices.

The model is calibrated on the regional Social Accounting Matrix for 1998. The model has been solved by using the general algebraic modelling system GAMS (Brooke *et al.,* 1998).

[1] A presentation of the production sectors considered in the model is given in section 4.11.

The following conventions are adopted for the presentation of the model. Variable names are given in capital letters; small letters denote parameters calibrated from the database (SAM) and elasticity parameters. Subscript *sec* stands for an identifier of one of the 16 production activities and one of the 16 commodities. Subscript *ct* stands for an identifier of the wholesale and retail trade services. Subscript *nct* stands for an identifier of one of the 15 commodities (except wholesale and retail trade services).

4.2 Firms

The CGE model does not take into account the behaviour of individual firms, but of groups of similar ones aggregated into sectors. The model distinguishes 16 perfectly competitive production sectors (summarized in section 4.11).

The usual assumption for such a model is that producers operate on perfectly competitive markets and maximize profits (or minimize costs) to determine optimal levels of inputs and output. For example, for the firms operating internationally, the world market dictates the output price to a large extent, so, for an optimal outcome they have to produce as efficiently as possible. Some other firms are constrained in the costs level by domestic competitors. Thus, the optimizing producers minimize their production costs at every output level, given their production technology. Furthermore, production prices equal average and marginal costs, a condition that implies profit maximization for a constant returns to scale technology.

Gross output for each sector is determined from a nested production structure. At the outer nest producers are assumed to choose intermediate inputs and a capital-labour *(KL)* bundle, according to a Leontief production function, which assume an optimal allocation of inputs. At the second nest, producers choose the optimal level of labour and capital, according to a constant elasticity of substitution (CES) function which assumes substitution possibilities between labour and capital. Rigidities in the labour market are further introduced by the inter-sectoral wage differentials. The inter-sectoral wage differentials are derived as the ratio between the sectoral wage rate and the average wage rate at the national level (Dervis, De Melo and Robinson, 1982).

The demand equations for intermediate inputs, labour and capital and the corresponding zero profit conditions for these sectors are provided in section 4.12, equations (4.12.5-4.12.9). The nested structure and the functional forms used by these sectors are further given in figure 1.

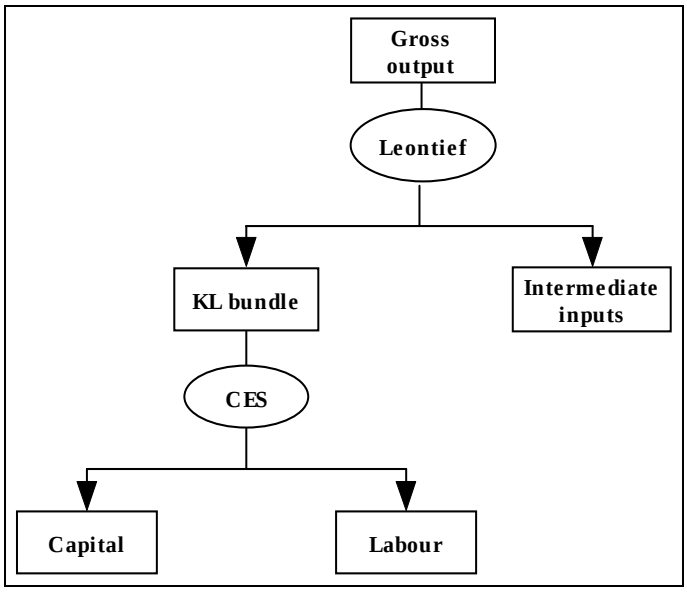

Figure 1: The nested Leontief and CES production technology

Treated at an aggregate level, firms receive income from sales of goods; they purchase intermediate inputs, make wage payments and save (see equation (4.12.10), section 4.12).

4.3 Households

The households receive income from labour and a fixed share of the capital income and transfers from the government as unemployment benefits (see equation (4.12.2), section 4.12) and pay taxes on income to government and save a fixed fraction of net (money) income (see equation (4.12.3), section 4.12). Further, households' budget devoted to consumption of commodities is given by the total income minus the taxes and savings (see equation (4.12.4), section 4.12). A schematic representation of households' decisions is given in figure 2.

The optimal allocation between the consumption commodities (C_{sec}) is given by maximizing a Stone-Geary utility function:

$$U(C_{sec}) = \prod_{sec} (C_{sec} - \mu H_{sec})^{\alpha H_{sec}} \tag{1}$$

subject to the budget constraint:

$$CBUD = (1\text{-}tsc_{sec}) \cdot (1+tc_{sec}) \cdot P_{sec} \cdot C_{sec} \tag{2}$$

where: $\sum_{sec} \alpha H_{sec} = 1$.

C_{sec} represents the consumption of commodity *sec* by the households, P_{sec} is the consumer price net of taxes for the commodity *sec*, μ_{sec} is the minimum (subsistence) level of consumption of commodity *sec* by the households, and αH_{sec} is the income elasticity of the demand for commodity *sec*.

Sixteenth categories of consumer goods are distinguished. As already explained, each production sector is assumed to produce one homogenous commodity. Thus, the classification of the commodities follows the classification of the production sectors.

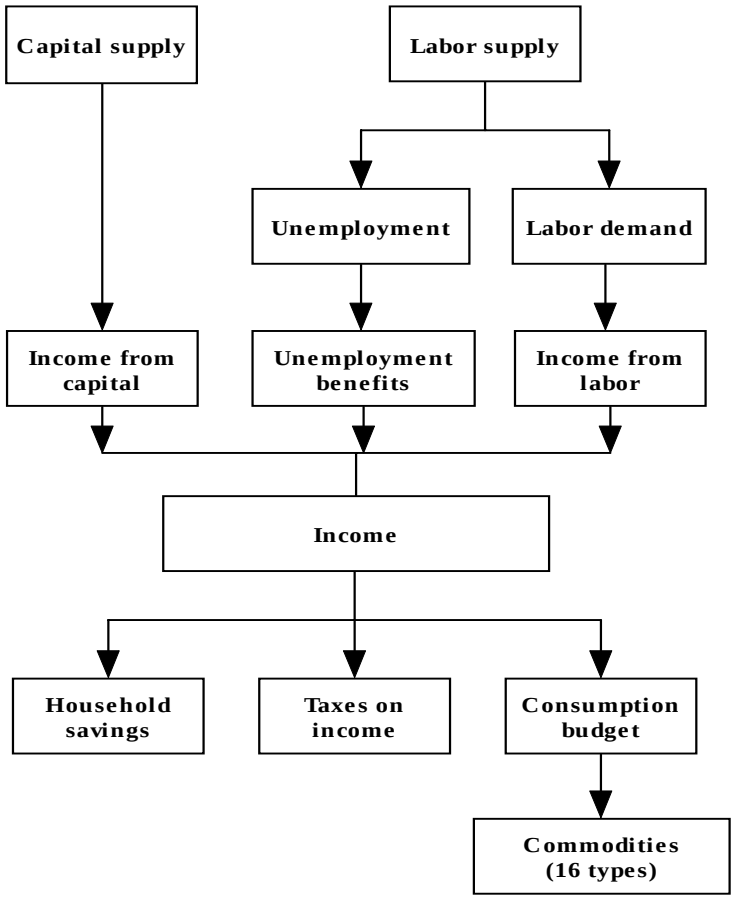

Figure 2: Decision structure of the households

Consumption is valued at consumer prices $(1\text{-}tsc_{sec})\cdot(1+tc_{sec})\cdot P_{sec}$, which incorporate taxes on consumption (tc_{sec}) and subsidies on consumption (tsc_{sec}).

After some rearrangements, the optimization process generates the demand equations for consumption commodities (see equations (4.2.12), section 4.12)[2].

To evaluate the overall change in consumer welfare we use the equivalent variation in income (EV), which is based on the concept of a money metric indirect utility function (Varian, 1992):

$$EV = (V\text{-}VZ)\cdot \prod_{sec}\left[\frac{PZ_{sec}\cdot(1+tc0_{sec})\cdot(1-tsc0_{sec})}{\alpha H_{sec}}\right]^{\alpha H_{sec}} \tag{3}$$

The indirect utility function of the LES function in the counter-factual (policy scenario) equilibrium (V) is defined as:

$$V = \left[CBUD - \sum_{sec} P_{sec}\cdot(1+tc_{sec})\cdot(1-tsc_{sec})\cdot\mu H_{sec}\right]\cdot \prod_{sec}\left[\alpha H_{sec}/(P_{sec}\cdot(1+tc_{sec})\cdot(1-tsc_{sec}))\right]^{\alpha H_{sec}} \tag{4}$$

and the indirect utility function of the LES function in the benchmark equilibrium (VZ) is given by:

[2] The Linear Expenditure System (LES) was developed by Stone (1954) and represents a set of consumer demand equations linear in total expenditure.

$$VZ = \left[CBUDZ - \sum_{sec} PZ_{sec} \cdot (1 + tc0_{sec}) \cdot (1 - tsc0_{sec}) \cdot \mu H_{sec} \right] \cdot \prod_{sec} \left[\alpha H_{sec} / (PZ_{sec} \cdot (1 + tc0_{sec}) \cdot (1 - tsc0_{sec})) \right]^{\alpha H_{sec}} \quad (5)$$

where $CBUDZ$ reflects the household's budget available for consumption in the benchmark equilibrium, PZ_{sec} is the price of commodity *sec* in the benchmark and $tc0_{sec}$ and $tsc0_{sec}$ are the consumption tax rate and the subsidy rate in the benchmark equilibrium, respectively.

Equivalent variation measures the income needed to make the household as well off as she is in the new counter-factual equilibrium (policy scenario) evaluated at benchmark prices. Thus, the equivalent variation is positive for welfare gains from the policy scenario and negative for losses (Harrison and Kriström, 1997).

4.4 Government

Government revenues $(TAXR)$ consist of taxes on households' income, consumption taxes, taxes on investment goods and taxes on production plus transfers received by the government from the rest of the world:

$$TAXR = ty \cdot YH + \sum_{sec} (P_{sec} \cdot C_{sec} \cdot (1\text{-}tsc_{sec}) \cdot tc_{sec} + XD_{sec} \cdot PD_{sec} \cdot tp_{sec}) + \sum_{sec} P_{sec} \cdot I_{sec} \cdot tcinv_{sec} + ER \cdot TRGW \quad (6)$$

where ty is the tax rate on households income (YH), tp_{sec} is the tax on production of sector *sec* and $tcinv_{sec}$ is the tax rate on investment good *sec*. XD_{sec} represents the gross output of sector *sec*, where its price is given by PD_{sec}, and I_{sec} reflects the demand for the investment commodity *sec*. The transfers received by the government from the rest of the world $(TRGW)$ are transformed in domestic currency by multiplying them with the exchange rate (ER).

Government expenditures $(GEXP)$ consists of disposable budget for current consumption $(CGBUD)$, unemployment benefits to the households' and subsidies on consumption and production:

$$GEXP = CGBUD + trep \cdot PL \cdot UNEMP + \sum_{sec} (P_{sec} \cdot C_{sec} \cdot tsc_{sec} + XD_{sec} \cdot PD_{sec} \cdot tsp_{sec}) \quad (7)$$

where $UNEMP$ represents the number of unemployed, PL is the average wage rate, $trep$ is the replacement rate out of the average wage rate, tsc_{sec} is the subsidy rate on consumption of commodity *sec* and tsp_{sec} is the subsidy rate on production of sector *sec*.

Thus, government savings are given by the difference between government revenues and government expenditures:

$$SG = TAXR\text{-}GEXP \quad (8)$$

The optimal consumption of commodities by the government is given by the maximization of a Cobb-Douglas utility function:

$$U(CG_{sec}) = \prod_{sec} CG_{sec}^{\alpha CG_{sec}} \quad (9)$$

subject to the budget constraint:

$$CGBUD = \sum_{sec} CG_{sec} \cdot P_{sec} \tag{10}$$

With: $\sum_{sec} \alpha CG_{sec} = 1$. The optimization process yields the demand equations for each type of commodity (see equation (4.12.13), section 4.12).

4.5 Foreign trade

The specification of foreign trade is based on the small-country assumption, which means that the country is a price taker in both its imports and exports markets. As a result, both world import prices and world export prices are exogenously fixed. Two main groups of trading partners are distinguished in the model: the Mainland and the rest of the world.

The assumption of limited substitution possibilities between domestically produced and imported goods, which goes back to Armington (1969), is now a standard feature of applied models and will also be adopted here. It indicates that domestic consumers use composite goods (X_{sec}) of imported and domestically produced goods, according to a CES function:

$$X_{sec} = aA_{sec} \cdot (\gamma A1_{sec} \cdot MML_{sec}^{-\rho A_{sec}} + \gamma A2_{sec} \cdot MROW_{sec}^{-\rho A_{sec}} + \gamma A3_{sec} \cdot XDD_{sec}^{-\rho A_{sec}})^{-1/\rho A_{sec}} \tag{11}$$

Minimizing the cost function:

$$Cost_{sec}(MML_{sec}, MROW_{sec}, XDD_{sec}) = PMML_{sec} \cdot MML_{sec} + PMROW_{sec} \cdot MROW_{sec} + PDD_{sec} \cdot XDD_{sec} \tag{12}$$

subject to (11), yields the demand equations for imports from Mainland (MML_{sec}), for imports from the rest of the world $(MROW_{sec})$ and domestically produced goods (XDD_{sec}) (see equations (4.12.16-4.12.18), section 4.12); where aA_{sec} is the efficiency parameter, $\gamma A1_{sec}$, $\gamma A2_{sec}$, $\gamma A3_{sec}$ are the distribution parameters and the elasticity of substitution between imports from different regions and domestically produced goods (σA_{sec}) is given by $1/(1+\rho A_{sec})$. $PMML_{sec}$ is the domestic price of imports of commodity *sec* from Mainland including trade margins, $PMROW_{sec}$ is the domestic price of imports of commodity *sec* from the rest of the world including trade margins, and PDD_{sec} is the price of domestically produced commodity *sec* delivered to the domestic market also including trade margins.

The corresponding zero profit condition for the CES function is given by:

$$P_{sec} \cdot X_{sec} = PMML_{sec} \cdot MML_{sec} + PMROW_{sec} \cdot MROW_{sec} + PDD_{sec} \cdot XDD_{sec} \tag{13}$$

where P_{sec} is the composite price of commodity *sec* net of taxes.

A limited substitution is also assumed to exist between goods produced for the domestic market (XDD_{sec}), exports to Mainland (EML_{sec}) and exports to the rest of the world $(EROW_{sec})$, as captured by a constant elasticity of transformation (CET) function:

$$XD_{sec} = aT_{sec} \cdot (\gamma T1_{sec} \cdot EML_{sec}^{-\rho T_{sec}} + \gamma T2_{sec} \cdot EROW_{sec}^{-\rho T_{sec}} + \gamma T3_{sec} \cdot XDD_{sec}^{-\rho T_{sec}})^{-1/\rho T_{sec}} \quad (14)$$

where aT_{sec} is the efficiency parameter, $\gamma T1_{sec}$, $\gamma T2_{sec}$, $\gamma T3_{sec}$ are the distribution parameters, and the elasticity of substitution (σT_{sec}) between exports to different regions and domestically produced goods delivered to domestic market is given by $1/(1+\rho T_{sec})$.

By maximizing the revenue function of the producer:

$$Revenue_{sec}(EML_{sec}, EROW_{sec}, XDD_{sec}) = PEML_{sec} \cdot EML_{sec} + PEROW_{sec} \cdot EROW_{sec} + PDS_{sec} \cdot XDD_{sec} \quad (15)$$

subject to (14) we derive the demand equations for exports and domestically produced goods (see equations (4.12.20-4.12.22), section 4.12), where $PEML_{sec}$ is the domestic price of exports of sector *sec* to the Mainland, $PEROW_{sec}$ is the domestic price of exports of sector *sec* to the rest of the world, and PDS_{sec} is the price of domestic output of sector *sec* delivered to domestic market excluding trade margins.

The zero profit condition for the CET function is further given by:

$$PD_{sec} \cdot XD_{sec} = PEML_{sec} \cdot EML_{sec} + PEROW_{sec} \cdot EROW_{sec} + PDS_{sec} \cdot XDD_{sec} \quad (16)$$

where PD_{sec} is the price of output produced by sector *sec*. Both exports and domestic output delivered to the domestic market are valued at basic prices, $PEML_{sec}$, $PEROW_{sec}$ and PDS_{sec}.

The balance of payments is now determined as all international incoming and outgoing payments have been taken into account:

$$\sum_{sec} (MML_{sec} \cdot PWMMLZ_{sec} + MROW_{sec} \cdot PWMROWZ_{sec}) = \sum_{sec} (EML_{sec} \cdot PWEMLZ_{sec} + EROW_{sec} \cdot PWEROWZ_{sec}) + TRGW + SW + LW \cdot PLWZ \quad (17)$$

The surplus/deficit of the balance of payments (SW), expressed in foreign currency, is determined by the difference between imports and exports, valued at world prices, the transfers received by the government from the rest of the world $(TRGW)$ and the labor income from non-residential firms $(LW \cdot PLWZ)$, where $PWMMLZ_{sec}$ is the foreign price of imports of commodity *sec* from the Mainland, $PWMROWZ_{sec}$ is the foreign price of imports of commodity *sec* from the rest of the world, and $PWEMLZ_{sec}$, $PWEROWZ_{sec}$ are the foreign prices of exports of sector *sec* to the Mainland and to the rest of the world, respectively.

4.6 Investment demand

Total national savings are given by:

$$S = SH + SF + SG - SW \cdot ER + \sum_{sec} DEP_{sec} \cdot PI \quad (18)$$

where SH are the households' savings, SF firms savings, SG government savings and DEP_{sec} is the depreciation of the capital stock. Depreciation is modelled as a fixed share of capital stock (see equation 4.12.26, section 4.12).

The demand for investment commodities by type of commodity (I_{sec}) is modelled in a simple way, by maximizing a Cobb-Douglas utility function:

$$U(I_{sec}) = \prod_{sec} I_{sec}^{\alpha I_{sec}} \tag{19}$$

subject to the budget constraint:

$$S - \sum_{sec} SV_{sec} \cdot P_{sec} = \sum_{sec} I_{sec} \cdot P_{sec} \cdot (1 + tcinv_{sec}) \tag{20}$$

with $\sum_{sec} \alpha I_{sec} = 1$, where SV_{sec} are the changes in stocks of commodity *sec* and $tcinv_{sec}$ is the tax rate on investment commodity *sec*. Changes in stocks are modelled in this case as a fixed share out of supply of commodities (see equation (4.12.27), section 4.12). Further, the maximization process yields the demand equations for investment commodities by type of commodity (see equation (4.12.28), section 4.12). The price of the composite investment commodity is further given by:

$$PI = \prod_{sec} [(P_{sec} \cdot (1 + tcinv_{sec})) / \alpha I_{sec}]^{\alpha I_{sec}} \tag{21}$$

4.7 Price equations

A common assumption for CGE models, which has also been adopted here, is that the economy is initially in equilibrium with the quantities normalized in such a way that prices of commodities equal unity. Due to the homogeneity of degree zero in prices, the model only determines relative prices. Therefore, a particular price is selected to provide the numeraire price level against which all relative prices in the model will be measured. In this case, the GDP deflator $(GDPDEF)$ is chosen as the numeraire.

Different prices are distinguished for all producing sectors, exports and imports. The domestic price of exports to Mainland $(PEML_{sec})$ reflects the price received by the domestic producers for selling their output to the Mainland, where $PWEMLZ_{sec}$ is the foreign price of exports to Mainland and ER is the exchange rate. The cost of trade inputs further reduces the domestic price received by the producers:

$$PEML_{sec} = PWEMLZ_{sec} \cdot ER - \sum_{ct} tcoeml_{ct,sec} \cdot P_{ct} \tag{22}$$

where $tcoeml_{ct,sec}$ is the quantity of commodity *ct* as trade input per unit of commodity *sec* exported and P_{ct} represents the price of commodity *ct*. Commodity *ct* is in fact the wholesale and retail sale commodity. In a similar way is defined the domestic price of exports to the rest of the world (see equation (4.12.38), section 4.12).

The domestic price of imports from Mainland $(PMML_{sec})$ is determined by the foreign price of imports from Mainland $(PWMMLZ_{sec})$, the exchange rate, and the cost of trade inputs for imports:

$$PMML_{sec} = ER \cdot PWMMLZ_{sec} + \sum_{ct} tcomml_{ct,sec} \cdot P_{ct} \tag{23}$$

where $tcomml_{ct,sec}$ is the quantity of commodity *ct* as trade input per imported unit of commodity *sec*.

The model distinguishes the price of domestic output supplied to domestic market paid by the consumers (PDD_i) and the price received by the producers (PDS_i). The difference between the two prices is represented by the cost of trade inputs for domestic output delivered to domestic market:

$$PDD_{sec} = PDS_{sec} + \sum_{ct} tcod_{ct,sec} \cdot P_{ct} \tag{24}$$

where $tcod_{ct,sec}$ is the quantity of commodity *ct* as trade input per unit of commodity *sec* delivered to the domestic market.

The consumer price index $(INDEX)$ used in the model is of the Laspeyres type and is defined as:

$$INDEX = \sum_{sec}\left[P_{sec} \cdot CZ_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec})\right] / \sum_{sec}\left[PZ_{sec} \cdot CZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec})\right] \tag{25}$$

Furthermore, GDP deflator is defined as the ratio of GDP at current market prices to GDP at constant prices (see equation (4.12.42), section 4.12).

4.8 Labour market

Labour services are used by firms in the production process (see equation (4.12.7), section 4.12). The model also allows for endogenous unemployment. Thus, the average wage rate paid by the firms is a function of consumer prices and the unemployment rate, as follows:

$$(PL/INDEX)/(PLZ/INDEXZ) - 1 = beta \cdot \left((UNEMP/LSR)/(UNEMPZ/LSRZ) - 1\right) \tag{26}$$

where LSR is the domestic labour supply, PL is the average wage rate in the current year and $beta$ is a parameter. PLZ, $INDEXZ$, $UNEMPZ$ and $LSRZ$ represent the average wage rate, the consumer price index, the unemployment level and the domestic labour supply in the base year, respectively.

A labour supply curve, which assumes a positive correlation between the domestic labour supply and the real average wage rate:

$$LSR = LSRZ \cdot ((PL \cdot INDEXZ)/(PLZ \cdot INDEX))^{elasLS} \tag{27}$$

is used to endogenize labour supply in the model, where $elasLS$ is the real wage elasticity of labour supply.

Labour market is closed by changes in unemployment:

$$\sum_{sec} LSK_{sec} = LSR - UNEMP \tag{28}$$

where LSK_{sec} is the labour demand by sector *sec*. Further, total labour supply (LS) is given by:

$$LS = LSR + LW \tag{29}$$

where LW is the labour supply to non-residential firms.

4.9 Market clearing equations

Equilibrium in the product, capital and labour markets requires that demand equals supply at the prevailing prices (taking into account unemployment for the labour market). The clearing equation for the labour market has already been presented above (see equation (28)).

Similarly, the sum of demand for intermediate inputs *nct* (excluding the wholesale and retail trade commodity) of sector *sec* $(io_{nct,sec} \cdot XD_{sec})$, of demand for government and households consumption, of demand for investment goods and inventories must equal the supply of the composite good *nct* from domestic deliveries and imports (X_{nct}):

$$\sum_{sec} io_{nct,sec} \cdot XD_{sec} + C_{nct} + I_{nct} + SV_{nct} + CG_{nct} = X_{nct} \tag{30}$$

For the wholesale and retail trade commodity the market clearing equation is given by:

$$\sum_{sec} io_{ct,sec} \cdot XD_{sec} + C_{ct} + I_{ct} + SV_{ct} + CG_{ct} + MARG_{ct} = X_{ct} \tag{31}$$

where $MARG_{ct}$ is the demand for trade services (Löfgren, Harris and Robinson, 2002). Total demand for trade services is further given by the sum of demand for trade services generated by the domestic output delivered to the domestic market, of the demand for trade services generated by the imports, and of the demand for trade services generated by the exports:

$$\begin{aligned} MARG_{ct} = \sum_{sec} (&tcod_{ct,sec} \cdot XDD_{sec} + tcomml_{ct,sec} \cdot MML_{sec} + \\ &tcomrow_{ct,sec} \cdot MROW_{sec} + tcoeml_{ct,sec} \cdot EML_{sec} + tcoerow_{ct,sec} \cdot EROW_{sec}) \end{aligned} \tag{32}$$

Further, capital stock is fixed by sector; therefore the equation for the clearing of the capital market has been dropped.

4.10 Closure rules

The closure rule refers to the manner in which demand and supply of commodities, the macroeconomic identities and the factor markets are equilibrated ex-post. Due to the complexity of the model, a combination of closure rules is needed. The particular set of closure rules should also be consistent, to the largest extent possible, with the institutional structure of the economy and with the purpose of the model.

To balance the number of endogenous variables and the number of independent equations in the model, additional assumptions are needed. Therefore, the transfers received by the government form the rest of the world and the labour income from non-residential firms is exogenously fixed in real terms. Further, in order to achieve the clearing of the labour market, inter-sectoral mobility of labour is assumed. However, the presence of unemployment introduces rigidities in the labour market. The unemployment is endogenously determined through a wage curve. Labour supply is endogenously determined through a labour supply curve. On the capital market the sectoral capital stock is exogenously fixed, introducing rigidities.

The most widely accepted macro closure rule for CGE models implies the assumption that investment and savings balance. In the model, the investment is assumed to adjust to the available domestic and foreign savings. This reflects an economy in which savings form a binding constraint. The interest rate is assumed to effectively balance the supply and demand for investments, even if the specific mechanism is not incorporated

in the model. This macro closure rule is neoclassical in spirit. However, the fact that the model allows for unemployment introduces a Keynesian element. As already mentioned, in models of this size it is not uncommon that a few closure rules are combined to get as close as possible to a realistic representation of the economy.

The government behaviour is modelled through an optimization process, which yields the optimal allocation of governments' consumption by type of commodity. The budget deficits/surpluses of the government are fixed as a share of GDP. For the external sector, the surplus/deficit of the balance of payments is fixed and the endogenous exchange rate brings the balance of payments into equilibrium.

Gross domestic product is obtained at both constant prices and current market prices (see equations 4.12.43-4.12.44, section 4.12). According to Walras' law if *(n-1)* markets are cleared the *n*th one is cleared as well. Therefore, in order to avoid over-determination of the model, balance of payments equation (equation 17) has been dropped. However, the system of equations guarantees, through Walras' law, that its balance is equal to the difference between the exports and imports and the transfers from the rest of the world.

4.11 Classification of the production sectors in the SAM

Table 3: Classification of the production sectors in the SAM

Code Azores core model	Classification of the production sectors in the SAM and in AzoresMod	NACE Division
sec1	Products of agriculture, hunting and forestry	A
sec2	Fish	B
sec3	Products from mining and quarrying	C
sec4	Manufactured products	D
sec5	Electrical energy, gas, steam and hot water	E
sec6	Contruction work	F
sec7	Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	G
sec8	Hotel and restaurant services	H
sec9	Transport, storage and communication services	I
sec10	Financial intermediation services	J
sec11	Real estate, renting and business services	K
sec12	Public administration and defence services, compulsory social security services	L
sec13	Education services	M
sec14	Health and social services	N
sec15	Other community, social and personal services	O
sec16	Private household with employed persons	P

4.12 Model equations

4.12.1 Households

$$P_{sec} \cdot C_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec}) = P_{sec} \cdot \mu H_{sec} \cdot (1+tc_{sec}) \cdot (1-tc_{sec}) + \alpha H_{sec} \cdot (CBUD - \sum_{sec\,c} \mu H_{sec\,c} \cdot P_{sec\,c} \cdot (1+tc_{sec\,c}) \cdot (1-tsc_{sec\,c})) \quad (4.12.1)$$

$$YH = aich \cdot \sum_{sec} KSK_{sec} \cdot RK_{sec} + \sum_{sec} LSK_{sec} \cdot wdif_{sec} \cdot PL + trep \cdot PL \cdot UNEMP + PLWZ \cdot ER \cdot LW \quad (4.12.2)$$

$$SH = mps \cdot (YH - ty \cdot YH) \quad (4.12.3)$$

$$CBUD = YH\text{-}ty \cdot YH\text{-}SH \tag{4.12.4}$$

4.12.2 Firms

$$aKL_{sec} \cdot XD_{sec} = KL_{sec} \tag{4.12.5}$$

$$(1\text{-}tp_{sec}+tsp_{sec}) \cdot PD_{sec} \cdot XD_{sec} = KL_{sec} \cdot PKL_{sec} + \sum_{secc} io_{secc,sec} \cdot XD_{sec} \cdot P_{secc} \tag{4.12.6}$$

$$LSK_{sec} = KL_{sec} \cdot [PKL_{sec}/(PL \cdot wdif_{sec})]^{\sigma P_{sec}} \cdot \gamma P2_{sec}^{\sigma P_{sec}} \cdot aP_{sec}^{(\sigma P_{sec}-1)} \tag{4.12.7}$$

$$KSK_{sec} = KL_{sec} \cdot (PKL_{sec}/(RK_{sec}+d_{sec} \cdot PI))^{\sigma P_{sec}} \cdot \gamma P1_{sec}^{\sigma P_{sec}} \cdot aP_{sec}^{(\sigma P_{sec}-1)} \tag{4.12.8}$$

$$PKL_{sec} \cdot KL_{sec} = RK_{sec} \cdot KSK_{sec} + DEP_{sec} \cdot PI + PL \cdot LSK_{sec} \cdot wdif_{sec} \tag{4.12.9}$$

$$SF = aicf \cdot \sum_{sec} KSK_{sec} \cdot RK_{sec} \tag{4.12.10}$$

4.12.3 Government

$$TAXR = ty \cdot YH + \sum_{sec} [P_{sec} \cdot C_{sec} \cdot (1\text{-}tsc_{sec}) \cdot tc_{sec} + XD_{sec} \cdot PD_{sec} \cdot tp_{sec} + P_{sec} \cdot I_{sec} \cdot tcinv_{sec}] + ER \cdot TRGW \tag{4.12.11}$$

$$GEXP = CGBUD + trep \cdot PL \cdot UNEMP + \sum_{sec} [P_{sec} \cdot C_{sec} \cdot tsc_{sec} + XD_{sec} \cdot PD_{sec} \cdot tsp_{sec}] \tag{4.12.12}$$

$$P_{sec} \cdot CG_{sec} = \alpha G_{sec} \cdot CGBUD \tag{4.12.13}$$

$$SG = TAXR\text{-}GEXP \tag{4.12.14}$$

$$RATIO = SG/GDPC \tag{4.12.15}$$

4.12.4 Foreign trade

$$MML_{sec} = (X_{sec}/aA_{sec}) \cdot (\gamma A1_{sec}/PMML_{sec})^{\sigma A_{sec}} \cdot [\gamma A1_{sec}^{\sigma A_{sec}} \cdot PMML_{sec}^{(1-\sigma A_{sec})} + \gamma A2_{sec}^{\sigma A_{sec}} \cdot PMROW_{sec}^{(1-\sigma A_{sec})} + \gamma A3_{sec}^{\sigma A_{sec}} \cdot PDD_{sec}^{(1-\sigma A_{sec})}]^{\sigma A_{sec}/(1-\sigma A_{sec})} \tag{4.12.16}$$

$$MROW_{sec} = (X_{sec}/aA_{sec}) \cdot (\gamma A2_{sec}/PMROW_{sec})^{\sigma A_{sec}} \cdot [\gamma A1_{sec}^{\sigma A_{sec}} \cdot PMML_{sec}^{(1-\sigma A_{sec})} + \gamma A2_{sec}^{\sigma A_{sec}} \cdot PMROW_{sec}^{(1-\sigma A_{sec})} + \gamma A3_{sec}^{\sigma A_{sec}} \cdot PDD_{sec}^{(1-\sigma A_{sec})}]^{\sigma A_{sec}/(1-\sigma A_{sec})} \tag{4.12.17}$$

$$XDD_{sec} = (X_{sec}/aA_{sec}) \cdot (\gamma A3_{sec}/PDD_{sec})^{\sigma A_{sec}} \cdot [\gamma A1_{sec}^{\sigma A_{sec}} \cdot PMML_{sec}^{(1-\sigma A_{sec})} + \gamma A2_{sec}^{\sigma A_{sec}} \cdot PMROW_{sec}^{(1-\sigma A_{sec})} + \gamma A3_{sec}^{\sigma A_{sec}} \cdot PDD_{sec}^{(1-\sigma A_{sec})}]^{\sigma A_{sec}/(1-\sigma A_{sec})} \tag{4.12.18}$$

$$P_{sec} \cdot X_{sec} = PMML_{sec} \cdot MML_{sec} + PMROW_{sec} \cdot MROW_{sec} + PDD_{sec} \cdot XDD_{sec} \tag{4.12.19}$$

$$EML_{sec} = (XD_{sec}/aT_{sec}) \cdot (\gamma T1_{sec}/PEML_{sec})^{\sigma T_{sec}} \cdot [\gamma T1_{sec}^{\sigma T_{sec}} \cdot PEML_{sec}^{(1-\sigma T_{sec})} + \gamma T2_{sec}^{\sigma T_{sec}} \cdot PEROW_{sec}^{(1-\sigma T_{sec})} + \gamma T3_{sec}^{\sigma T_{sec}} \cdot PDS_{sec}^{(1-\sigma T_{sec})}]^{\sigma T_{sec}/(1-\sigma T_{sec})} \tag{4.12.20}$$

$$EROW_{sec} = (XD_{sec}/aT_{sec}) \cdot (\gamma T2_{sec}/PEROW_{sec})^{\sigma T_{sec}} \cdot [\gamma T1_{sec}^{\sigma T_{sec}} \cdot PEML_{sec}^{(1-\sigma T_{sec})} + \gamma T2_{sec}^{\sigma T_{sec}} \cdot PEROW_{sec}^{(1-\sigma T_{sec})} + \gamma T3_{sec}^{\sigma T_{sec}} \cdot PDS_{sec}^{(1-\sigma T_{sec})}]^{\sigma T_{sec}/(1-\sigma T_{sec})} \tag{4.12.21}$$

$$XDD_{sec} = (XD_{sec}/aT_{sec}) \cdot (\gamma T3_{sec}/PDS_{sec})^{\sigma T_{sec}} \cdot [\gamma T1_{sec}^{\sigma T_{sec}} \cdot PEML_{sec}^{(1-\sigma T_{sec})} + \gamma T2_{sec}^{\sigma T_{sec}} \cdot PEROW_{sec}^{(1-\sigma T_{sec})} + \gamma T3_{sec}^{\sigma T_{sec}} \cdot PDS_{sec}^{(1-\sigma T_{sec})}]^{\sigma T_{sec}/(1-\sigma T_{sec})} \tag{4.12.22}$$

$$PD_{sec} \cdot XD_{sec} = PEML_{sec} \cdot EML_{sec} + PEROW_{sec} \cdot EROW_{sec} + PDS_{sec} \cdot XDD_{sec} \quad (4.12.23)$$

4.12.5 Investments

$$PI = \prod_{sec} [(P_{sec} \cdot (1+tcinv_{sec}))/\alpha I_{sec}]^{\alpha I_{sec}} \quad (4.12.24)$$

$$S = SH + SF + SG - SW \cdot ER + \sum_{sec} DEP_{sec} \cdot PI \quad (4.12.25)$$

$$DEP_{sec} = d_{sec} \cdot KSK_{sec} \quad (4.12.26)$$

$$SV_{sec} = svr_{sec} \cdot X_{sec} \quad (4.12.27)$$

$$(1+tcinv_{sec}) \cdot P_{sec} \cdot I_{sec} = \alpha I_{sec} \cdot (S - \sum_{secc} SV_{secc} \cdot P_{secc}) \quad (4.12.28)$$

4.12.6 Labor market

$$\sum_{sec} LSK_{sec} = LSR - UNEMP \quad (4.12.29)$$

$$LS = LSR + LW \quad (4.12.30)$$

$$LSR = LSRZ \cdot \left((PL \cdot INDEXZ) / (PLZ \cdot INDEX) \right)^{elasLS} \quad (4.12.31)$$

$$(PL / INDEX) / (PLZ / INDEXZ) - 1 = beta \cdot \left((UNEMP / LSR) / (UNEMPZ / LSRZ) - 1 \right) \quad (4.12.32)$$

4.12.7 Market clearing

$$MARG_{ct} = \sum_{sec} (tcod_{ct,sec} \cdot XDD_{sec} + tcomml_{ct,sec} \cdot MML_{sec} + tcomrow_{ct,sec} \cdot MROW_{sec} + tcoeml_{ct,sec} \cdot EML_{sec} + tcoerow_{ct,sec} \cdot EROW_{sec}) \quad (4.12.33)$$

$$\sum_{sec} io_{nct,sec} \cdot XD_{sec} + C_{nct} + I_{nct} + SV_{nct} + CG_{nct} = X_{nct} \quad (4.12.34)$$

$$\sum_{sec} io_{ct,sec} \cdot XD_{sec} + C_{ct} + I_{ct} + SV_{ct} + CG_{ct} + MARG_{ct} = X_{ct} \quad (4.12.35)$$

4.12.8 Price equations

$$INDEX = [\sum_{sec} P_{sec} \cdot CZ_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec})] / [\sum_{sec} PZ_{sec} \cdot CZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec})] \quad (4.12.36)$$

$$PEML_{sec} = PWEMLZ_{sec} \cdot ER - \sum_{ct} tcoeml_{ct,sec} \cdot P_{ct} \quad (4.12.37)$$

$$PEROW_{sec} = PWEROWZ_{sec} \cdot ER - \sum_{ct} tcoerow_{ct,sec} \cdot P_{ct} \quad (4.12.38)$$

$$PMML_{sec} = ER \cdot PWMMLZ_{sec} + \sum_{ct} tcomml_{ct,sec} \cdot P_{ct} \quad (4.12.39)$$

$$PMROW_{sec} = ER \cdot PWMROWZ_{sec} + \sum_{ct} tcomrow_{ct,sec} \cdot P_{ct} \quad (4.12.40)$$

$$PDD_{sec} = PDS_{sec} + \sum_{ct} tcod_{ct,sec} \cdot P_{ct} \quad (4.12.41)$$

$$GDPDEF = GDPC/GDP \quad (4.12.42)$$

4.12.9 Other macroeconomic variables

$$GDP = \sum_{sec} [C_{sec} \cdot PZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec}) + CG_{sec} \cdot PZ_{sec} + I_{sec} \cdot PZ_{sec} \cdot (1+tcinv0_{sec}) + SV_{sec} \cdot PZ_{sec} + EML_{sec} \cdot PWEMLZ_{sec} \cdot ERZ + EROW_{sec} \cdot PWEROWZ_{sec} \cdot ERZ - MML_{sec} \cdot PWMMLZ_{sec} \cdot ERZ - MROW_{sec} \cdot PWMROWZ_{sec} \cdot ERZ] \quad (4.12.43)$$

$$GDPC = \sum_{sec} [C_{sec} \cdot P_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec}) + CG_{sec} \cdot P_{sec} + I_{sec} \cdot P_{sec} \cdot (1+tcinv_{sec}) + SV_{sec} \cdot P_{sec} + EML_{sec} \cdot PWEMLZ_{sec} \cdot ER + EROW_{sec} \cdot PWEROWZ_{sec} \cdot ER - MML_{sec} \cdot PWMMLZ_{sec} \cdot ER - MROW_{sec} \cdot PWMROWZ_{sec} \cdot ER] \quad (4.12.44)$$

$$UNRATE = UNEMP/LS \cdot 100 \quad (4.12.45)$$

$$V = \left[CBUD - \sum_{sec} P_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec}) \cdot \mu H_{sec} \right] \cdot \prod_{sec} \left[\alpha H_{sec} / (P_{sec} \cdot (1+tc_{sec}) \cdot (1-tsc_{sec})) \right]^{\alpha H_{sec}} \quad (4.12.46)$$

$$VZ = \left[CBUDZ - \sum_{sec} PZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec}) \cdot \mu H_{sec} \right] \cdot \prod_{sec} \left[\alpha H_{sec} / (PZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec})) \right]^{\alpha H_{sec}} \quad (4.12.47)$$

$$EV = (V-VZ) \cdot \prod_{sec} \left[\frac{PZ_{sec} \cdot (1+tc0_{sec}) \cdot (1-tsc0_{sec})}{\alpha H_{sec}} \right]^{\alpha H_{sec}} \quad (4.12.48)$$

4.12.10 Endogenous variables

CBUD	household's disposable budget for consumption
CGBUD	disposable budget for public consumption
CG_{sec}	government demand for commodity *sec*
C_{sec}	consumer demand for commodity *sec*
DEP_{sec}	depreciation in sector *sec*
EML_{sec}	export supply of sector *sec* to Mainland
ER	exchange rate
$EROW_{sec}$	export supply of sector *sec* to ROW (rest of the world)
EV	equivalent variation in income
GDP	gross domestic product at constant prices
GDPC	gross domestic product at current prices
GDPDEF	GDP deflator
GEXP	total government expenditures
INDEX	consumer price index
I_{sec}	investment demand for commodity *sec*
LS	total labour supply

LSK_{sec}	labour demand by sector *sec*
LSR	labour supply to domestic market
$MARG_{ct}$	trade margins
MML_{sec}	import demand of commodity *sec* from Mainland
$MROW_{sec}$	import demand of commodity *sec* from ROW
PDD_{sec}	price level of domestic commodity *sec* delivered to the domestic market (including trade margins)
PD_{sec}	price level of domestic production of sector *sec*
PDS_{sec}	price level of domestic commodity *sec* delivered to the domestic market (excluding trade margins)
$PEML_{sec}$	price of exports to Mainland in domestic currency
$PEROW_{sec}$	price of exports to ROW in domestic currency
PI	price of the composite investment good
PL	average wage rate
$PMML_{sec}$	price of imports from Mainland in domestic currency
$PMROW_{sec}$	price of imports from ROW in domestic currency
P_{sec}	price level of domestic composite commodity *sec* (net of taxes)
PKL_{sec}	return to capital-labour bundle
RK_{sec}	return to capital in sector *sec*
S	total saving
SF	firms' savings
SG	government savings
SH	household's savings
SV_{sec}	changes in stocks of commodity *sec*
$TAXR$	government revenue
$UNEMP$	number of unemployed
$UNRATE$	unemployment rate
V	household's indirect utility function
KL_{sec}	capital-labour bundle
XDD_{sec}	domestic production delivered to domestic markets
XD_{sec}	sectoral production
X_{sec}	domestic sales of commodity *sec*
YF	firms' income
YH	households' income

4.12.11 Exogenous variables

ERZ	exchange rate in the benchmark

INDEXZ	consumer price index in the benchmark
KSK_{sec}	capital stock in sector *sec*
LSRZ	labour supply to domestic market in the benchmark
LW	labour supply to non-residential firms
PLWZ	return to labour employed by the non-residential firms
PLZ	average wage rate in the benchmark
$PWEMLZ_{sec}$	price of exports to Mainland in foreign currency
$PWEROWZ_{sec}$	price of exports to ROW in foreign currency
$PWMMLZ_{sec}$	price of imports from Mainland in foreign currency
$PWMROWZ_{sec}$	price of imports from ROW in foreign currency
RATIO	government savings to GDP ratio
SW	foreign savings
TRGW	transfers received by the government from the rest of the world
UNEMPZ	number of unemployed in the benchmark
VZ	households' indirect utility function in the benchmark

4.12.12 Parameters

aA_{sec}	efficiency parameter in the Armington function
aicf	share of capital income received by the firms
aich	share of capital income received by the households
aP_{sec}	efficiency parameter in the CES production function (capital-labour)
aT_{sec}	efficiency parameter in the CET production function
aKL_{sec}	Leontief parameter corresponding to the capital-labour bundle
beta	wage curve parameter
d_{sec}	depreciation rate
elasLS	real wage elasticity of domestic labour supply
$io_{sec,secc}$	technical coefficients
mps	marginal propensity to save
svr_{sec}	share of inventories of commodity *sec* in domestic sales
$tc0_{sec}$	initial average tax rate on households' consumption of commodity *sec* (to be used in the definition of CPI)
$tcinv_{sec}$	average tax rate on investment commodity *sec*
$tcinv0_{sec}$	initial average tax rate on investment commodity *sec* (to be used in the definition of GDP at constant prices)
$tcod_{ct,sec}$	quantity of commodity *ct* as trade input per unit of commodity *sec* produced and sold domestically

$tcoeml_{ct,sec}$	quantity of commodity *ct* as trade input per exported unit of commodity *sec* to Mainland
$tcoerow_{ct,sec}$	quantity of commodity *ct* as trade input per exported unit of commodity *sec* to ROW
$tcomml_{ct,sec}$	quantity of commodity *ct* as trade input per imported unit of commodity *sec* from Mainland
$tcomrow_{ct,sec}$	quantity of commodity *ct* as trade input per imported unit of commodity *sec* from ROW
tc_{sec}	average tax rate on households' consumption of commodity *sec*
tp_{sec}	average tax rate on production of sector *sec*
trep	replacement rate
$tsc0_{sec}$	initial average subsidy rate on households' consumption of commodity *sec* (to be used in the definition of CPI)
tsc_{sec}	average subsidy rate on households' consumption of commodity *sec*
tsp_{sec}	average subsidy rate on production of sector *sec*
ty	tax rate on households' income
$wdif_{sec}$	wage rate differential of sector *sec* with respect to the national average wage rate
αG_{sec}	income elasticity of government demand for commodity *sec*
αH_{sec}	income elasticity of households' demand for commodity *sec*
αI_{sec}	income elasticity of demand for investment commodity *sec*
$\gamma A1_{sec}$	distribution parameter for imports of commodity *sec* from Mainland in the Armington function
$\gamma A2_{sec}$	distribution parameter for imports of commodity *sec* from ROW in the Armington function
$\gamma A3_{sec}$	distribution parameter for domestic demand from the domestic market of commodity *sec* in the Armington function
$\gamma P1_{sec}$	distribution parameter for capital in the CES production function of sector *sec*
$\gamma P2_{sec}$	distribution parameter for labour in the CES production function of sector *sec*
$\gamma T1_{sec}$	distribution parameter for exports of sector *sec* to Mainland in the CET production function
$\gamma T2_{sec}$	distribution parameter for exports of sector *sec* to ROW in the CET production function
$\gamma T3_{sec}$	distribution parameter for domestic deliveries to domestic market of sector *sec* in the CET production function
μH_{sec}	subsistence households' consumption of commodity *sec*

σA_{sec}	elasticity of substitution between imports from ROW, imports from Mainland and domestic demand from domestic market for commodity *sec* in the Armington function
σP_{sec}	elasticity of substitution between capital and labour in sector *sec*
σT_{sec}	elasticity of transformation in the CET production function

4.12.13 Indexes

ct	a subscript for wholesale and retail trade sector (1 sector) and also a subscript for wholesale and retail trade commodity (1 commodity)
sec	a subscript for one of the production sectors (16 sectors) and also a subscript for one of the commodities (16 types of commodities)
secc	the same as *sec* (used for exposition purposes)
nct	a subscript for one of the production sectors except wholesale and retail trade sector (15 sectors) and also a subscript for one of the commodities except wholesale and retail trade services (15 commodities)

5. Simulation of various base closure policies

Main results of the policy measure

This simulation exercise aims at evaluating the economic impacts of the Lajes Field base removal from Azores.

The setup of the policy scenario relies on the evaluation in terms of construction works and repair, employment and private consumption, provided by the U.S. Air Force. The main assumptions are summarized in tables 4 and 5. Table 4 provides an estimation of the losses in terms of construction works and repair caused by the removal of the Lajes Field base, expressed in US dollars.

Table 4: Construction works and repair commissioned by the Lajes Field base

Major FY04 projects and dollar value	Dollars
Repair breakwater	14,400,000
Construct Nascer do Sol, phase 3	13,392,000
Add/renovate fitness center, phase 1	4,086,000
Community improvements	3,865,644
Airfield improvements	407,592
Housing improvements	833,241
Fuel system improvements	556,046
DoDDS improvements	568,117
Total	**38,108,640**

Source: U.S. Air force

An evaluation of the loss in terms of private consumption, expressed in US dollars, due to the removal of the NATO base is given in table 5. To estimate the local impact on private consumption it has been assumed that 30 per cent of the consumption of active duty personnel living on base originates from the domestic economy. For the active duty personnel living off base the share of private consumption originating from the domestic economy is 50 per cent, while for the US civilians 55 per cent and for the Portuguese civilians 100 per cent.

Table 5: Estimates regarding the loss in terms of private consumption

Base personnel	Annual Payroll ($)	Local impact* ($)
Active duty on base	19,814,147	5,944,244
Active duty off base	13,209,431	6,604,716
US civilians	5,163,335	2,839,834
Portuguese civilians	19,322,146	19,322,146
Total impact of annual payroll	**57,509,059**	**34,710,940**
Local lodging contracted quarters		**1,503**

Source: U.S. Air force
*Note: *Estimated pay spent in local economy: 30% of active-duty pay, living on base; 50% of active-duty pay, living off base; 55% civilian pay.*

The facility replacement value ($1,075,649,430) has not been taken into account in this policy scenario.

The closing of the Lajes Field base will have direct and indirect impacts on the Azores economy through the following four channels:

- The reduction in the demand for construction works and repair;
- The employment loss of Portuguese civilians working on the base, which leads to a loss in factor income;
- The loss in demand from the US active duty personnel living on base and off base;
- The loss of rents of local lodging contracted quarters.

The decline in the demand for construction works and repair by the Lajes Field base leads to a decline in investment demand which further affects the production of construction work sector (see table 10). Both profitability and employment in the sector reduce (see tables 11 and 19).

The loss of employment by Portuguese civilians generates a fall in labour income for the Portuguese households. Thus, consumption demand for all products declines (see table 7). Consequently, production of most sectors goes down leading to a downwards adjustment in employment by the sectors.

All these effects are strengthened by the fact that demand from US active duty personnel living on base and off base as well as the US civilians falls. As a consequence, consumption demand for commodities drops by about 2 per cent (see table 7 in the Appendix).

The domestic currency depreciates to maintain the fixed trade deficit thus giving a boost to the external competitiveness by increasing exports to both Mainland and Rest of the World. Therefore, the negative impact induced by the private demand on the production and employment in the agriculture, hunting and forestry sector (sec1), fish (sec2), manufacture products (sec4), transport and communication services (sec9) and financial intermediation services (sec10) is reversed (see tables 10-11). Furthermore, imports from both Mainland and Rest of the World decline due to the relative increase of world prices of imports compared with the domestic prices and the drop in domestic sales.

The fall in domestic and foreign savings, i.e. supply of loanable funds, generates a reduction in the demand for investment goods (see table 16).

At the macro level, GDP drops by 0.89 per cent, due to the retrenchment of the private and investment demand. Furthermore, the negative impact on employment accounts for about 0.1 percentage points (see table 6).

Table 6: Macroeconomic effects (% changes compared with the baseline)

Macroeconomic variables	
GDP (% change)	-0.89
Unemployment rate (%)	4.09
Change in unemployment rate (% points)	1.16
Welfare gains/losses (thousands EURO)	-27,919
Welfare gains/losses (% of households income)	-2.13

The measure generates a loss in households' welfare of about 28 million €, which is equivalent to 2.13 per cent of households' income.

The detailed sector results on output and prices are depicted in the Appendix.

6. Conclusions

The closure of the Lajes air base does adversely affect the economy. The mechanism is largely driven through the exogenous cut in American expenditure affecting the demand for services, construction and rental housing, besides increase in unemployment on account of job losses. The job loss leads to a fall in income and demand for both domestic and imported commodities forcing the producers to export more to the mainland and ROW.

References

Armington, P. (1969). A theory of demand for products distinguished by place of production. *IMF Staff Papers, 16,* 159-178.

Brooke, A., Kendrick, D., Meeraus, A., & Raman, R. (1998). *GAMS – A user's guide.* Washington: GAMS Development Corporation.

Harrison, G. W., & Kriström B. (1997). General equilibrium effects of increasing carbon taxes in Sweden. Retrived from: http://www.sekon.slu.se/~bkr/Beijer.pdf.

Löfgren, H., Harris, R. L., & Robinson S. (2002). A standard computable general equilibrium (CGE) in GAMS. *IFPRI, Microcomputers in Policy Research,* vol.5.

Stone, R. (1954). Linear expenditure systems and demand analysis: An application to the pattern of British demand. *Economic Journal, 64,* 511-527.

Varian, H.R. (1992). *Microeconomic analysis.* New York: W.W. Norton.

Dervis, K., De Melo, J., & Robinson, S. (1982). *General equilibrium models for development policy.* Cambridge, UK: Cambridge University Press.

Sandra Hoffmann, Sherman Robinson, & Shankar Subramanian (1996) The role of defense cuts in the California recession computable general equilibrium models and interstate factor mobility, *The Journal of Regional Science*, Basil Blackwell, Volume 36 Issue 4 Page 571-595, November 1996

Appendix

Detailed sector results of the policy measure

Table 7: Changes in private consumption compared with the baseline (%)

Private consumption	Commodities	% change
Products of agriculture, hunting and forestry	sec1	-1.95
Fish	sec2	-1.88
Products from mining and quarrying	sec3	-2.62
Manufactured products	sec4	-2.68
Electrical energy, gas, steam and hot water	sec5	-1.51
Contruction work	sec6	-2.05
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-2.03
Hotel and restaurant services	sec8	-2.71
Transport, storage and communication services	sec9	-3.00
Financial intermediation services	sec10	-2.73
Real estate, renting and business services	sec11	-2.66
Public administration and defence services, compulsory social security services	sec12	-2.36
Education services	sec13	-2.37
Health and social services	sec14	-2.32
Other community, social and personal services	sec15	-2.53
Private household with employed persons	sec16	-2.58

Table 8: Changes in government purchase of goods and services w.r.t. baseline (%)

Public consumption	Commodities	% change
Manufactured products	sec4	-2.12
Electrical energy, gas, steam and hot water	sec5	-1.49
Transport, storage and communication services	sec9	-2.04
Public administration and defence services, compulsory social security services	sec12	-1.25
Education services	sec13	-1.31
Health and social services	sec14	-1.12
Other community, social and personal services	sec15	-1.35

Table 9: Changes in domestic sales by sector compared with the baseline (%)

Domestic sales	Commodities	% change
Products of agriculture, hunting and forestry	sec1	-0.56
Fish	sec2	-1.34
Products from mining and quarrying	sec3	-0.84
Manufactured products	sec4	-1.97
Electrical energy, gas, steam and hot water	sec5	-1.04
Contruction work	sec6	-2.15
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-1.28
Hotel and restaurant services	sec8	-1.97
Transport, storage and communication services	sec9	-1.07
Financial intermediation services	sec10	-0.82
Real estate, renting and business services	sec11	-1.53
Public administration and defence services, compulsory social security services	sec12	-1.27
Education services	sec13	-1.35
Health and social services	sec14	-1.57
Other community, social and personal services	sec15	-1.95
Private household with employed persons	sec16	-2.58

Table 10: Changes in sectoral gross output compared with the baseline (%)

Domestic output	Sectors	% change
Products of agriculture, hunting and forestry	sec1	0.07
Fish	sec2	0.42
Products from mining and quarrying	sec3	-0.11
Manufactured products	sec4	0.47
Electrical energy, gas, steam and hot water	sec5	-1.03
Contruction work	sec6	-2.15
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-1.18
Hotel and restaurant services	sec8	-1.41
Transport, storage and communication services	sec9	0.62
Financial intermediation services	sec10	0.11
Real estate, renting and business services	sec11	-0.02
Public administration and defence services, compulsory social security services	sec12	-1.27
Education services	sec13	-1.35
Health and social services	sec14	-1.57
Other community, social and personal services	sec15	-0.99
Private household with employed persons	sec16	-2.58

Table 11: Changes in employment by sector compared with the baseline (%)

Employment	Sectors	% change
Products of agriculture, hunting and forestry	sec1	0.78
Fish	sec2	0.96
Products from mining and quarrying	sec3	-0.22
Manufactured products	sec4	0.70
Electrical energy, gas, steam and hot water	sec5	-1.18
Contruction work	sec6	-3.09
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-2.39
Hotel and restaurant services	sec8	-1.54
Transport, storage and communication services	sec9	1.25
Financial intermediation services	sec10	0.16
Real estate, renting and business services	sec11	-0.10
Public administration and defence services, compulsory social security services	sec12	-1.40
Education services	sec13	-1.45
Health and social services	sec14	-1.88
Other community, social and personal services	sec15	-1.04
Private household with employed persons	sec16	-2.58

Table 12: Changes in exports to Mainland compared with the baseline (%)

Exports to Mainland	Sectors	% change
Products of agriculture, hunting and forestry	sec1	0.73
Fish	sec2	1.81
Products from mining and quarrying	sec3	5.60
Manufactured products	sec4	1.65
Hotel and restaurant services	sec8	1.10
Transport, storage and communication services	sec9	1.63
Real estate, renting and business services	sec11	2.96
Other community, social and personal services	sec15	1.88

Table 13: Changes in exports to ROW compared with the baseline (%)

Exports to ROW	Sectors	% change
Products of agriculture, hunting and forestry	sec1	0.73
Fish	sec2	1.81
Products from mining and quarrying	sec4	1.65
Electrical energy, gas, steam and hot water	sec5	3.41
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	6.74
Hotel and restaurant services	sec8	1.10
Transport, storage and communication services	sec9	1.63
Financial intermediation services	sec10	2.74
Real estate, renting and business services	sec11	2.96
Other community, social and personal services	sec15	1.88

Table 14: Changes in imports from Mainland compared with the baseline (%)

Imports from Mainland	Commodities	% change
Products of agriculture, hunting and forestry	sec1	-0.64
Products from mining and quarrying	sec3	-4.88
Manufactured products	sec4	-2.46
Hotel and restaurant services	sec8	-5.01
Transport, storage and communication services	sec9	-3.08
Financial intermediation services	sec10	-3.06
Real estate, renting and business services	sec11	-5.40

Table 15: Changes in imports from ROW compared with the baseline (%)

Imports from ROW	Commodities	% change
Products of agriculture, hunting and forestry	sec1	-0.64
Fish	sec2	-1.71
Products from mining and quarrying	sec3	-4.88
Manufactured products	sec4	-2.46
Electrical energy, gas, steam and hot water	sec5	-3.33
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-11.15
Hotel and restaurant services	sec8	-5.01
Transport, storage and communication services	sec9	-3.08
Financial intermediation services	sec10	-3.06
Real estate, renting and business services	sec11	-5.40
Other community, social and personal services	sec15	-6.58

Table 16: Changes in demand for investment commodities w.r.t. baseline (%)

Investment demand	Commodities	% change
Products of agriculture, hunting and forestry	sec1	-4.86
Manufactured products	sec4	-4.33
Contruction work	sec6	-2.31
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-1.73
Real estate, renting and business services	sec11	-4.02
Other community, social and personal services	sec15	-3.58

Table 17: Changes in commodities prices net of taxes w.r.t. the baseline (%)

Domestic prices	Commodities	% change
Products of agriculture, hunting and forestry	sec1	1.58
Fish	sec2	1.21
Products from mining and quarrying	sec3	0.07
Manufactured products	sec4	1.01
Electrical energy, gas, steam and hot water	sec5	0.37
Contruction work	sec6	-1.08
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-1.66
Hotel and restaurant services	sec8	0.79
Transport, storage and communication services	sec9	0.93
Financial intermediation services	sec10	0.96
Real estate, renting and business services	sec11	0.69
Public administration and defence services, compulsory social security services	sec12	0.13
Education services	sec13	0.18
Health and social services	sec14	-0.01
Other community, social and personal services	sec15	0.22
Private household with employed persons	sec16	0.39

Table 18: Changes in price of domestic output compared with the baseline (%)

Price of domestic output	Sectors	% change
Products of agriculture, hunting and forestry	sec1	1.92
Fish	sec2	1.97
Products from mining and quarrying	sec3	0.26
Manufactured products	sec4	1.13
Electrical energy, gas, steam and hot water	sec5	0.37
Contruction work	sec6	-1.08
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-1.66
Hotel and restaurant services	sec8	0.69
Transport, storage and communication services	sec9	1.27
Financial intermediation services	sec10	0.66
Real estate, renting and business services	sec11	0.29
Public administration and defence services, compulsory social security services	sec12	0.13
Education services	sec13	0.18
Health and social services	sec14	-0.01
Other community, social and personal services	sec15	0.53
Private household with employed persons	sec16	0.39

Table 19: Rental rate of capital services compared with the baseline (%)

Rental rate of capital services	Sectors	% change
Products of agriculture, hunting and forestry	sec1	3.47
Fish	sec2	4.01
Products from mining and quarrying	sec3	-0.14
Manufactured products	sec4	4.27
Electrical energy, gas, steam and hot water	sec5	-6.76
Contruction work	sec6	-12.95
Wholesale and retail trade services; repair services of motor vehicles, motorcycles and personal and household goods	sec7	-9.55
Hotel and restaurant services	sec8	-5.69
Transport, storage and communication services	sec9	5.17
Financial intermediation services	sec10	1.38
Real estate, renting and business services	sec11	0.14
Public administration and defence services, compulsory social security services	sec12	-8.13
Education services	sec13	-10.81
Health and social services	sec14	-10.16
Other community, social and personal services	sec15	-5.90