USING A CGE MODEL TO EVALUATE IMPORT TARIFF REDUCTIONS IN UKRAINE

by

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Abstract

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The problem of trade barriers has been important for Ukraine for a long time, since high levels of protection do not allow Ukraine to join world trade organizations like the WTO. This thesis analyses the impacts of import tariffs reductions on national welfare under the hypothesized condition of Ukraine's accession to the WTO. A pilot Shoven-Whalley general equilibrium model is developed for Ukraine according to Rutherford and Paltsev (1999). Then, the impact of import tariffs reduction is calculated using a recent (1999) input-output table of Ukraine and GAMS computer software. Based on the simple static model, I find that import tariffs significantly decrease welfare and have the highest marginal excess burden on consumers among other taxes. The CGE model shows that the bigger are import tariffs reductions the lower is marginal excess burden of import tariffs and, therefore, the higher is welfare. The key condition for Ukraine's accession to the WTO is its import tariffs reductions. The results of this thesis show that membership in the WTO will be beneficial for Ukraine.

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GLOSSARY

CES	Constant elasticity of substitution
CET	Constant elasticity of transformation
CGE	Computable General Equilibrium
CIF	Cost, insurance, freight
CIS	Commonwealth of Independent States - is comprised of all the states of the former Soviet Union except for the three Baltic countries (Estonia, Latvia and Lithuania).
Derzhkomstat	State Statistics Committee of Ukraine
EC	European Community
EU	European Union
Eurostat	European System of Integrated Economic Accounts
FSU	Former Soviet Union
GATT	General Agreement on Tariffs and Trade
GDP	Gross Domestic Product
IO	Input-Output table that contains information about the market allocation of resources
NIS	Newly Independent States
NTB	Non-tariff barriers
SAM	Social Accounting Matrix, an extended version of IO that contains information on interrelations between accounts

Static General Equilibrium model	Model that represents production and distribution of goods and services in an economy in a given period of time
VAT	Value-added tax
WTO	World Trade Organization

Chapter 1

INTRODUCTION

Together with the transition process in the Ukrainian economy, there have been crucial events in the world's policy over the last ten years. World integration and creation of the World Trade Organization (WTO) have made huge differences in the economic environment of Ukraine thus having a direct effect on its economic performance.

The problem of trade barriers has been important for Ukraine for a long time, since high levels of protection do not allow Ukraine to join world trade organizations like the WTO. Membership in the WTO will allow Ukraine to trade with other countries more freely and on better conditions. Ukraine adopted the convention "Of transformation of customs tariff of Ukraine for 1996-2005 according to GATT/WTO system" [1] which requires a decrease in tariff to the average level of no more than 14%.

According to the presidential decree "On Additional Measures for Speeding up Ukraine's Entry into the World Trade Organization" [2], from now on, completion of the process of the country's entry into the WTO is a priority foreign policy task of the Cabinet of Ministers and national executive bodies.

The decree provides for step-by-step realization of a respective program. The Cabinet has to work out and institute a number of measures, including introduction of a system ensuring effective information support to Ukraine's accession to the WTO. That system should be focused on maintaining

[1] "Про Концепцію трансформації митного тарифу України на 1996-2005 роки відповідно до системи ГАТТ/СОТ." 06.04.1996 № **255/96**

[2] "Про додаткові заходи щодо прискорення вступу України до Світової організації торгівлі" 05.09.2001 № **797/2001**

Ukraine's positive international image by means of a large-scale information campaign in both domestic and foreign mass media.

Up until January 1, 2002, the Cabinet of Ministers, the National Academy of Sciences and the National Security and Defense Council of Ukraine have been charged with researching, with the assistance of foreign experts, the possible national security implications of the country's entry into the WTO and with developing measures for enhancing competitiveness of industries that could be adversely affected.

By October 2002, the Cabinet has to complete bilateral negotiations about access to commodity and services markets with the member countries of the working group considering Ukraine's application for WTO entry. Accelerating the adoption of laws aimed at harmonization of national legislation with provisions of the WTO agreements and their compliance with existent WTO requirements is envisaged. Moreover, all draft legal acts in the sphere of reforming Ukraine's foreign economic treatment are subject to approval by the Interagency Commission on the Problems of Ukraine's Entry into the WTO.

The above should ensure compliance of newly enacted documents with provisions and principles of the system of WTO agreements. Rendering legal support to Ukraine's accession to the WTO is extremely important, as the number of member countries of the WTO is constantly growing and failure to join it can have negative foreign economic consequences for Ukraine. Ukraine can miss opportunities of entering new markets and of signing trade contracts on favorable for Ukraine conditions.

The purpose of this thesis is to examine the effects import tariffs could impose on output, prices and general welfare. In particular, I calculate the effects of import tariff reduction after Ukraine's accession to the WTO.

Chapter 2 is a brief look on previous findings in this field; it presents the major points of reference which are Rutherford and Paltsev (1999), Brown and Whalley (1980), and (Bond 1997). Chapter 3 describes the Ukrainian situation, with emphasis on the behavior of Ukrainian trade during the transition period. Chapter 4 presents the CGE model, methodology of estimation and the results. Chapter 5 is devoted to data description. Chapter 6 examines estimates of the CGE model proposed by Rutherford and Paltsev (1999). In Chapter 6, I also discuss the findings and policy implications.

Chapter 2

LITERATURE REVIEW

International trade theory states that tariff reduction in general (not for large countries) causes increase in national welfare. This problem is studied in two categories: trade diversion and trade creation. Trade creation means that after tariff reduction a country increases the range of traded goods and thus improves its allocation of resources. All this together with the improvement of terms of trade leads to increases in welfare.

Trade diversion means that after tariff reduction a country switches from a more efficient supplier to a less efficient one. Suppose that there are two countries exporting to Ukraine: A and B. Country A is assumed capable of supplying the product at a lower price than country B. We assume that Ukraine has a specific tariff set on imports from both countries A and B that raises the domestic supply prices. Since, with the tariff, the product is cheaper from country A, Ukraine A will import the product from country A and will not trade initially with country B. Next, assume Ukraine and country B form a Free Trade Agreement and Ukraine eliminates the tariff on imports from country B. Since the domestic price on goods from country B is less than from country A, Ukraine would import all of the product from country B after the FTA and would import nothing from country A. At the lower domestic price imports would rise. Also since the non-distorted (i.e., free trade) price in country A is less than the price in country B, trade is said to be *diverted* from a more efficient supplier to a less efficient supplier. Therefore, the overall effect is ambiguous.[3]

[3] Explanation of trade diversion is taken from "International Trade Theory & Policy Analysis" by Steven M. Suranovic available at http://internationalecon.com/v1.0/ch110/110c030.html

A reduction in import tariffs leads to a decrease in the domestic price of the imported good (Rutherford and Paltsev 1999). Therefore, domestic consumers will substitute this good for the same good from other countries (or from domestic production). Import of this good increases and the price of composite imports decreases because the share of cheaper imports increases. This means that its price as an intermediate good for domestic industries also decreases. Consequently, demand for imported composite good of domestic industries that use this good as input increases. Producers will experience a rise in their profits, as taxes, endowment and supply prices remain constant. Positive profit will bring an increase in output. As technology is held constant, the demand for other inputs will also increase, which will increase their prices and thus spread the tariff reduction shock to other domestic industries. Therefore, import tariff reduction will lead to the redistribution of wealth.

In many developing countries import tariff revenues constitute a large part of total government revenues from taxes. So the loss in revenues from import tariff reduction must be compensated by other taxes. It is optimal for a small open economy to simultaneously reduce import taxes and increase taxes on consumption to maintain production efficiency (Diamond, Mirrlees 1971). This tax reform should be done in a way that leaves consumer prices unchanged. Keen and Ligthart argue that other features should be taken into account: nontradables, intermediates, and imperfect competition. Also they state that there may be cases when tariffs "perform some function that is not better served by domestic tax instruments" (Keen, Ligthart 1999, p.18) without clearly defining those functions.

The compensation of import tariff reduction by consumption tax increase will be effective only if marginal revenue of the import tariff is lower than marginal revenue of the consumption tax. Bizer and Stuart measured the marginal efficiency cost of an oil import tax and other taxes in the United States using a general equilibrium model (Bizer and Stuart, 1987). They came to the conclusion that an import tax has the highest marginal efficiency cost among all taxes. This means that a tariff reform that replaces import tariffs with the corresponding consumption taxes will lead to welfare improvements. They also conclude that a protective tariff may have a high marginal efficiency cost when the rest of the world retaliates depending on the extent of this retaliation.

This statement contradicts the earlier finding of Johnson that a country may actually gain by imposing a tariff, even if other countries retaliate (Johnson 1954). He outlines two possibilities: the adjustment process may converge on a policy equilibrium point, or it may converge on a tariff cycle. The adjustment process begins when country A imposes an optimum tariff and country B imposes a tariff in response, i.e. country B retaliates. The outcome of tariff retaliation depends on which country makes the first move. The country will gain from imposing an optimum tariff under special conditions: "if the elasticity of country A's demand for import were 2.0, country A would be better off under tariffs than under free trade if the elasticity of country B's demand were 1.5 or less; both countries would be worse off if the elasticity of country B's demand lay between 1.6 and 2.8 inclusive; while country B would be better off under tariffs than under free trade if (country A's elasticity remaining at 2.0) its elasticity of demand for imports were 2.9 or greater" (Johnson 1954, p.152).

The conditions imposed by Johnson are rather special and rare. In general, import tariff reduction will increase national welfare of developing countries. Golub and Finger showed that the reciprocal elimination of trade barriers between developed and developing countries will raise output in developing countries more than it will decrease output in developed countries (Golub and Finger 1979).

Trade liberalization influences not only tariff revenues but also real exchange rates. Reduction in trade protection tends to depreciate the equilibrium real exchange rate, which in turn improves competitiveness of exports (Sorsa

1999). An increase in import tariffs increases the relative price of imported goods. Therefore, domestic consumers will switch to nontradables and their price will increase. The associated real appreciation will reduce the competitiveness of exported goods and goods of import competing industries. Thus, more profitable import competing and nontradable industries will attract resources from production of exported goods. So protection hits domestic producers of exported goods twice and encourages rent seeking with an adverse impact on growth.

But if tariff reduction is applied only to a subset of commodities subject to tariffs, the results are different. The concertina theorem (Lopez and Panagariya 1992) says that in a small open economy if the highest tariff rate is reduced to the next highest one, welfare will rise provided that the import demand for the good with the highest tariff exhibits gross substitutability with respect to all other goods. Lopez and Panagariya demonstrate that when a pure imported intermediate input is present, it may be impossible to satisfy the substitutability condition of the concertina theorem (Lopez and Panagariya 1992). A rise in the price of input will be accompanied by an expansion of at least one final good (if the Rybczynski relationship holds). Lopez and Panagariya give three cases sufficient for the complementarity between the pure imported input and at least one final good:

1) the imported input is used in fixed proportions;
2) the number of inelastically supplied primary factors equals the number of produced goods;
3) there is one commonly shared factor and one specific factor in each sector, and not all goods use the imported input.

Assuming case 1, a decrease in the tariff rate of the imported input will reduce welfare (if this rate is the highest) provided that the final imported good is also taxed and the least protected good also uses the imported input least intensively (Lopez, Panagariya 1992, p.616). Even if this condition is not satisfied, a reduction in the tariff is not necessary welfare-improving. It will be welfare improving if the good with the highest nominal tariff also is subject to the highest effective rate of protection.

Pankiv in her research paper shows that for the small country an optimal import tariff may be positive in special cases (Pankiv 1999).

As all the previous review shows, the question of import tariffs has some peculiarities and the problem of measuring the impacts of reducing import tariffs is very important. Bond presents a tariff index that uses constant-elasticity-of-substitution aggregators of tariff line data to calculate how preferential tariff reductions affect both prices and average tariff rates (Bond 1997). He examined the effects of free trade agreements between Chile and MERCOSUR countries and between Chile and NAFTA countries presenting an example of a simple general-equilibrium model. Bond's model consists of two components: aggregate import goods and tariff rates, and a general equilibrium model. After the aggregation stage it is possible to measure the effect of a tariff cut on the relative price of the composite imported goods. After developing the general equilibrium model, it is possible to measure the effects of tariff changes on domestic activity levels, tariff revenue, and welfare. This model combines information on tariffs and trade volumes, which is available at very low levels of product classification, with data on domestic input usage and consumption, which is available at more highly aggregated levels. Bond argues that ignoring the information available in tariff line data could lead to an overestimate of the average tariff rate on imports after a preferential reduction.

Rutherford and Paltsev also use a general equilibrium model to calculate the excess burden of different taxes in Russia (Rutherford, Paltsev 1999). They formulate a standard, static, constant-returns to scale model, and use this model to assess the excess burden of various tax instruments based on what can be inferred from the input-output data. Their results show that an import tax imposes a higher distortion cost than other tax instruments because it favors domestic production over imports.

Davar compares Leontief's scheme with the underlying approach by Walras (Davar 2000). He states that Leontief enriched Walras' system in accordance with the changes in real economic life by adding a public sector and exports on the demand side, and taxation and imports on the supply side. However, this scheme describes only the supply side of the economic system and thus fails its goal to describe reality. Davar concludes that some combination of positive attributes of Walras' theory and Leontief's analysis is needed to improve the applicability of input-output system for practical goals.

Several economic models were developed to estimate the welfare effects of general reductions in tariff rates. One of these models, by Brown and Whalley (1980), appears to be the most relevant for present purposes. Due to the high computational cost of solving a general equilibrium model, Brown and Whalley specify a model with a limited number of product sectors and trading blocks. Specifically, their model has five product groups and four geographic trading areas. The demand side of the model includes separate demands for consumption, investment, and government spending for each product group in each geographic area. Brown and Whalley adopt an Armington (1969) type model that considers each product from each area as a differentiated product. Within a given product group, consumers have the same degree of substitutability between the products from any pair of areas. Moreover, consumers also have a different degree of substitutability between any two product groups. The supply side of the model assumes competitive conditions and constant returns to scale. The production function for each product is viewed as a long-run relationship that allows substitution between capital services and labor as well as substitution among intermediate inputs from each area. This means that all long-run supply curves are horizontal but the supply curves can shift.

Summarizing, it can be noted that trade liberalization that consists mainly of tariff reductions and non-tariff barriers (NTB) removal would result in benefits and costs to the economy. The comprehensive impact of trade liberalization has some uncertainty. The aim of the present thesis is to assess the potential economic effects on Ukraine of Ukraine's market accession commitments for WTO membership (that assumes import tariff reduction to the level of average 14%). For this purpose a general equilibrium model based on an input-output table of the Ukrainian economy will be used.

Chapter 3

THE UKRAINIAN SITUATION

The Ukrainian tax system has evolved continually since Ukraine's independence in 1991; however, it remains far from coherent. The daunting menu of a value-added tax (20%), import taxes (ranging from 5-200%), and excise taxes (10-300%) presents a major obstacle to trade with Ukraine. The VAT is levied at 20%, based on the customs value on the invoice, and is generally payable at the time of customs clearance by the importer.[4] A promissory note can also be applied. Many agricultural enterprises are exempt from paying VAT. As the list of goods exempted from VAT changes frequently, businesses should contact Customs Service Kyiv for the most up-to-date list. Import duties differ and largely depend upon whether a similar item to that being imported is produced in Ukraine; if so, the rate may be higher. Excise taxes are applied to a number of luxury goods, including alcohol, automobiles, jewelry, tires, and tobacco. Excise duty rates are expressed as a percentage of the declared customs value, plus customs duties and customs fees paid for importing products.

To the uninitiated, importing into Ukraine can prove to be a daunting experience of paperwork and frustration. Importers are required to complete a customs freight declaration for every item imported. It is recommended to use licensed customs brokers to navigate the morass of the Ukrainian customs bureaucracy, as constantly changing regulations and, in many cases, the mood of the customs officer, impinge upon the successful import of a product. According to international practice, all imported/exported goods are subject to customs and border control checks. There are 70 approved customs clearance points across Ukraine - at all international ports, international (and

[4] The State Customs Service of Ukraine http://www.customs.gov.ua/eng/frame_e.html

several domestic) airports, and railway and road border crossing points. Every checkpoint covers a particular geographical area.

Import/export operations involve several authorities – not only customs but also number of different state bodies such the tax administration, the sanitary and epidemiological services, and the Chamber of Commerce depending what kind of external economic activity is undertaken. Typically in Ukraine all state bodies work with so-called zero tolerance. This zero tolerance is a special characteristic of customs in Ukraine as well as tax authorities. It means that during import/export operations any incorrectness in documentation such as contract, packing list or Load Customs Declaration (LCD), absence of original stamp, or absence of some peripheral documents can result in days-long delays of customs clearance or even confiscation of goods being considered as contraband.

Customs tariff regulation is one of the main functions of Ukrainian customs bodies. The fundamental Law, which is a basis for tariff regulation in Ukraine is the Law of Ukraine "On a single customs tariff" of February 5, 1992.[5] This law foresees the opportunity to introduce import and export duty, seasonal duty, special, antidumping and compensation duties, spells the rules for defining the country of commodity origin, the order of calculating customs value, exemption from import duty etc.

The Single Customs Tariff of Ukraine is a systemized group of duties, applied for commodities and other objects imported to the customs territory of Ukraine. A single tariff of Ukraine was enforced by the Decree of the Cabinet of Ministers of Ukraine N4-93 of January 11, 1993 "On a single customs tariff of Ukraine", which entered into force February 12, 1993.[6]

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[5] "Про Єдиний митний тариф" 05.02.1992 № **2097-XII**

The rates of the Single Customs Tariff of Ukraine are single for all the foreign trade business entities regardless of their ownership type, organization of economic activity and territorial location, except for the cases foreseen by Ukrainian legislation and Ukraine's international treaties.

Effective legislation foresees application of the following rates of import duty:

- preferential rates for the commodities manufactured in developing countries;
- preferential rates for the commodities manufactured in countries enjoying maximal favoring treatment in Ukraine;
- general rates for the commodities manufactured in other countries.

The list of countries where Ukraine signed agreements on free trade and of countries where Ukraine signed trade and economic agreements on most favored treatment and national treatment are listed in the Law of Ukraine "On making changes to selected legislative documents on the issues of applying import duties to commodities and other objects imported to the customs territory of Ukraine" of April 3, 1997.[7]

The order of fixing import duty rates is spelled out in the Law of Ukraine #171-XIV "On the order of fixing duty rates and collections (obligatory payments), other elements of tax bases, as well as tax preferences" of October 14, 1998.[8] According to this law, before the legal regulation of the issues on the Single Customs Tariff, the Cabinet of Ministers of Ukraine is authorized to fix or change import duty rates for the commodities imported to the Ukrainian territory, except for the rates of import duty for excised products within the groups 1-24 of the Harmonized System of Description

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[6] "Про Єдиний митний тариф України" 11.01.1993 № **4-93**

[7] "Про внесення змін до деяких законодавчих актів з питань обкладення ввізним митом товарів та інших предметів, що ввозяться на митну територію України" 03.04.1997 № **170/97-ВР**

[8] "Про порядок встановлення ставок податків і зборів (обов'язкових платежів), інших елементів податкових баз, а також пільг щодо оподаткування" 14.10.1998 № **171-XIV**

and Coding of Commodities spelled by the Ukrainian laws. In accordance with the Article 1 of the aforementioned Law of Ukraine, import duty in Ukraine will be set only by the Ukrainian parliament.

The presently existing Single customs tariff of Ukraine was changed by over 25 Laws of Ukraine and 70 Regulations of the Cabinet of Ministers, starting from the moment of its enforcement. The resulting changes affected 95% of tariff rates. Customs tariff policy of the state was aimed at liberalization of foreign trade and creation of a competitive environment for certain types of domestically made products.

Thus, in the year 2000, most regulations approved by the Cabinet of Ministers of Ukraine developed conjointly with the State Customs Service lowered the level of maximal import duty rate from 30% to 25% for the commodities within groups 25-97 of the Commodity Classification for Foreign Economic Activities. As regards light industry commodities, import duty rates were lowered by 10-15%, and even by 20% for selected commodities.

According to the calculations of the experts with the State Customs Committee, as of the moment, the average rate of import duty is at some 10%, and some 8% - for the light industry commodities. However, presently, there is no systemized group of import duty rates in Ukraine. Besides, the effective Single Tariff is based on an out-of-date system of commodity coding, which is not applied anywhere else in the world.

The State Customs Committee developed the draft of the new Customs Tariff[9], which is a systemized group of rates of import duty applied for the commodities imported to the customs committee of Ukraine. This new customs tariff is based on the Ukrainian classification of foreign trade

[9] "Про надіслання Закону України "Про митний тариф України"18.05.2001 № **2/14-2501-ЕП**

commodities. Adoption of the national classifier corresponding to international standards is one of the preconditions for Ukraine's participation in the international convention on the harmonized system of description and coding of products, as well as integration to the WTO.

The new document will invalidate scores of contradictory legislative acts, bringing Ukraine closer to the GATT-WTO system and easing access to world markets for Ukrainian exporters. The Uniform Customs Tariff consists of 21 chapters comprising 97 groups of goods and lists over 10,000 customs rates. The highest degree of goods specification is a 10-digit code, which stands for the goods subcategory and serves as a basis for the calculation of taxes and customs clearance of goods.

The new Uniform Customs Tariff imposes three kinds of customs tax rates (preferential, reduced and full), not two (reduced and full) as before. Preferential rates, including tax exemption, are imposed on goods imported from countries which are party to customs unions or customs zones with Ukraine or if stipulated by Ukraine's international agreements. Reduced rates are imposed for goods imported from countries or economic communities that award Ukraine a most-favored-nation status. Full rates usually exceed reduced rates two times. Full rates are imposed for goods imported from countries that do not award Ukraine a most-favored-nation status and for goods imported by Ukraine's natural persons. Many goods are subject to combined or special rates of the customs tax, namely, farming products, food, alcoholic beverages, cigarettes, consumer goods, cars, video equipment and other high-liquidity goods which are traditionally subject to lower taxes. These rates of the customs tax are set in Euro.

Ukraine has signed free trade agreements with each of the former Soviet republics, excluding Kyrgyzstan and Tajikistan. Ukraine participates in the Black Sea Cooperation Council, along with Albania, Armenia, Azerbaijan, Bulgaria, Georgia, Greece, Moldova, Romania, the Russian Federation, and

Turkey. Ukraine established a customs union with neighboring Moldova, as well as discusses a Baltic-Black Sea cooperation agreement. Ukraine intends to become a full member of the Central European Free Trade Agreement (CEFTA), which is predicated on Ukraine first becoming a member of the World Trade Organization. Ukraine is not planning to join the Commonwealth of Independent States customs union.

In the year 2000, for the first time since independence, Ukraine experienced positive growth. Ukrainian GDP grew by 6%, industrial output – by 12.9% and the real incomes of individuals – by 6.2%. Statistics for early 2001 seemed to confirm former expectations of positive macroeconomic changes. In January-March, for instance, GDP grew by 7.7%, real incomes – by 8.6%, industrial output – by 17.4%. This growth is the highest among all CIS members. A 19% growth of foreign trade, of which turnover totaled USD 33.4 billion, was an important component of economic development in 2000.

In the context of these encouraging trends, the integration of Ukraine into the global economic environment has become of exceptional importance. WTO membership is a key element of this integration. Today the effort of the Government is focused on the following objectives that were proposed and adopted at the 7th meeting of the Working Party (a working party of WTO members guides the accession process and negotiations for each membership applicant) and the informal meeting of December 11, 2000:

- implementation of the plan of harmonizing the national trade-related legislation with WTO rules and disciplines;
- speeding-up of bilateral market access negotiations;
- formulation of commitments on state support in agriculture.

The Governmental Commission on Ukraine's Accession to the WTO has done a comprehensive analysis of trade-related laws and normative acts. The purpose of the analysis was to find out the most 'WTO-sensitive' areas of trade, and to set up a schedule for adoption of the priority laws. A detailed schedule of the adoption of priority laws, together with the required reference materials, were presented in a package that was submitted to the WTO Secretariat on March 26, 2001. The package is structured in a way that was agreed on at the informal meeting on December 11, 2000. The package consists of a schedule of adoption of Ukrainian legislation required for harmonization with WTO rules and disciplines.

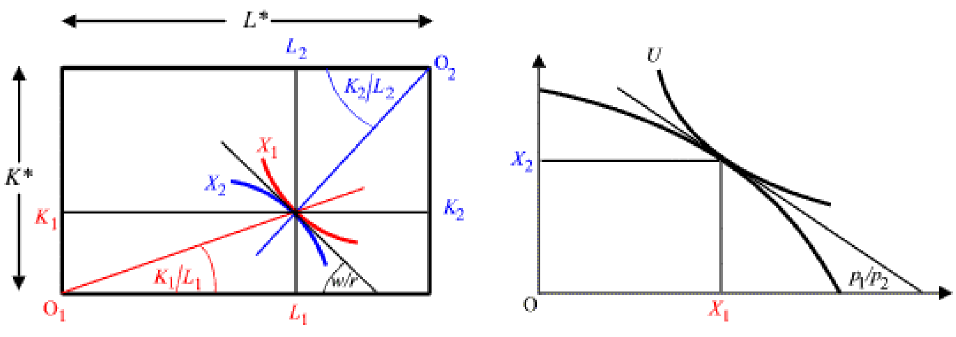
The schedule consists of 20 draft laws that directly relate to the implementation of WTO requirements. Two of them have already been adopted by the Parliament, namely the Law "On Amendment of Certain Laws on the Reinforcement of Responsibility for Violation of Intellectual Property Rights" and a new reading of the Law "On Protection of Rights to Inventions and Utility Models". Among 7 draft laws, which passed the first reading in the Parliament, are the Customs Code and the Tax Code, as well as laws on standardization, on recognition of conformity assessments, and on accreditation of conformity assessment bodies.

THE COMPUTABLE GENERAL EQUILIBRIUM MODEL: METHODOLOGY AND ESTIMATION

CGE models are microeconomic simulation models. They are applied to a wide range of issues, among them: trade policy, taxation design, economic development and environmental issues. CGE models figure(d) prominently in the analysis of compliance with the Kyoto Protocol, the Uruguay Round of trade negotiations, the FTA, expansion of NAFTA, and analysis of farm supports and industrial policy.

The specification of a simple Computable General Equilibrium (CGE) Model

The following diagrammatic representation shows the general equilibrium in the closed economy model with 2 goods, 2 mobile factors of production and a single 'representative household', under the standard assumptions of universal perfect competition and constant returns to scale.



Source: "Applied General Equilibrium Modelling" 2000, http://www.nottingham.ac.uk/~lezgr/teaching/CGE/lectures_1&2.htm

Figure 1 Closed 2 good, 2 factor, 1 household economy with perfect competition and constant returns to scale

On the diagram (X_1, $\boldsymbol{X_2}$) are outputs/consumption of the two goods, (K_1, L_1, $\boldsymbol{K_2}$, $\boldsymbol{L_2}$) - inputs of the two factors, (K^*, L^*) - factor endowments, (w/r) - relative factor prices, ($p_1/\boldsymbol{p_2}$)- relative goods prices, (K_1/L_1, $\boldsymbol{K_2/L_2}$) - factor intensity ratios. It can be inferred from the diagram that one good/factor is the numeraire (Walras Law), factors are fully employed, factor prices are common across sectors, and demand equals supply for both goods. Given this, values of outputs and factor payments can be obtained. This diagram also shows that profits in long run are zero, household receives income from factors, household spends all income on consumption (no savings), marginal products of factors are determined uniquely by K/L ratios, and factor payments are determined by marginal products.

The model described is derived from one given in Dinwiddy and Teal (1988, Table 4.1, p. 55). It uses Cobb-Douglas functions for both production and preferences in a 2-good, 2-factor closed economy with universal perfect competition. Household income is Y, consumption quantities are identified by C_1, $\boldsymbol{C_2}$, and **unit** factor inputs are k_1, l_1, $\boldsymbol{k_2}$, $\boldsymbol{l_2}$. The assumptions that there are constant returns to scale and perfect competition have two important implications. First, long-run profits are necessarily zero (Euler's Theorem). Second, we cannot define a supply function for either producing sector.

If the production functions are

$$X_1 = K_1^{1/4}L_1^{3/4}$$

$$X_2 = K_2^{1/2}L_2^{1/2},$$

and the household utility function is

$$U = C_1^{1/2}C_2^{1/2},$$

then we may derive the following:

COMMODITY MARKETS

Demand

$$C_1 = \frac{Y}{2p_1} \qquad (1)$$

$$C_2 = \frac{Y}{2p_2} \qquad (2)$$

Unit price equations

$$p_1 = rk_1 + wl_1 \qquad (3)$$

$$p_2 = rk_2 + wl_2 \quad (4)$$

Market clearing

$$C_1 = X_1 \quad (5)$$

$$C_2 = X_2 \quad (6)$$

FACTOR MARKETS

Demand

$$k_1 = \left(\frac{1}{3}\frac{w}{r}\right)^{\frac{3}{4}} \quad (7)$$

$$K_1 = k_1 X_1 \quad (8)$$

$$l_1 = \left(3\frac{r}{w}\right)^{\frac{1}{4}} \quad (9)$$

$$L_1 = l_1 X_1 \quad (10)$$

$$k_2 = \left(\frac{w}{r}\right)^{\frac{1}{2}} \quad (11)$$

$$K_2 = k_2 X_2 \quad (12)$$

$$l_2 = \left(\frac{r}{w}\right)^{\frac{1}{2}} \quad (13)$$

$$L_2 = l_2 X_2 \quad (14)$$

Market clearing

$$K_1 + K_2 = K^* \quad (15)$$

$$L_1 + L_2 = L^* \quad (16)$$

HOUSEHOLD INCOME

$$Y = rK^* + wL^* \quad (17)$$

The 17 endogenous variables are:

$P_1, P_2, w, r, C_1, C_2, X_1, X_2, k_1, k_2, K_1, K_2, l_1, l_2, L_1, L_2, Y$.

However, the 17 equations are not independent (Walras' Law), so we must choose one good or factor as the numeraire. Dinwiddy & Teal offer the following solution to this problem for $K^* = 0.8$, $L^* = 2.0$ when the wage rate *w* is chosen as the numeraire.

$$P_1 = 1.95, P_2 = 2.46$$
$$r = 1.52, w = 1$$
$$C_1 = X_1 = 0.82, C_2 = X_2 = 0.65$$
$$K_1 = 0.26, K_2 = 0.53$$
$$L_1 = 1.20, L_2 = 0.80$$

In order to set up such a model for a 'real' economy so that it reflects the current state of affairs, data on factors and goods is needed. It is very hard to obtain factor and goods prices, factor uses and outputs – in particular because in working with such a low dimension model it is necessary to aggregate industries. It is possible, though, to find data in value terms – output values, payments to factors, household income and expenditure. From such data we can construct a Social Accounting Matrix (SAM) that records, in an internally consistent manner, financial flows between producers, factor owners and so on.

A Social Accounting Matrix is a comprehensive, economy-wide data framework, typically representing the economy of a nation. More technically, a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the account of its row – the incomes of an account appear along its row, its expenditures along its column. The underlying principle of double-entry accounting requires that, for each account in the SAM, total revenue (row total) equals total expenditure (column total).

The CGE model explains all the payments that are recorded in the SAM. Consequently, the model follows the SAM disaggregation of factors, activities, commodities, and institutions. It is written as a set of simultaneous equations, many of which are non-linear. There is no objective function. The equations define the behavior of the different actors. In part, this behavior follows simple rules captured by fixed coefficients (for example, *ad valorem* tax rates). For production and consumption decisions, behavior is captured by non-linear, first-order optimality conditions. The equations also include a set of constraints that have to be satisfied by the system as a whole but which are not necessarily considered by any individual actor. These constraints cover markets (for factors and commodities) and macroeconomic aggregates (balances for savings-investment, the government, and the current account of the rest of the world).

The resulting model should be calibrated, i.e. the parameters in the model should be chosen so that they are consistent with the data in the SAM. In general, the Cobb-Douglas production functions used in the Dinwiddy & Teal model may be written as

$$X_1 = AK_1^{\alpha}L_1^{1-\alpha}$$

$$X_2 = BK_2^{\beta}L_2^{1-\beta}$$

and the household utility function as

$$U = X_1^{\theta}X_2^{1-\theta}$$

Each producer (represented by an activity) is assumed to maximize profits, defined as the difference between revenue earned and the cost of factors and intermediate inputs. Profits are maximized subject to a production technology, the structure of which is shown in Figure 2. At the top level, the technology is specified by a CES or, alternatively, a Leontief function of the quantities of value-added and aggregate intermediate input. The Leontief alternative is the default. The CES alternative may be preferable in particular sectors if empirical evidence suggests that available techniques permit the aggregate mix between value-added and intermediate inputs to vary. Value-added is itself a CES function of primary factors whereas the aggregate intermediate input is a Leontief function of disaggregated intermediate inputs.

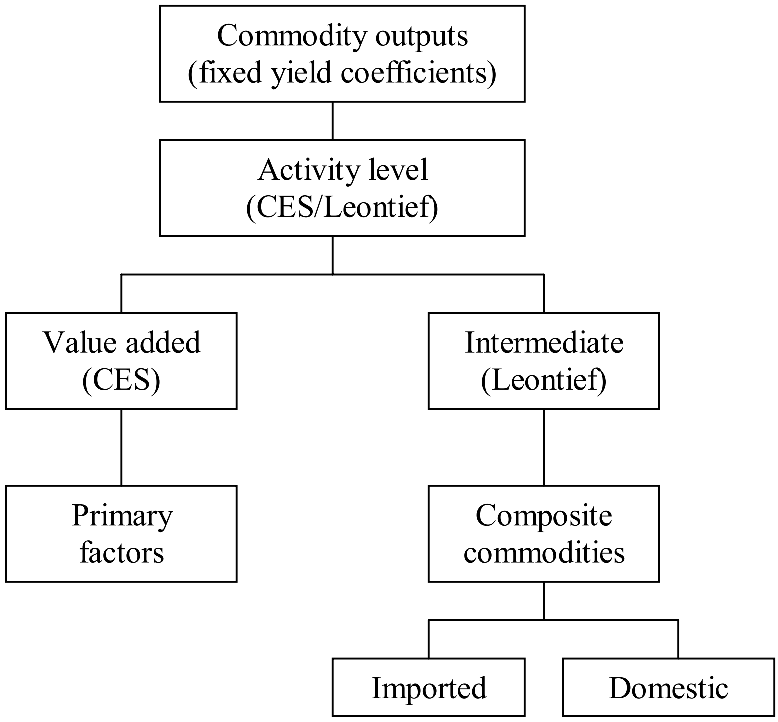


Figure 2—Production technology

Each activity produces one or more commodities according to fixed yield coefficients. (As noted, any commodity may be produced by more than one activity.) The revenue of the activity is defined by the level of the activity, yields, and commodity prices at the producer level.

As part of its profit-maximizing decision, each activity uses a set of factors up to the point where the marginal revenue product of each factor is equal to its wage (also called factor price or rent). Factor wages may differ across activities, not only when the market is segmented but also for mobile factors. In the latter case, the model incorporates discrepancies that stem from exogenous causes (for example wage differences across activities due to considerations such as status, comfort, or health risks).

Household consumption covers marketed commodities, purchased at market prices that include commodity taxes and transactions costs, and home commodities, which are valued at activity-specific producer prices. Household consumption is allocated across different commodities (both market and home commodities) according to Linear Expenditure System (LES) demand functions. Instead of being paid directly to the households, factor incomes may be paid to one or more enterprises. Enterprises may also receive transfers from other institutions. Enterprise incomes are allocated to direct taxes, savings, and transfers to other institutions. Enterprises do not consume. Apart from this, the payments to and from enterprises are modeled in the same way as the same payments to and from households.[10]

With perfect competition, each factor is paid the value of its marginal product (and with constant returns to scale, the total value of output is equal to the total payments to factors of production). So for sector 1

$$r = p_1 \frac{\partial\left(AK_1^{\alpha} L_1^{1-\alpha}\right)}{\partial K_1} = p_1 \alpha A K_1^{\alpha-1} L_1^{1-\alpha} = p_1 \alpha \frac{X_1}{K_1}$$

so that

$$\alpha = \frac{rK_1}{P_1 X_1}$$

That is, α is the share of sector 1 revenue that is paid to capital.

To calibrate A and B we need to assume prices = 1, so that the values in the SAM become quantities. Then

$$A = \frac{X_1}{K_1^{\alpha} L_1^{1-\alpha}}$$

In the simple small open economy model we have five new variables: 2 quantities – E (the exports of good 1) and $\boldsymbol{M}$ (the imports of good 2), two prices – p_1^{W}, $\boldsymbol{p_2^{W}}$ (the world prices of goods 1 and 2), and the exchange rate, F (a relative price). The two world prices are exogenous, but the exchange rate is endogenous.

[10] "Applied General Equilibrium Modelling" 2000, lecture notes, http://www.nottingham.ac.uk/~lezgr/teaching/CGE/lectures_1&2.htm

There are new market clearing equations:

$$C_1 = X_1 - E$$

$$C_2 = X_2 + M$$

and foreign sector price equations and balance of payments constraint

$$p_1 = p_1^W F$$

$$p_2 = p_2^W F$$

$$p_1^W E - p_2^W M = 0$$

The 20 endogenous variables are

$p_1, p_2, w, r, C_1, C_2, X_1, X_2, k_1, k_2, K_1, K_2, l_1, l_2, L_1, L_2, Y, E, M, F$.

The exogenous variables are

K^*, L^*, p_1^W, p_2^W.

We also need to introduce taxes and subsidies to the model. All taxes and subsidies create two prices, separated by the tax/subsidy 'wedge'. For example, with a domestic indirect tax on a good the price received by the producers is lower than that paid by the household(s), while with an import tariff the domestic price of the good is above the world price. Taxes and subsidies may be either 'specific', for example, in the case of a domestic indirect tax on good 1, $p_1^C = p_1^P + T$, or '*ad valorem*', e.g. $p_1^C = p_1^P(1 + t)$, where in both cases p_1^C is the price paid by consumers and p_1^P is the price received by producers.

Tax revenue is received by the government, and is subsequently spent/transferred by the government (subsidy expenditures are met by the government, which must raise the revenue from somewhere), so we need to model these two activities. In simple models it is usually assumed that the government has a balanced budget (tax revenue = government expenditure/transfers). Many simple models assume that the government simply transfers any net income to the household as a lump-sum payment (or raises any revenue needed to pay for subsidies by a lump-sum tax on households); this is consistent with the basic textbook analysis of fiscal policy). More sophisticated models model the government as spending any net revenue according to its own preference (utility) function so that its expenditure is modelled in a way similar to that of a consumer.

The new price equation is

$$p_2 = p_2^W F(1+t)$$

GOVERNMENT SECTOR

Tariff revenue

$$R = t(p_2^W F)M$$

Government budget constraint

$$R - G = 0$$

The 22 endogenous variables are

$p_1, p_2, w, r, C_1, C_2, X_1, X_2, k_1, k_2, K_1, K_2, l_1, l_2, L_1, L_2, Y, E, M, F, G, R$.

There are 4 exogenous variables, K^*, L^*, p_1^W, $\boldsymbol{p_2^W}$, and one exogenous 'policy' variable, the tariff rate *t*.

The use of intermediates is usually modelled as a 2 stage (nested) process. The standard assumption is that the use of (each of the) intermediates is a constant proportion of the output of the final good (i.e. Leontief), and that value is added to these intermediates by the use of factors of production. There is no substitution between intermediates and value–added by factors (i.e. Leontief again), but factors may be substituted for one another as in a standard production function (e.g. Cobb-Douglas or CES).

A basic trade (GE) theorem states that, with homogenous goods, the number of traded goods that a small open economy can produce is less than or equal to the number of distinct factors (no limit on number of non-traded goods). This underlies the specification in many models that at least one factor is sector-specific, and that goods are differentiated by their country of origin (the Armington Assumption). The main reason for the use of the Armington Assumption is that in many SAMs cross-hauling is observed (the 'simultaneous' importing and exporting of the 'same' good). This can only be accommodated by assuming that goods are differentiated or that there is oligopolistic competition.

The modelling of this is broadly as follows (assuming one Armington importable, one 'normal' exportable).

1. Consumers decide on the allocation of expenditure between the normal and the Armington good on the basis of income, the price of the normal good and the 'average price' of the Armington good.

2. They then allocate expenditure on the Armington good based on the relative prices of the domestic and imported varieties.

Such modeling implies that there is imperfect transmission of changes in the 'world price' of the Armington good to the domestic price of that good. It is also likely to give 'exaggerated' terms-of-trade changes when (trade) policy instruments are introduced.

With the exception of home-consumed output, all commodities (domestic output and imports) enter markets. Figure 3 shows the physical flows for marketed commodities and associated quantity and price variables.

Domestic output may be sold in the market or consumed at home. For marketed output, the first stage in the chain consists of generating aggregated domestic output from the output of different activities of a given commodity. These outputs are imperfectly substitutable, for example because of differences in timing, quality, and location between different activities. A Constant-Elasticity-of-Substitution (CES) function is used as aggregation function. The demand for the output of each activity is derived from the problem of minimizing the cost of supplying a given quantity of aggregated output subject to this CES function. Activity-specific commodity prices serve the role of clearing the implicit market for each disaggregated commodity.

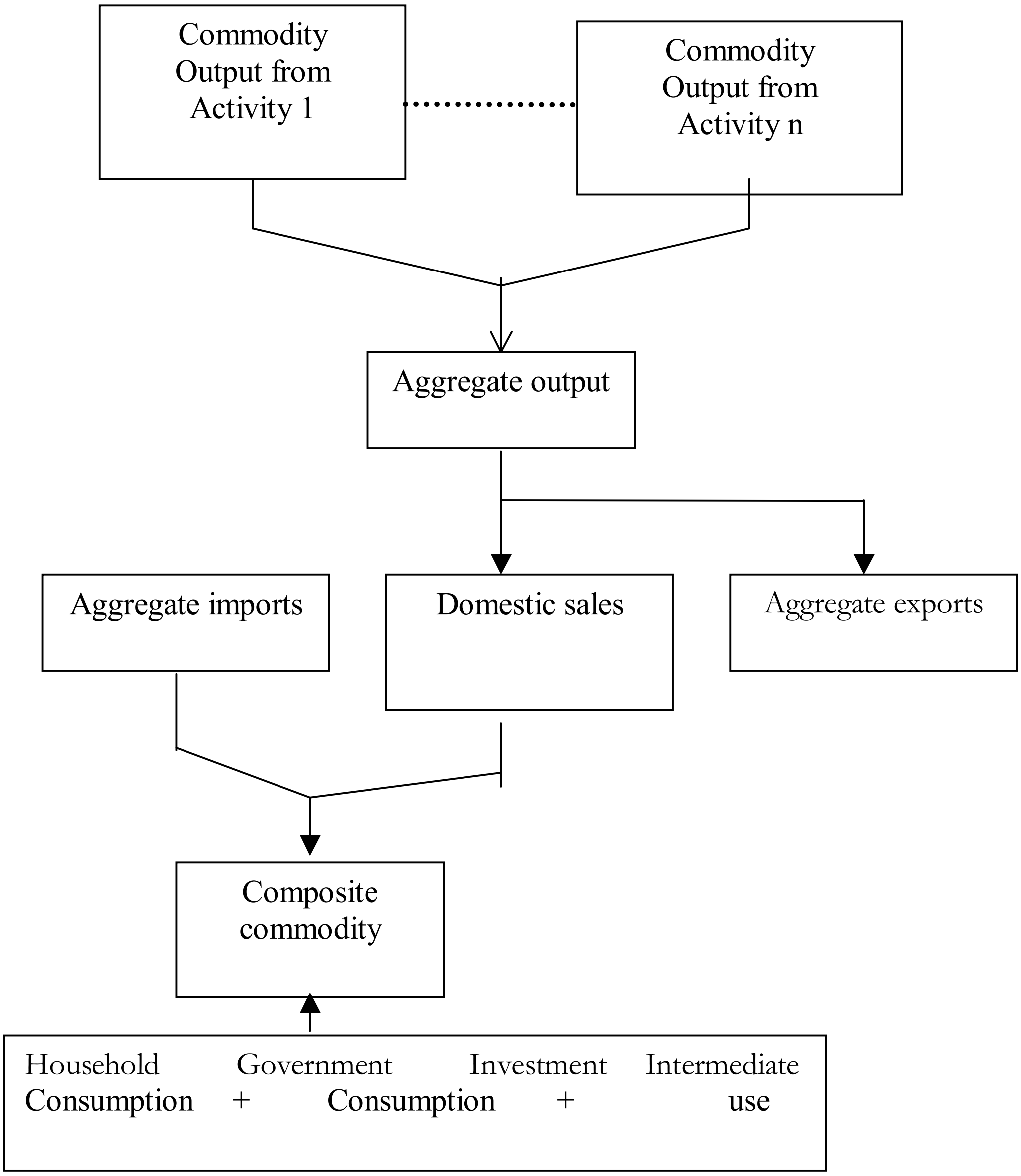


Figure 3. Physical flows for marketed commodities.

Chapter 5

DATA DESCRIPTION

A 1999 table is provided by Ukraine's State Committee of Statistics (Derzcomstat). Converting a particular IO table into a general economic equilibrium model may bring several problems. At first, different IO tables may have different formats, not exactly corresponding to an IO table described by Leontieff (1936). In regard to that, a modeler faces the question of interpreting different rows and columns. Second, assumptions on the nature of equilibrium, particular functional forms, elasticities, etc., should be made.

The original 1999 Ukraine IO table is different from the Eurostat standard. It allows me to highlight possible adjustments. For compactness, I have made several changes to the original IO table including aggregation of 13 sectors of industry into one industry sector and other minor changes. An aggregated IO table is presented in Appendix B. In order to fit this into paper size, Table B is divided into four subtables. Tables B.1, B.2, and B.3 correspond to Table's A Matrices A, D, and B, respectively. Table B.4 does not exactly fit into the Eurostat standard. It represents taxes, margins, and imports evaluated at basic prices to convert the output into basic prices. The available data on imported goods is aggregated, and I have no information on Matrices D and E. Another important issue is that the IO table is not balanced. Here I make an assumption that the IO data represents an equilibrium and statistical errors occurred during the collection of the data. In this case, statistical errors should be corrected by balancing the IO table in the way described later in the paper.

Table B corresponds with Table A in the following way. Rows in the Tables B.1, B.3, and B.4 are identical. They represent production sector outputs, which are used as intermediate inputs for other sectors and in final consumption. Rows in Table B.2 show the other factors of production, such as capital and labor, depreciation, indirect taxes, and other adjustments. Columns in Tables B.1-B.3 represent demanders of factors of production: intermediate consumers (production sectors which use an output of production sectors as intermediate inputs), final consumers (households and government), investment, and export. Looking along a particular column of Tables B.1 and B.2, one can see how inputs are used for production in a certain sector.

Chapter 6

EMPIRICAL WORK

From Appendix B, there are 19 parameters: one 9x9 matrix of intermediate demand, and the other 11 columns and 7 rows (excluding rows and columns representing subtotals and totals). Three rows, *Net Profit, Net Mixed Income,* and *Depreciation* will be combined into one GAMS parameter, *Gross return to capital*. As a result of iodata.gms program, a dataset file ukraine.dat with 17 GAMS parameters is created. In the process of creating the dataset file, several checks of corrrectness of data transfer are made. For convenience, I move from a numeric to symbol representation of the sectors and make an adjustment in the data, dividing it by 100.

The program iodata.gms has the following structure (see Appendix C.1 for a file listing). After reading data into GAMS format with xlimport utility (Appendix C.1, row 4), a single parameter IODATA is created (App.C.1, row 5). The next step is to transfer data into appropriate parameters of a dataset file. As such, we need to declare all 19 parameters (App.C.1, rows 6-7).

To do the transfer from IODATA parameter, a set MAP(N,I) is used where N is a number representation of industries and I is a symbol representation (App.C.1, row 8). For intermediate demand it is done as:

$$iod_{ij} = \frac{\sum_{n}\sum_{m} iodata_{nm}}{100} \text{ (App.C.1, row 13).}$$

For row based parameters:

$$wages_i = \frac{\sum iodata_{11,n}}{100} \text{ (App.C.1, row 14).}$$

And for column based parameters:

$$consum_i = \frac{\sum iodata_{n,11}}{100} \text{ (App.C.1, row 23).}$$

Then we check to see if the transfer was correct by comparing major rows and columns in GAMS and Excel files (App.C.1, rows 36-40).

The same type of checks is done for all subtotals and totals (App.C.1, rows 43-63).

Table 1. Check of total use.

	gross value added	value added check	total use	check of total use	total use at basic prices	check of total use at basic prices
manufact	1820.03		2187.45		1298.07	1778.76
construct	87.48		144.03		113.35	61.36
agricultur	204.99		440.67		398.02	85.3
transport	195.27		294.69		254.18	81.02
trade	154.16		207.02	3.16	178.41	60.38
commun	105.72	-1.42E-14	151.25		149.71	3.08
education	165.92		161.53		160.92	1.22
finance	30.38		40.15		36.57	7.16
other	175.67	-2.84E-14	234.27	-3.16	194.13	77.12
Sum			3861.06		2783.36	

Then a profit check is performed. It shows the difference between total input and total output for every sector.

$$prchk_{j,output} = \sum_i iod_{ij} + grvad_j \text{ (App.C.1, row 66),}$$

$$prchk_{i,use} = usetotbas_i \text{ (App.C.1, row 67),}$$

$$prchk_{i,chk} = prchk_{i,use} - prchk_{i,output} \text{ (App.C.1, row 68).}$$

Table 2. Profit check.

	check	output	use
manufact	-1664.16	2962.23	1298.07
construct	-33.53	146.88	113.35
agricultur	-67.83	465.85	398.02
transport	-41.58	295.76	254.18
trade	-55.19	233.6	178.41
commun	-48.54	198.25	149.71
education	-65.2	226.12	160.92
finance	-10.11	46.68	36.57
other	-90.07	284.2	194.13
total profit	-2076.21	4859.57	2783.36

Because the IO table is not balanced, an adjustment is done. Return to capital is modified by the amount of difference between inputs and outputs. We compute net profit, mixed income, and depreciation into one parameter of gross return to capital. If return is negative, we adjust the corresponding wage account. As such, gross value added equals to a sum of non-negative return to capital, wages, and social security contributions.

$$return_i = prchk_{i,chk} + deprec_i + profit_i + mixed_i \text{ (App.C.1, row 81)}$$

$$wages_i = wages_i + \min\{0, return_i\} \text{ (App.C.1, row 82)},$$

$$return_i = \max\{0, return_i\} \text{ (App.C.1, row 83)},$$

$$va_i = return_i + wages_i + soc\sec_i \text{ (App.C.1, row 84)}.$$

Table 3. Gross value added calculations.

	gross return to capital	wage payments	max{0, return}	value added
manufact	-45.75	155.05	0	159.83
construct	10.17	35.02	10.17	53.66

agricultur	83.35	42.58	83.35	135.42
transport	75.7	62.84	75.7	152.15
trade	39.14	48.6	39.14	91.34
commun	18.7	28.85	18.7	56.16
education	3.88	72.21	3.88	100.39
finance	8.65	10.06	8.65	19.91
other	-20.84	56.58	0	84.57

Then a check of data is done to make sure that we balanced an IO table.

$$prchk_{j,balanced} = va_j + othtax_j - subsidy_j + \sum_i iod_{ij} - prchk_{j,use}$$

(App.C.1, row 85).

Table 4. Check of balancing an IO table.

	check	output	use	balanced
manufact	-1664.16	2962.23	1298.07	
construct	-33.53	146.88	113.35	1.42109E-14
agricultur	-67.83	465.85	398.02	
transport	-41.58	295.76	254.18	
trade	-55.19	233.6	178.41	
commun	-48.54	198.25	149.71	
education	-65.2	226.12	160.92	
finance	-10.11	46.68	36.57	
other	-90.07	284.2	194.13	-2.8422E-14

In terms of Table A.1, the balance means that there is an exact correspondence between Matrices C and J. After checking that the data is balanced, relevant GAMS parameters are created using gams2prm utility (App.C.1, rows 89-105). The result is a file, ukraine.dat, with the data assigned to all 19 parameters (App.C.1, rows 87-88). We use ukraine.dat file as our dataset file. The program which reads the data from the dataset, prepares it for a static model, and describes the static model in MPSGE format is model.gms (see Appendix C.2 for a file listing).

At first, we simply read the data into one array and copy it into another, e.g. $export_i$ is copied into $x0_i$ (App.C.2, row 9). This is done simply due to the preference to use shorter identifiers in the MPSGE model. At the same time, the other assignment to the static model parameters are made in the following way. For private consumption, investment and government:

private consumption $= c0 = \sum_i consum_i$ (App.C.2, rows 7-8),

investment $= i0 = \sum_i (stock_i + fixedi_i)$ (App.C.2, rows 13-14),

government output $= g0 = \sum_i govdem_i$ (App.C.2, rows 15-16).

For export and import:

import tariff $= tm_i = \dfrac{imptax_i}{import_i}$ (App.C.2, row 11),

benchmark import price $= pm0_i = 1 + tm_i$ (App.C.2, row 12).

For capital, labor, labor tax, and labor reference price, accordingly:

capital supply $= ks0 = \sum_i return_i$ (App.C.2, rows 17-18),

labor supply $= ls0 = \sum_i wages_i$ (App.C.2, rows 19-20),

social security tax $= tl_i = \dfrac{soc\sec_i}{wages_i}$ (App.C.2, row 21),

benchmark gross wage $= pl0_i = 1 + tl_i$ (App.C.2, row 22).

For trade and transportation margins:

trade margin $= trd_i = \max\{0, trade_i\}$ (App.C.2, row 24),

transport margin $= trn_i = \max\{0, trnspt_i\}$ (App.C.2, row 25),

$margin_i = \max\{0, -trade_i\} + \max\{0, -trnspt_i\}$ (App.C.2, row 26).

For Armington supply, VAT and net taxes:

Armington supply =

$$a0_i = \sum_j (input - outputDemand)_{ij} +$$
$$(privateConsumption)_i + (governmentDemand)_i + (investmentDemand)_i$$

(App.C.2, row 28),

VAT rate = $ta_i = \dfrac{vat_i}{a0_i}$ (App.C.2, row 29),

net tax on goods = $tn_i = \dfrac{nettax_i}{a0_i}$ (App.C.2, row 30).

For domestic sales and indirect production taxes:

domestic sales = $d0_i = a0_i(1 - ta_i - tn_i) - pm0_i * (imports)_i - trn_i - trd_i$ (App.C.2, row 31),

output tax = $ty_i = \dfrac{(othtax_i - subsidy_i)}{(d0_i + margin_i + (exports)_i)}$ (App.C.2, row 32).

For balance of payment:

balance of payments deficit = $bopdef = \sum_i (imports_i - exports_i)$ (App.C.2, row 36).

The template static general equilibrium model in model.gms contains a minimal set of elements to illustrate the data. The general equilibrium model is intended to be as standard as possible. A representative agent is endowed with primary factors (labor, capital). Investment demand, public provision, and the balance of payments deficit are held constant. After selling primary factors, purchasing investment and public provision, the remaining income is devoted to private consumption. The MPSGE code equalizes domestic demand and supply using the following formulae (App.C.2, row 58):

$$(d0_i + margin_i)*\left(\frac{PD_i}{\left(\theta d_i * PD_i^{1+\eta} + (1-\theta d_i)*PX_i^{1+\eta}\right)^{\frac{1}{1+\eta}}}\right)^{\eta} * Y_i =$$

$$= A_i * d0_i * \left(\frac{C\_A1_i}{PD_i}\right)^{dm} + \left(\sum_j A_j * trdmrg_j\right) + \left(\sum_j A_j * trnmrg_j\right),$$

where $d0_i$ – domestic sales; PD_i – domestic price; θd_i - domestic share; PX_i – export price; η - elasticity of transformation between domestic output and exports; Y_i – output; A_i – Armington aggregation of domestic and imported goods; C_A1_i – Armington aggregation; dm – elasticity of substitution between domestic and imported goods; trdmrg and trnmrg – trade and transport margins.

Here Armington aggregation is computed using the following formulae:

$$C\_A1_i = ((1-\theta m_i)*PD_i^{1-dm} + (\theta m_i)*PM_i^{1-dm})^{\frac{1}{1-dm}},$$

where θm – import share; PD – domestic price; PM – import price.

Investment and public output aggregates are both Leontief aggregates across Armington composites of domestic and imported goods. All users are based on an identical CES aggregation of imports and domestic varieties. These functions are:

Public output equilibrium condition (App.C.2, row 55)

$$g0 * \sum_i PA_i^{\theta g_i} = PG * g0,$$

where g0 – government output; PA – Armington composite price; θg_i - government share; PG – public provision.

Investment equilibrium condition (App.C.2, row 56)

$$i0 * \sum_i PA_i^{\theta i_i} = PINV * i0,$$

where i0 – investment; θi – investment share; PINV – investment price.

Private consumption is a Cobb-Douglas aggregation of goods, defined in the model as (App.C.2, row 57):

$$c0 * \prod_i PA_i^{\theta p_i} = PC * c0,$$

where c0 – private consumption; θp – private share; PC – private demand.

The Armington aggregation sector combines domestic and imported varieties and applied trade and transport margins. There is an elasticity of substitution equal to 4 between domestic and imported goods. This function is defined as follows (App.C.2, row 52):

$$\left(d0_i + \left(pm0_i * m0_i\right)\right) * C\_A1_i + trdmrg_i * PD + PD * trnmrg_i =$$
$$= (1 - ta_i - TAU - tn_i) * PA_i * a0_i$$

where d0 – domestic sales; pm0 – benchmark import price; m0 – imports (gross of tariff); trdmrg – trade margin; trnmrg – transport margin; ta – VAT rate; TAU – tax adjustment; PA – Armington composite price; a0 – Armington supply.

$$a0_i * A_i = \sum_j (iod_{ij} * Y_j) + cd0_i * \frac{\prod_j PA_j^{\theta p_j}}{PA_i} * C + gd0_i * G + id0_i * INV$$

where Y – output; cd0 – consumption demand; C – private consumption; gd0 – government demand; G – public provision; id0 – investment demand; INV – investment.

The production of goods follows from a nested Leontief-Cobb Douglas production function. Output is allocated to the domestic and export markets according to a constant elasticity of transformation. Intermediate inputs are Leontief, while labor and capital enter as a Cobb-Douglas value-added aggregate, identified as nest "va:" in the MPSGE production block (App.C.2, row 51):

$$\sum_j (iod_{ij} * PA_j) + kd0_i * \left(\frac{PL * (1 + tl_i)}{pl0_i}\right)^{\theta l_i} * PK^{\theta k_i} + ld0_i * pl0_i * \left(\frac{PL * (1 + tl_i)}{pl0_i}\right)^{\theta l_i} *$$
$$* PK^{\theta k_i} = (1 - ty_i)\left(\left(PD_i * (d0_i + margin_i)\right) + PX_i * x0_i\right)$$

where iod – input-output demand; PA – Armington composite price; kd0 – capital demand; PL – wage rate; tl – social security tax; pl0 – benchmark gross wage; θl – labor share; θk – capital share; PK – return to capital; ld0 – labor demand; ty – output tax; PD – domestic price; d0 – domestic sales; PX – export price; x0 – exports.

Finally, income balance condition is specified:

Expenditure = Income

Income balance

Expenditure =

$= RA = PL * ls0 + PK * ks0 + PFX * bopdef - PINV * i0 - PC * dt$,

Income =

$$GOV = PC * dt + \sum_i [ty_i * Y_i * (PX_i * A\_X_i + PD_i * A\_D_i)] +$$
$$+ \sum_i [(ta_i + TAU) * PA_i * a0_i * A_i] + \sum_i [tn_i * PA_i * a0_i * A_i] +$$
$$+ \sum_i [tl_i * PL * A\_L_i * Y_i] + \sum_i [tm_i * PFX * m0_i * M_i]$$

where tm – import tariff rate; PFX – foreign exchange; dt – direct tax;

second part of GOV – output tax;

third part – VAT;

fourth part – net taxes on goods;

fifth part – labor tax;

sixth part – import tax.

Here direct tax is (App.C.3, rows 3-4):

$$dt = g0 - \left(\sum_i ((ta_i + tn_i) * a0_i + tm_i * m0_i + tl_i * ld0_i + ty_i * (d0_i + margin_i + x0_i) \right)$$

$$A\_X_i = x0_i * \left(\frac{PX_i}{\left(\theta d_i * PD_i^{1+\eta} + (1 - \theta d_i) PX_i^{1+\eta}\right)^{\frac{1}{1+\eta}}} \right)^{\eta},$$

where θd – domestic share.

$$A\_D_i = (d0_i + margin_i) * \left(\frac{PD_i}{\left(\theta d_i * PD_i^{1+\eta} + (1-\theta d_i) PX_i^{1+\eta}\right)^{\frac{1}{1+\eta}}} \right)^{\eta}$$

$$A\_L_i = ld0_i * \left(\frac{PL*(1+tl_i)}{pl0_i} \right)^{\theta l_i} * \frac{PK^{\theta k_i}}{\left(\frac{PL*(1+tl_i)}{pl0_i} \right)}$$

The model outlined above contains certain assumptions about the basic structure of the economy and a behavior of economic agents. In this model, choices are consistent with optimization and market clearing. That is, a government can change relative prices using different tax instruments. Then consumers and producers adjust their optimal behavior based on the new set of prices (the procedure of general equilibrium calculation see in Appendix D).

The program computes and displays a listing of the benchmark tax rates (in %) for all sectors. As one can see from Table 5, these rates exhibit a high variance across sectors. Tax rates are calculated based on IO information. They do not represent statutory rates.

Table 5. Calculated rates of different tax instruments.

	VAT tax	Net tax on goods	Social security tax	Import tariff	Output tax
Manufacturing	4	4	3	2	
Construction	15		24		
Agriculture	4		22	6	
Transport	14	-2	22		1
Trade	4		7		4
Communal services	6	-10	30		1
Education	1	-1	34		

Finance			12		1
Others	3		49		1

Taxes distort decisions made by economic agents. One measure of the distortion is an excess burden. The excess burden is defined as a reduction in utility in addition to the amount taken by the government if it uses a lump-sum taxation. As such, a total burden of a tax is equal to a sum of a tax burden (an amount which consumer actually pays) and the excess burden (extra loss of utility). The excess burden arises when a behavior of the economic agents changes due to introduction of taxes. The excess burden increases with the square of a tax rate.

Excess burden can be evaluated using a Hicksian equivalent variation. For this, I compute a Hicksian money-metric welfare index for a consumer and compare welfare level in a benchmark with a counterfactual calculation. Change in welfare is

$$EV = 100 * \frac{W_1 - W_0}{W_0},$$

where W_0 is a benchmark welfare level and W_1 is a welfare level after introduction or removal of a tax.

If, in a presence of an existing tax, a government decides to raise an additional tax revenue, then the change in excess burden per hryvna of extra revenue constitutes a Marginal Excess Burden (MEB). MEB is defined as the percentage efficiency cost of a marginal transfer of funds from the private consumer to the government using the specified tax instrument. It means that if the MEB of, for example, import tax is 15 per cent, then for every 100 hryvnas raised by the Ukrainian government through import tax, Ukrainian consumers *effectively* pay 15 hryvnas in addition to the 100 that they transfer to the government. These extra costs are not paid literally to the government, but reflect lower standards of living due to higher prices and resource misallocation induced by the increase in taxes.

I compute MEB of different tax instruments in the following way. A government, as a separate economic agent who collects taxes and demands government goods, is introduced. Then, I increase a government spending by 1 per cent and calculate a change in the excess burden as:

$$MEB = 100 * \frac{(W_0 - W_1) - (G_1 - G_0)}{G_1 - G_0},$$

where G_0 is a benchmark level of a government spending and G_1 is a level of a government spending in a counterfactual experiment. For a consistent comparison with a money-term government spending, the change in consumer welfare is measured by means of money-metric utility concept, such as equivalent variation.

The results of the MEB calculations, based on different elasticities of transformation between domestic output and exports, η, and elasticities of substitution between domestic goods and imports, σ, are presented in Table 6. Based on the core model, I find that import tax is relatively costly. The MEB of all other tax instruments is approximately the same with small differences. Output tax is relatively efficient. Import tax is particularly costly with a MEB of 9 – 14% depending on different elasticities. Import tax imposes a higher distortion cost than other tax instruments because it favors domestic production over imports (elasticities are chosen according to (Rutherford and Paltsev 1999)).

Table 6. Marginal Excess Burden in a core model

η	σ	Output taxes	Social security tax	Value added tax	Net taxes on goods	Import tax
1	4	3.191	9.178	9.482	9.482	9.689
1	16	10.399	10.343	10.274	10.399	10.951
4	4	14.053	14.049	14.053	14.053	14.079

4	16	8.647	12.067	12.180	12.180	12.209

Note: Output taxes include other taxes included into cost of production, η is elasticity of transformation between domestic output and exports, σ is elasticity of substitution between domestic goods and imports.

An assumption about the elasticities plays an important role in MEB calculation. Higher values of elasticities imply more responsive behavior of economic agents when taxes (hence, relative prices) are changed. That is, in the case of higher elasticity of substitution between domestic goods and imports, consumers may switch between these goods more easily. An excess burden arises when a behavior of economic agents changes due to introduction of taxes, and the excess burden is bigger when behavior changes to a greater degree. From econometric estimations for the United States, η is usually around unity for manufacturing goods and σ is around four. However, in CGE literature these values are higher and sometimes they assumed to be infinity. I provide the results of calculations for both low- and medium- levels of elasticities.

Marginal Excess Burden in Table 6 is calculated with different import tariffs for different sectors with agricultural import tariffs being the highest. Ukrainian accession to the WTO requires reduction of these agricultural tariffs. Therefore, I change my model to take into account decreased import tariffs. The results of MEB calculations are presented in Tables 7 - 9.

Table 7. Marginal Excess Burden in a 10% tariff reduced model

η	σ	Output taxes	Social security tax	Value added tax	Net taxes on goods	Import tax
1	4	1.856	8.100	8.100	8.100	5.304
1	16	6.949	6.730	7.461	7.461	7.503
4	4	12.067	11.800	12.180	12.180	12.209
4	16	10.274	10.128	10.343	10.343	10.399

Note: Output taxes include other taxes included into cost of production, η is elasticity of transformation between domestic output and exports, σ is elasticity of substitution between domestic goods and imports.

Table 8. Marginal Excess Burden in a 25% tariff reduced model

η	σ	Output taxes	Social security tax	Value added tax	Net taxes on goods	Import tax
1	4	7.311	5.304	7.353	7.353	14.477
1	16	7.476	6.949	10.399	10.399	10.734
4	4	8.304	8.100	8.503	8.503	8.647
4	16	12.160	12.067	12.180	12.180	12.209

Table 9. Marginal Excess Burden in a 50% tariff reduced model

η	σ	Output taxes	Social security tax	Value added tax	Net taxes on goods	Import tax
1	4	5.590	5.304	5.671	5.742	8.647
1	16	5.266	2.160	5.278	5.278	5.304
4	4	4.934	5.590	5.671	5.671	5.742
4	16	11.241	8.503	11.275	11.275	12.209

As can be seen from Table 7 - 9, MEB of import tariff is significantly reduced while MEB of other taxes have either fallen or stayed at the same level. It can be noted though that different degrees of import tariff reduction do not change marginal excess burden of import tariff much while MEB of other tax instruments becomes more significant.

WTO membership will require import tariffs reductions of 10-15% for the most of commodities. Therefore, the scenario of 10% import tariffs reduction is the most realistic.

The results from this analysis are tentative, as I have ignored a number of potentially important mechanisms. First, in my basic model I have not modeled important aspects of Ukrainian tax system such as tax avoidance or corruption. Second, the result is sensitive to interpretation of data in the IO table. Different benchmark models can be built based on different interpretation of tax data.

The results of the MEB calculation may be different if a steady-state constraint is introduced. If we assume that an economy is on a steady-state balanced growth path, then there is a specific relationship between capital and investment (Rutherford and Tarr, 1999). An increase in government spending will produce a new equilibrium, where for many of the changes it will be necessary to consider the rate of return on capital changes (relative to the cost of investment) due to a less efficient allocation of resources. This implies that, in a dynamic sense, a fixed capital stock can no longer be optimal in the new equilibrium of the static model. Investment would be changing until the marginal productivity of capital is reduced to the long run equilibrium where the ratio of rate of return on capital to the cost of the capital good is restored to its initial value.

CONCLUSIONS

An IO table provides an overview of the relative magnitude of tax rates and economic activities, yet it gives limited information regarding the economic cost of raising public funds. This paper has described how an IO table can be used to construct a general economic equilibrium model that can then be used to assess the excess burden of different tax instruments. Creating a general equilibrium model is a multi-stage process. Features of the model depend on a modeler's assumptions and interpretation of an input-output data. After developing an appropriate equilibrium structure and calibrating the model, the static model might be modified to study specific issues, such as Ukraine's accession to the WTO.

Using 1999 IO table, this paper has assessed the marginal excess burden of different tax instruments. Based on the simple static model, I find that import tax is the least efficient source of public funds and that its reduction can significantly decrease marginal excess burden. Not surprisingly, the higher the elasticities of transformation between domestic output and exports, η, and elasticities of substitution between domestic goods and imports, σ, the higher is the marginal excess burden and correspondingly the higher is an increase in consumers' welfare after import tariff reduction. However, the results are sensitive to interpretation of data and the choice of the model. For example, an estimated welfare loss of an increase in government spending may be significantly different if issues related to tax evasion and existence of shadow economy are introduced.

The model produced plausible results concerning the effects of trade liberalization after WTO accession, and indicated that the welfare effects of the proposed trade agreement would have aggregate welfare consequences. In particular, the direction of welfare change depends on elasticities of substitution that correspond approximately to notions of trade creation and trade diversion.

Import tariffs reductions are key condition to Ukraine's accession to the WTO. Results obtained from simulation show that reduction of import tariffs increases national welfare. Therefore, membership in the WTO would be beneficial for Ukrainian consumers because of reduced import prices and for producers because of reduced prices of intermediate inputs and availability of new markets for their products. However, the Ukrainian government should also apply cost-benefit analysis of import tariffs reduction to every commodity separately because some commodities like agricultural products deserve special treatment.

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APPENDIX A. INPUT-OUTPUT TABLE

Data for a particular country is often organized in the form of an input-output table. An input-output table contains the valuable information about the market allocation of resources in an economic system. Based on this information, a variety of general economic equilibrium models can be created.

Input-output table was first proposed by Wassily Leontief who constructed it in order to supply an empirical background for the study of the interdependence between the different parts of economy (Leontief 1936). He uses for construction the expenditure and revenue account that registers on its credit side the outflow of goods and services from the enterprise or household (total sales) and on the debt side the acquisition of goods or services by the particular enterprise or household (total outlays).

Such a table describes the flows among the various sectors of the economy. It represents the value of economic transactions in a given period of time. Transactions of goods and services are broken down by intermediate and final use. An input-output table also shows the cost structure of production activities: intermediate inputs, compensation to labor and capital, taxes on production. Table 1 illustrates a general structure of an input-output table, according to the European System of Integrated Economic Accounts (Eurostat, 1986).

Table A.1 Input-Output Table

	INTERMEDIATE USE By Production Sectors 1 2 …j… n	**FINAL USE** *Private* *Gov't* Consum Consum Invest Export	OUT- PUT
Domestic 1 Production 2 : i : n	A	B	C
Imports 1 2 : i : n	D	E	F
Value added: -labor -capital -indirect taxes	G	H	I
INPUT	J		

In the standard Eurostat framework, Matrix A represents an intermediate demand. Rows in the matrix A describe production sector outputs. Columns represent sectors that use outputs of production as intermediate inputs. As such, a number in a cell A_{ij} tells the amount of sector i's output used in the production of a sector j. A breakdown of a final demand on private consumption, government consumption, investment, and export is shown in Matrix B. Matrix C gives the information on total domestic production. Matrices D, E and F give the corresponding information on imported goods and services. Payments to labor and capital, depreciation, and indirect taxes are presented in Matrix G. Matrix H is normally empty, and summation over rows in Matrix I gives information on value-added. If an input-output table is balanced, then columns of Matrix J should be the same as the rows of Matrix C because total input equals total output for production sectors. In this work we use Ukrainian input-output table of 1999 (the most recent available).

APPENDIX B. UKRAINIAN INPUT-OUTPUT TABLE OF 1999

Table B.1

		Industry	Construction	Agriculture	Transport	Lease	Communal	Education	Banking	Others	Interm, Cons
		1	2	3	4	5	6	7	8	9	10
Industry	1	78055	4927	7709	7659	2568	8030	3777	222	4985	117932
Construction	2	200	21	41	115	103	108	23	9	52	672
Agriculture and forestry	3	8716	52	14781	23	339	22	359	3	558	24853
Transport and communications	4	5528	409	717	804	1259	221	478	292	806	10514
Lease, advertising, trade	5	15671	0	1660	0	0	0	0	0	412	18059
Communal services	6	1061	275	188	723	2023	658	979	451	1414	7772
Education, medicine	7	37	3	9	45	9	5	78	9	11	206
Banking, insurance	8	941	38	30	205	508	151	104	360	1507	3844
Others	9	4011	215	951	475	1135	58	222	284	1108	8143
Subtotal	10	114220	5940	26086	10049	7944	9253	6020	1630	10853	191995

Table B.2

Wage	11	20080	3502	4258	6284	4860	2885	7221	1006	7742	57838
Social insurance contrib.	12	98778	4047	14854	964	2907	6420	3169	609	9620	141368
Net profit	13	15364	2055	1676	2068	780	-662	4	17	675	21977
Net mixed income	14	15838	1864	11058	8931	4274	2731	2818	985	1130	49629
Other taxes on production	15	1679	136	384	211	763	102	45	36	105	3461
Subsidies on production	16	-2075	-107	-210	-57	0	0	-12	0	-2	-2463
Depreciation	17	35522	5395	15490	15369	9897	5718	10072	2027	8975	108465
Gross value added	18	165106	13390	43252	27486	18621	14309	16096	3674	20503	322437
Total input (row 10+row 18)	19	279326	19330	69338	37535	26565	23562	22116	5304	31356	514432

Table B.3

		Final Consumption		Gross Accumulation			
		Households	Government	Incr.in fixed assets	Chg.in Stocks	Export	Total use
		11	12	13	14	15	16
Industry	1	41763	-1064	10374	-1926	51666	218745
Construction	2	0	0	13451	19	261	14403
Agriculture and forestry	3	15716	547	308	-595	3238	44067
Transport and communications	4	4232	1556	0	0	13167	29469
Lease, advertising, trade	5	1667	2	411	0	879	21018
Communal services	6	3675	2978	0	0	700	15125
Education, medicine	7	1648	14216	0	0	83	16153
Banking, insurance	8	93	0	0	0	78	4015
Others	9	2516	10936	587	117	812	23111
Subtotal	10	71310	29171	25131	-2385	70884	386106

Table B.4

		Transp .margin	Trade margin	VAT use	in Taxes goods	on Import taxes	Import	Total
		17	18	19	20	21	22	23
Industry	1	4138	15671	7496	6655	1339	53639	307683
Construction	2	0	0	2055	0	0	1013	17471
Agriculture and forestry	3	114	1660	1630	0	46	815	48332
Transport and communications	4	0	0	2329	-261	0	1983	33520
Lease, advertising, trade	5	0	0	780	0	0	2081	23879
Communal services	6	0	0	826	-1488	0	816	15279
Education, medicine	7	0	0	163	-159	0	57	16214
Banking, insurance	8	0	0	17	0	0	341	4373
Others	9	3	412	723	-57	9	2924	27125
Subtotal	10	4255	17743	16019	4690	1394	63669	493876

APPENDIX C. FILE LISTINGS

Appendix C contains a listing of three GAMS Files iodata.gms, model.gms and meb.gms. The iodata.gms file reads the data into GAMS format, checks the data, and creates a dataset file ukraine.dat. The model.gms file prepares the data for a static model and contains a core static MPSGE model. The meb.gms file shows the modification of the core static model for the marginal excess burden calculations.

File 1. IODATA.GMS

```
1 $title Excel into GAMS
2 parameter iodata(*,*);
3 * Read data from a file iopaper.xls to parameter IODATA
4 $libinclude xlimport iodata iopaper.xls b2..y21
5 display iodata;
6 set n  Sectors numeric /
                    1      Industry
                    2      Construction
                    3      Agriculture and forestry
                    4      Transport and communications
                    5      Lease advertising audit trade
                    6      Communal services
                    7      Education science medical care and
recreation services
                    8      Administration banking insurance
                    9      Others      /;

7 set i  Sectors - symbols /
                    IND    Industry
                    CON    Construction
                    AGR    Agriculture and forestry
                    TRN    Transport and communications
                    TRD    Lease advertising audit trade
                    COM    Communal services
                    EDU    Education science medical care and recreation
services
                    FIN    Administration banking insurance
                    OTH    Others  /;

8 set map(n,i) /
```

```
      1.IND, 2.CON, 3.AGR, 4.TRN, 5.TRD,
      6.COM, 7.EDU, 8.FIN, 9.OTH /;
9 alias (n,m),(i,j);
10 * Assign data to parameters *******************
11 * Row parameters
12 parameter iod     Input-output demand
              wages   Wage payments
              socsec  Social security contribution
              profit  Net return to capital
              mixed   Net mixed income
              othtax  Other taxes
              subsidy Other subsidies
              deprec  Depreciation
              grossva Gross value-added
              vachk   Check of value-added;

13 iod(i,j)=sum((n,m)$(map(n,i) and map(m,j)),iodata(n,m))/100;
14 wages(i)=sum(map(n,i),iodata("11",n))/100;
15 socsec(i)=sum(map(n,i),iodata("12",n))/100;
16 profit(i)=sum(map(n,i),iodata("13",n))/100;
17 mixed(i)=sum(map(n,i),iodata("14",n))/100;
18 othtax(i)=sum(map(n,i),iodata("15",n))/100;
19 subsidy(i)=-sum(map(n,i),iodata("16",n))/100;
20 deprec(i)=sum(map(n,i),iodata("17",n))/100;

21 *Column parameters
22 parameter    consum  Household consumption
                govdem  Government demand
                fixedi  Increments in fixed assets
                stock   Stock change
                export  Export demand
                trnspt  Transport margin
                trade   Trade margin
                vat     VAT in use
                nettax  Net taxes on goods
                imptax  Import taxes
                import  Import evaluated at basic prices;

23 consum(i)=sum(map(n,i), iodata(n,"11"))/100;
24 govdem(i)=sum(map(n,i), iodata(n,"12"))/100;
25 fixedi(i)=sum(map(n,i), iodata(n,"13"))/100;
26 stock(i)=sum(map(n,i), iodata(n,"14"))/100;
27 export(i)=sum(map(n,i), iodata(n,"15"))/100;
28 trnspt(i)=sum(map(n,i), iodata(n,"17"))/100;
29 trade(i)=sum(map(n,i), iodata(n,"18"))/100;
30 vat(i)=sum(map(n,i), iodata(n,"19"))/100;
31 nettax(i)=sum(map(n,i), iodata(n,"20"))/100;
```

```
imptax(i)=sum(map(n,i), iodata(n,"21"))/100;
import(i)=sum(map(n,i), iodata(n,"22"))/100;

* Checks***************************************
*Check of Subtotal (row 10)
iod("rowsum",j)=sum(i,iod(i,j));
iod("chk",j)=sum(map(m,j), iodata("10",m))/100-iod("rowsum",j);

*Check of Intermediate Consumption (column 10)
iod(i,"colsum")=sum(j,iod(i,j));
iod(i,"chk")=sum(map(n,i), iodata(n,"10"))/100-iod(i,"colsum");
display iod;

* Zero out check rows and columns
iod("rowsum",j)=0;
iod("chk",j)=0;
iod(i,"colsum")=0;
iod(i,"chk")=0;

*Check of Gross Value added (row 18)
parameter grvad, vachk1;
grvad(i)=wages(i)+socsec(i)+profit(i)+mixed(i)+othtax(i)-
subsidy(i)+deprec(i);
vachk1(i)=sum(map(n,i), iodata("18",n))/100-grvad(i);
display grvad,vachk1;

* Check of Total Use (Final+Intermediate+Export) (column 16)
parameter usetot, vachk2, ops;
usetot(i)=sum(j,iod(i,j))+consum(i)+govdem(i)+stock(i)+fixedi(i)+
export(i);
vachk2(i)=sum(map(n,i),iodata(n,"16"))/100-usetot(i);
ops=sum(i,usetot(i));
display usetot, vachk2, ops;

* Check of Total Use at Basic Prices (column 23)
parameter usetotbas, vachk3, ops1;
usetotbas(i)=usetot(i)-trnspt(i)-trade(i)-vat(i)-nettax(i)-imptax(i)-import(i);
vachk3(i)=sum(map(n,i),iodata(n,"23"))/100-usetotbas(i);
ops1=sum(i,usetotbas(i));
display usetotbas, vachk3, ops1;

* Profit check
parameter prchk;
prchk(j,"output")=sum(i,iod(i,j))+grvad(j);
prchk(i,"use")=usetotbas(i);
prchk(i,"chk")=prchk(i,"use")-prchk(i,"output");
display prchk;
```

```
parameter totprofit;
totprofit("output")=sum(i,prchk(i,"output"));
totprofit("use")=sum(i,prchk(i,"use"));
totprofit("total")=totprofit("output")-totprofit("use");
totprofit("dumb")=sum(i,prchk(i,"chk"));
display totprofit;

* Additional parameters to correct for gross return
* Gross return = sectoral profit(use-output)+ net profit+ depreciation+ mixed income
* if return is negative - move to wage account
* value added = return(positive)+wages+social security

parameter      return  Imputed gross return to capital
               va      Sectoral value added;

return(i)=prchk(i,"chk")+deprec(i)+profit(i)+mixed(i);
wages(i)=wages(i)+min(0,return(i));
return(i)=max(0,return(i));
va(i)=return(i)+wages(i)+socsec(i);
prchk(j,"balanced")=va(j)+othtax(j)-subsidy(j)+sum(i,iod(i,j))-prchk(j,"use");
display prchk;

file kdat /ukraine.dat/;
put kdat;
$libinclude gams2prm consum
$libinclude gams2prm govdem
$libinclude gams2prm stock
$libinclude gams2prm fixedi
$libinclude gams2prm export
$libinclude gams2prm trnspt
$libinclude gams2prm trade
$libinclude gams2prm vat
$libinclude gams2prm nettax
$libinclude gams2prm imptax
$libinclude gams2prm import
$libinclude gams2prm iod
$libinclude gams2prm wages
$libinclude gams2prm socsec
$libinclude gams2prm othtax
$libinclude gams2prm subsidy
$libinclude gams2prm return
```

File 2. MODEL.GMS

```
1 $title MPSGE static model
2 set  i   Industries - symbols /
           IND  Industry
           CON  Construction
           AGR  Agriculture and forestry
           TRN  Transport and communications
           TRD  Lease advertising audit trade
           COM  Communal services
           EDU  Education science medical care and recreation services
           FIN  Administration banking insurance
           OTH  Others  /;

3 alias (i,j);
4 parameter   iod(i,j)     Input-output demand
              wages(i)     Wage payments
              socsec(i)    Social security contribution
              return(i)    Gross return to capital
              othtax(i)    Other taxes
              subsidy(i)   Other subsidies
              consum(i)    Household consumption
              govdem(i)    Government demand
              stock(i)     Stock change
              fixedi(i)    Increments in fixed assets
              export(i)    Export demand
              trnspt(i)    Transport margin
              trade(i)     Trade margin
              vat(i)       VAT in use
              nettax(i)    Net taxes on goods
              imptax(i)    Import taxes
              import(i)    Imports evaluated at basic prices;

5 $include ukraine.dat
6 parameter   x0(i)        Exports
              d0(i)        Domestic sales
              ld0(i)       Labor demand
              kd0(i)       Capital demand
              ks0          Capital supply
              ty(i)        Output tax
              tl(i)        Social security tax
              pl0(i)       Benchmark gross wage
              a0(i)        Armington supply
              trd(i)       Trade margin
              trn(i)       Transport margin
              m0(i)        Imports (gross of tariff)
              pm0(i)       Benchmark import price
              tm(i)        Tariff rate
              g0           Government output
```

```
          gd0(i)       Government demand
          i0           Investment
          id0(i)       Investment demand
          c0           Private consumption
          cd0(i)       Consumption demand
          tn(i)        Net tax on goods rate
          ls0          Labor supply
          ta(i)        VAT rate
          margin       Margin
          bopdef       Balance of payments deficit;

cd0(i) = consum(i);
c0 = sum(i, cd0(i));
x0(i) = export(i);
m0(i) = import(i);
tm(i)$import(i) = imptax(i)/import(i);
pm0(i) = 1 + tm(i);
id0(i) = stock(i) + fixedi(i);
i0 = sum(i, id0(i));
gd0(i) = govdem(i);
g0 = sum(i, gd0(i));
kd0(i) = return(i);
ks0 = sum(i, kd0(i));
ld0(i) = wages(i);
ls0 = sum(i, ld0(i));
tl(i)$ld0(i) = socsec(i) / ld0(i);
pl0(i) = 1 + tl(i);
parameter profitchk;
trd(i) = max(0, trade(i));
trn(i) = max(0, trnspt(i));
margin(i) = max(0, -trade(i)) + max(0, -trnspt(i));

display margin;

a0(i) = sum(j, iod(i,j)) + cd0(i) + gd0(i) + id0(i);
ta(i) = vat(i)/a0(i);
tn(i) = nettax(i)/a0(i);
d0(i) = a0(i)*(1-ta(i)-tn(i)) - pm0(i) * m0(i) - trn(i) - trd(i);
ty(i) = (othtax(i)-subsidy(i))/(d0(i) + margin(i) + x0(i));
profitchk(i,"orig") = kd0(i) + pl0(i)*ld0(i) + sum(j, iod(j,i)) -
      (d0(i)+margin(i)+export(i))*(1-ty(i));
profitchk(i,"d0") = d0(i);
display profitchk;

bopdef = sum(i, m0(i) - x0(i));

parameter    taxes   Benchmark tax rates;
```

```
38 taxes(i, "ta") = round(100 * ta(i));
39 taxes(i, "tn") = round(100 * tn(i));
40 taxes(i, "tl") = round(100 * tl(i));
41 taxes(i, "tm") = round(100 * tm(i));
42 taxes(i, "ty") = round(100 * ty(i));
43 option taxes:0;
44 display taxes;

45 * core MPSGE model
46 $ontext
47 $model:static
48 $sectors:
    y(i)     ! Sectoral production
    a(i)     ! Armington supply
    x(i)     ! Export
    m(i)     ! Import
    c        ! Private consumption
    g        ! Public sector demand
    inv      ! Investment
49 $commodities:
    pa(i)    ! Armington price
    pd(i)    ! Domestic market price
    pm(i)    ! Import price
    px(i)    ! Export price
    pc       ! Consumption price
    pinv     ! Investment price
    pfx      ! Foreign exchange
    pg       ! Public goods price
    pl       ! Wage rate
    rk       ! Return to capital
50 $consumer:
    ra       ! Representative agent
51 $prod:y(i) t:1 s:0 va:1
    o:px(i)     q:x0(i)              a:ra     t:ty(i)
    o:pd(i)     q:(d0(i)+margin(i))  a:ra     t:ty(i)
    i:pa(j)     q:iod(j,i)
    i:pl        q:ld0(i)     p:pl0(i)    a:ra    t:tl(i)    va:
    i:rk        q:kd0(i)     va:
52 $prod:a(i)   s:0   dm:4
    o:pa(i)     q:a0(i)      a:ra     t:(ta(i)+tn(i))
    i:pd("trd")   q:trd(i)
    i:pd("trn")   q:trn(i)
    i:pd(i)     q:d0(i)         dm:
    i:pm(i)     q:(pm0(i)*m0(i))  dm:
53 $prod:x(i)
    o:pfx       q:x0(i)
    i:px(i)     q:x0(i)
```

```
54 $prod:m(i)
     o:pm(i)      q:(pm0(i)*m0(i))
     i:pfx        q:m0(i)    a:ra    t:tm(i)
55 $prod:g
     o:pg         q:g0
     i:pa(i)      q:gd0(i)
56 $prod:inv
     o:pinv       q:i0
     i:pa(i)      q:id0(i)
57 $prod:c  s:1
     o:pc         q:c0
     i:pa(i)      q:cd0(i)
58 $demand:ra
     d:pc         q:c0
     e:pl         q:ls0
     e:rk         q:ks0
     e:pfx        q:bopdef
     e:pg         q:(-g0)
     e:pinv       q:(-i0)
59 $offtext
60 $sysinclude mpsgeset static
61 static.iterlim = 0;
62 $include static.gen
63 solve static using mcp;
```

File 3. MEB.GMS

```
1 * MEB calculation: MPSGE formulation
2 parameter   dt      Direct tax
              taxrev  Indirect Tax revenue;

3 taxrev = sum(i,(ta(i)+tn(i))*a0(i) + tm(i)*m0(i) +
       tl(i)*ld0(i) + ty(i)*(d0(i)+margin(i)+x0(i)));
4 dt = g0 - taxrev;
5 parameter gsize Size of government;
6 gsize=1;

7 set  taxinst       Tax instruments /out, lab, vat, net, imp/
      inst(taxinst) Instrument;

8 inst(taxinst)=no;

9 * MPSGE model
10 $ontext
11 $model:static
12 $sectors:
      y(i)      ! Sectoral production
```

```
      a(i)     ! Armington supply
      x(i)     ! Export
      m(i)     ! Import
      c        ! Private consumption
      g        ! Public sector demand
      inv      ! Investment
13 $commodities:
      pa(i)    ! Armongton price
      pd(i)    ! Domestic market price
      pm(i)    ! Import price
      px(i)    ! Export price
      pc       ! Consumption price
      pinv     ! Investment price
      pfx      ! Foreign exchange
      pg       ! Public goods price
      pl       ! Wage rate
      rk       ! Return to capital
14 $consumer:
      ra       ! Representative agent
      gov      ! Government
15 $auxiliary:
      tau      ! Tax adjustment
16 $prod:y(i)  t:1  s:0  va:1
      o:px(i)      q:x0(i)      a:gov     t:ty(i)     n:tau$inst("out")
      o:pd(i)      q:(d0(i)+margin(i))  a:gov  t:ty(i) n:tau$inst("out")
      i:pa(j)      q:iod(j,i)
      i:pl     q:ld0(i)   p:pl0(i)    a:gov    t:tl(i)  n:tau$inst("lab") va:
      i:rk     q:kd0(i)    va:
17 $prod:a(i)  s:0   dm:4
      o:pa(i)    q:a0(i)   a:gov  t:tn(i)  n:tau$inst("net")
+ a:gov  t:ta(i)   n:tau$inst("vat")
      i:pd("trd")    q:trd(i)
      i:pd("trn")    q:trn(i)
      i:pd(i)       q:d0(i)       dm:
      i:pm(i)       q:(pm0(i)*m0(i))  dm:
18 $prod:x(i)
      o:pfx          q:x0(i)
      i:px(i)        q:x0(i)
19 $prod:m(i)
      o:pm(i)         q:(pm0(i)*m0(i))
      i:pfx          q:m0(i)    a:gov   t:tm(i)   n:tau$inst("imp")
20 $prod:g
      o:pg           q:g0
      i:pa(i)        q:gd0(i)
21 $prod:inv
      o:pinv         q:i0
      i:pa(i)        q:id0(i)
```

```
22 $prod:c  s:1
       o:pc            q:c0
       i:pa(i)         q:cd0(i)
23 $demand:ra
       d:pc            q:c0
       e:pl            q:ls0
       e:rk            q:ks0
       e:pfx           q:bopdef
       e:pc            q:(-dt)
       e:pinv          q:(-i0)
24 $demand:gov
       d:pg            q:g0
       e:pc            q:dt
25 $constraint:tau
       g =E= gsize;
26 $offtext
27 $sysinclude mpsgeset static
28 tau.l=0;
29 static.iterlim = 0;
30 $include static.gen
31 solve static using mcp;
32 static.iterlim=2000;

33 set sizegov Size of the government (percentage increase) /1*5/;
34 parameter eb Excess burden;

35 loop((sizegov,taxinst),
gsize = 1 + ord9sizegov)/100;
36 inst(taxinst)=yes;
37 $include static.gen
38 solve static using mcp;
39 eb(sizegov,taxinst) = 100*(c0*(1-c.l)/(g0*(g.l-1))-1);
40 inst(taxinst)=no;
);

41 display eb;
```

APPENDIX D. GENERAL EQUILIBRIUM CALCULATION PROCEDURE

The solution procedure is a generalized Newton method with a backtracking line search. In this implementation, subproblems are solved as linear complementarity problems (LCPs), using an extension of Lemke's almost-complementary pivoting scheme in which upper and lower bounds are represented implicitly.

"Generalized" or "mixed" complementarity problems are defined as follows:

Given: F: $R^n \to R^n$, $l, u \in R^n$

Find: z, w, v ∈ R^n

such that

$$F(z) = w - v$$

$$l \le z \le u, \; w \ge 0, v \ge 0$$

$$w^T(z - l) = 0, \; v^T(u - z) = 0$$

A model-builder specifies classes of nonlinear functions using a specialized tabular input format embedded within a GAMS program. Using benchmark quantities and prices, GAMS automatically calibrates function coefficients and generates nonlinear equations and Jacobian matrices.

The iterative procedure applied within GAMS to solve nonlinear complementarity problems is closely related to the classical Newton algorithm for nonlinear equations. Newton algorithms for nonlinear equations begin with a local (Taylor series) approximation of the system of nonlinear equations. For a point z in the neighborhood of $\hat{z}$, the system of nonlinear functions is linearized:

$$LF(z) = F(\hat{z}) + \nabla F(\hat{z})(z - \hat{z})$$

Solving the linear system LF (z) = 0 provides the Newton direction from $\hat{z}$ which is given by $d = -\nabla F^{-1} F(\hat{z})$.

Newton iteration k begins at point z^k. First, the linear model formed at z^k is solved to determine the associated "Newton direction", d^k. Second, a line search in direction d^k determines the scalar step-length λ and the subsequent iterate: $z^{k+1} = z^k + \lambda d^k$. An Armijo or "back-tracking" line search initially considers λ = 1. If $\left\| F(z^z + \lambda d^k) \right\| \leq \left\| F(z^k) \right\|$, the step size λ is adopted, otherwise λ is multiplied by a positive factor α, α < 1, and the convergence test is reapplied. This procedure is repeated until either an improvement results or $\lambda < \underline{\lambda}$. When $\underline{\lambda}$ = 0, a positive step is taken provided that:

$$\frac{d}{d\lambda} \left\| F(z^k + \lambda d^k) \right\| < 0 .$$

The application of Newton methods to nonlinear complementarity problems involves a modification of the search direction. Here, d solves a linear complementarity problem (LCP) rather than a linear system of equations. For iteration k, d solves:

$$F(z^k) + \nabla F(z^k) d - w + v = 0$$

$$l \leq d + z^k \leq u, w \geq 0, v \geq 0$$

$$w^T (d + z^k - l) = v^T (u - d - z^k) = 0$$

In practice, GAMS solves the linear problem in terms of the original variables $z = z^k + d$:

$$F(z^k) - \nabla F(z^k) z_k + \nabla F(z^k) z = w - v$$

$$l \leq z \leq u, w \geq 0, v \geq 0$$

$$w^T (z - l) = 0, v^T (u - z) = 0$$

After computing the solution z, GAMS sets $d^k = z - z^k$.

The linear subproblem incorporates upper and lower bounds on any or all of the variables, assuring that the iterative sequence always remains within the bounds: ($l \le z^k \le u$). This can be helpful when, as is often the case, F (*) is undefined for some z ∈ R^n.

Convergence of the Newton algorithm applied to MCP hinges on three questions: (i) Does the linearized problem always have a solution? (ii) If the linearized problem has a solution, does Lemke's algorithm find it? and (iii) Is it possible to show that the computed direction d^k will provide an "improvement" in the solution? Only for a limited class of functions F (*) can all three questions be answered in the affirmative. For a much larger class of functions, the algorithm converges in practice but convergence is not "provable".

The answer to question (iii) depends on the choice of a norm by which an improvement is measured. The introduction of bounds and complementarity conditions makes the calculation of an error index is made more complicated. In GAMS, the deviation associated with a candidate solution z, ∈ (z), is based on a measure of the extent to which z, w and v violate applicable upper and lower bounds and complementarity conditions.

Evaluating Convergence

Let δ_i^L and δ_i^U be indicator variables for whether z_i is off its lower or upper bound. These are defined as:

$\delta_i^L = \min(1,(z_i - l_i))$, and $\delta_i^U = \min(1,(u_i - z_i))$.

Given z, GAMS uses the value of F (z) to implicitly define the slack variables w and v:

$w_i = F_i(z)$, $v_i = (-F_i(z))$.

There are two components to the error term associated with index i, one corresponding to z_i's violation of upper and lower bounds:

$$\varepsilon_i^B = (z_i - u_i) + (l_i - z_i),$$

and another corresponding to violations of complementarity conditions:

$$\varepsilon_i^C = \delta_i^L w_i + \delta_i^U v_i.$$

The error assigned to point z is then taken:

$$\varepsilon(z) = \left\| \varepsilon^B(z) + \varepsilon^C(z) \right\|_P$$

for a pre-specified value of p = 1, 2 or $+\infty$.

Lemke's Method with Implicit Bounds

A mixed linear complementarity problem has the form:

Given: $M \in R^{nxn}$, q, l, $u \in R^n$

Find: z, w, $v \in R^n$

such that

$Mz + q = w - v$

$l \leq z \leq u, w \geq 0, v \geq 0$

$w^T (z - l) = 0, v^T (u - z) = 0$

In the Newton subproblem at iteration k, the LCP data are given by $q = F(z^k) - \nabla F(z^k) z^k$ and $M = \nabla F(z^k)$.

In GAMS, the pivoting scheme for solving the linear problem works with a re-labeled linear system of the form:

$Bx^B + Nx^N = q$

where $x^B \in \mathbf{R}^n$, $x^N \in \mathbf{R}^{2n}$, and the tableau [B | N] is a conformal "complementary permutation" of [-M | I | -I]. That is, every column i in B must either be the ith column of M, I or - I, while the corresponding columns i and i+ n in N must be the two columns which were not selected for B.

To move from the problem defined in terms of z, w and v to the problem defined in terms of x^B and x^N, we assign upper and lower bounds for the x^B variables as follows:

$$\underline{x}_i^B = \begin{cases} l_i \text{ if } x_i^B = z_i \\ 0 \text{ if } x_i^B = w_i \text{ or } v_i \end{cases}$$

$$\overline{x}_i^B = \begin{cases} u_i \text{ if } x_i^B = z_i \\ \infty \text{ if } x_i^B = w_i \text{ or } v_i \end{cases}$$

The values of the non-basic variables x_i^N and x_{i+n}^N are determined by the assignment of x_i^B :

$$x_i^B = \begin{cases} z_i \rightarrow \begin{cases} x_i^N = w_i = 0 \\ x_{i-n}^N = v_i = 0 \end{cases} \\ w_i \rightarrow \begin{cases} x_i^N = z_i = l_i \\ x_{i-n}^N = v_i = 0 \end{cases} \\ v_i \rightarrow \begin{cases} x_i^N = w_i = 0 \\ x_{i-n}^N = z_i = u_i \end{cases} \end{cases}$$

In words: if z_i is basic then both w_i and v_i equal zero. If z_i is non-basic at its lower bound, then w_i is possibly non-zero and v_i is non-basic at zero. If z_i is non-basic at its upper bound, then v_i is possibly non-zero and w_i is non-basic at zero.

Conceptually, we could solve the LCP by evaluating 3^n linear systems of the form:

$$x^B = B^{-1}\left(q - Nx^N\right)$$

Lemke's pivoting algorithm provides a procedure for finding a solution by sequentially evaluating some (hopefully small) subset of these 3^n alternative linear systems.

Initialization

Let B^0 denote the initial basis matrix. The initial values for basic variables are then:

$$\hat{x}^B = \left(B^0\right)^{-1}\left(q - N\hat{x}^N\right)$$

If $\underline{x}^B \le \hat{x}^B \le \overline{x}^B$, then the initial basis is feasible and the complementarity problem is solved. Otherwise, GAMS introduces an artificial variable z_0 and an artificial column h. Basic variables are then expressed as follows:

$$x^B = \hat{x}^B - \tilde{h} z_0$$

where $\tilde{h}$ is the "transformed artificial column" (the untransformed column is $h = B^0\tilde{h}$). The coefficients of $\tilde{h}$ are selected so that:

(i) The values of "feasible" basis variables are unaffected by

$$z_o : \left(\underline{x}_i^B \le x_i^B \le \overline{x}_i^B \rightarrow \tilde{h}_i = 0\right)$$

(ii) The "most infeasible" basic variable (i= p) is driven to its upper or lower bound when $z_0 = 1$:

$$\tilde{h}_P = \begin{cases} \hat{x}_p^B - \overline{x}_p^B \; if \; \tilde{x}_p^B > \overline{x}_p^B \\ \hat{x}_p^B - \underline{x}_p^B \; if \; \tilde{x}_p^B > \underline{x}_p^B \end{cases}$$

(iii) All other infeasible basic variables assume values between their upper and lower bounds when z_0 increases to 1:

$$x_i^B = \begin{cases} 1 + \underline{x}_i^B \; if \; \underline{x}_i^B > -\infty, \overline{x}_i^B = +\infty \\ \dfrac{\overline{x}_i^B + \underline{x}_i^B}{2} \; if \; \underline{x}_i^B > -\infty, \overline{x}_i^B < +\infty \\ \overline{x}_i^B - 1 \; if \; \underline{x}_i^B = -\infty, \overline{x}_i^B < +\infty \end{cases}$$

Pivoting Rules

When z_o enters the basis, it assumes a value of unity, and at this point (baring degeneracy), the subsequent pivot sequence is entirely determined. The entering variable in one iteration is determined by the exiting basic variable in the previous iteration. For example, if z_i were in B^o and introducing z_0 caused

z_i to move onto its lower bound, then the subsequent iteration introduces w_i. Conversely, if w_i were in B^o and z_0 caused w_i to fall to zero, the subsequent iteration increases z_i from l_i. Finally, if v_i were in B^0 and z^0 's introduction caused v_i to fall to zero, the subsequent iteration decreases z_i from u_i.

Termination on a Secondary Ray

Lemke's algorithm terminates normally when the introduction of a new variable drives z_o to zero. This is the desired outcome, but it does not always happen. The algorithm may be interrupted prematurely when no basic variable "blocks" an incoming variable, a condition known as "termination on a secondary ray". In anticipation of such outcomes, GAMS maintains a record of the value of z_0 for successive iterations, and it saves basis information associated with the smallest observed value, z_0^*. (In Lemke's algorithm, the pivot sequence is determined without regard for the effect on z_0, and the value of the artificial variable may follow an erratic (non-monotone) path from its initial value of one to the final value of zero.)

When GAMS encounters a secondary ray, a restart procedure is invoked in which the set of basic variables associated with z_0^* are reinstalled. This basis (augmented with one column from the non-basic triplet to replace z_0) serves as B^0, and the algorithm is restarted. In some cases, this procedure permits the pivot sequence to continue smoothly to a solution, while in others cases may only lead to another secondary ray.