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A tariff policy for Jamaica: a computable general equilibrium analysis

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**A tariff policy for Jamaica:
A computable general equilibrium analysis**

by

Courtney L. Gallimore

**A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of the
Requirement for the Degree of
DOCTOR OF PHILOSOPHY**

**Department: Economics
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For the Graduate College

**Iowa State University
Ames, Iowa**

1994

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CHAPTER 1.

INTRODUCTION

Many lesser developed countries (LDCs) continue to suffer from both the immediate and the proximate repercussions associated with a series of severe, exogenous economic shocks that occurred during the 1970s and 1980s. The catalogue of these external shocks includes:

- (1) The collapse of the Bretton Woods system in 1971, accompanied by profound disequilibria in international financial markets.
- (2) The dramatic price increases in petroleum products in 1973 and 1979, attended by two global recessions in the early 1970s and the early 1980s.
- (3) Unstable commodity export prices in the 1980s, resulting in the deterioration in the terms of trade for most LDCs.
- (4) The debt service crisis in the first half of the 1980s, aggravated by the appreciation of U.S. interest rates and the concurrent appreciation of the U.S. dollar (the currency in which most LDCs' international debt is denominated).
- (5) Sharp reductions in the availability of foreign aid and foreign investment, occasioned by the demise of Communism in the

former Soviet Union and Eastern Europe, along with the concomitant decline of savings in Europe and North America.

The circumstance of Jamaica, within the context of this new global environment, provides a particularly interesting study for economists and policy analysts alike. The exogenous shocks, and the vicissitudes that have accompanied them, have persisted for two decades, visiting considerable social and economic distress on a broad cross-section of the island's population. In response, a succession of governments, under the tutelage of the International Monetary Fund (IMF), the World Bank, and the Inter-American Development Bank (IDB), have continuously, for the past fifteen years,¹ subjected the economy to a variety of stabilization and structural-adjustment programs aimed primarily at alleviating the perennial dearth of foreign exchange and, to a much lesser extent, creating an environment suitable for sustained growth and economic development. Despite the best of intentions, these strategies have failed to realize their stated goals or even satisfy diminished public expectations. Unfortunately, the burden of these failures has fallen upon the average Jamaican who can ill-afford to participate in further real-life economic experiments.

The main objectives of the present research, which are tempered by this legacy of persistent economic depression and policy experimentation, are twofold in scope.

¹The fifteen year relationship between Jamaica and the IMF is the longest in the history of that institution (McAfee, 1991)

First, to advance a research procedure that can replace the current method of *in vivo* economic policy experiments with a more benign and less socially disruptive process: an *in vitro* economic simulation model. And second, with the aid of the simulation model, to design an optimal *revenue-neutral* tariff policy for the island.

A subsidiary objective of the study is to provide a much needed laboratory for preparing development plans and policy analyses that are consistent with the ability of the economic system. While development plans have been employed in Jamaica for several decades, they tend to be inspired by the disparate and irreconcilable objectives of the incumbent political party, much of which are incompatible with the economic realities of the island (Dawes, 1982). Moreover, this insouciant demeanor towards rigorous enquiry and analysis is not circumscribed solely to the governing coterie or the state bureaucracy. The indigenous private sector has been singularly unenterprising in its support of independent research to establish viable alternatives to the continuing economic distress. During the general parliamentary elections in 1989, for example, the local private sector contributed over J. \$100.00 million to the campaigns of the two principal political parties (Stone, 1989). This amount of money (equivalent to U.S. \$18.18 million at the prevailing rate of exchange) could have easily endowed the local university with the potential to employ several research economists, of international calibre, for a decade or more.

To-date, local private sector interests, especially the influential private sector lobbies, have yet to employ rigorous economic analysis in proffering viable

alternatives to the IMF's austerity programs. This, in spite of several celebrated instances when private sector groups confronted and accosted IMF representatives in Jamaica regarding the severity of IMF *conditionalities*. The simple truth is that the local private sector has found it unnecessary to acquire quantitative analytical methods in promoting their assorted economic self-interests.

As is the norm in almost all LDCs, the private sector's over-reliance on political solutions in addressing the prevailing economic and technological problems of the day is accompanied by a corresponding willingness by the incumbent government to supply political solutions without any reasonable recourse to other alternatives. In LDCs, this relationship between the political apparatus and the nascent business community is a clientelistic one, in which the economic survival of the local business community depends, to a large extent, upon government intercession with market mechanisms along with prodigious extensions of government patronage.

The dynamics of a clientelistic regime have profound ramifications which percolate through to the very essence, the *Zeitgeist*, of an economic system. In many instances, the unintended outcome of the alliance is the premature termination, if not the total demise, of that rare confederation of phenomena which constitute economic progress. Productivity and allocative efficiency are the immediate casualties, and over an extended time horizon, the potential beneficial impacts of the development

process -- improved income distribution, and augmented rates of economic growth -- are relentlessly retarded.

While the afflictions of clientelism have been documented elsewhere,² especially increased bureaucratic intervention (*dirigisme*), there is an important, if often overlooked, limitation on implementing the necessary policy reforms in a country like Jamaica. Unlike most newly independent countries, Jamaica had a genuine two-party democracy at the inception of its political *independence*, and the island continues to maintain its democratic institutions. However, the state in Jamaica is the coveted prize in a Hotelling-type duopoly in which the two political parties engage in the competitive provision of a wide range of social welfare programs (Stone and Wellisz, 1993). Policy reforms in Jamaica, therefore, must satisfy competing political interests within a democratic milieu.

Although the present research will abstract from modelling the complexities of these political-economic interrelationships, Jamaica's circumstance still admits a compelling need for a comprehensive simulation model to provide empirical guidance in the areas of economic analysis and policy choice.³

²Stone (1980) provides a perceptive analysis of clientelism in the Jamaican context.

³Clearly, the on-going economic crisis and the conditions imposed by the IMF and World Bank have severely weakened the clientelistic relationship between the government and the private sector. Even so, the private sector has yet to articulate an economic agenda of its own.

Scope of the Current Research

The remainder of this paper will address the implementation of a model to determine the optimal revenue-neutral tariff policy for Jamaica. Chapter 2 will review the literature on optimal tariff programs. In addition, Chapter 2 will summarize, very briefly, the economic history of the island, paying special attention to the role of tariffs as a source of revenues. Afterwards, Chapter 3 will focus on developing a model for the explicit purpose of deriving the optimal revenue-neutral tariff structure. Chapter 4 will discuss and evaluate the results from the actual simulation experiments. And finally, Chapter 5 will provide a conclusion based upon the results distilled from the preceding chapter.

CHAPTER 2.

TARIFFS AND THE JAMAICAN ECONOMY

National governments have at their disposal a wide range of policy instruments for restricting international trade and protecting domestic industries. These include tariffs on imports, price support schemes, export subsidies and taxes, import quotas, production subsidies, local content schemes, voluntary trade restraints, and other forms of non-tariff barriers. Some of these instruments, however, also serve as important sources of government revenue. The remainder of this chapter will address the role of tariffs in the Jamaican context. First, there will be a very brief evaluation on the Jamaican economy, including a short historical perspective on trade policy in Jamaica. Afterwards, the analysis will address the economic consequences of, and the arguments for and against, import tariffs in a small, open economy. Finally, there will be a very short literature review on tariffs as a source of government revenues.

Trade Policy and Jamaica

The history of post-emancipation Jamaica is an era in which stagnation and recession was the predominant feature in the economic landscape. Notwithstanding, there were intermittent periods when growth, as contrasted with development, briefly occupied small parcels of high-ground in the terrain. In 1832, six years before

emancipation, per capita output, measured in pounds sterling at 1910 prices, achieved a level of £15.6; it would take another ninety-eight years, in 1930, before the island's per capita output would surpass that accomplishment at some £15.7 using the same yardstick (Eisner, 1961). Although this feat was protracted in its accomplishment, its achievement was ephemeral, per capita output probably declined with the onset of the Great Depression. It was not until the brief economic boom, occasioned by the Second World War, before real per output income finally sustained a level above that of 1832!

Following the short wartime boom, national income appeared to have stagnated (Stone and Wellisz, 1993). However, the two decades between 1952 and 1972 witnessed the resurgence of the Jamaican economy for the first time in nearly a century and a-quarter. Fuelled by the inflow of foreign investment, first for the modernization of the sugar industry, then for the rapid development of the bauxite and alumina, and afterwards the tourist industries, GDP grew at an average annual rate of 6.3 per cent.

During the latter half of the economic boom, the level of foreign investment declined, and trade policy was increasingly used as an instrument of economic development. The prevailing assumption was that import substitution industrialization was the next logical phase in the precession of economic growth. Import licences and import quotas were the operative instruments of trade policy, very rarely were tariffs invoked as deliberate policy measures. Quantitative restrictions and import licensing

had existed in Jamaica long before the mid-1960s. The Trade Administrator's Office was inaugurated in 1938, in anticipation of wartime measures for allocating scarce imports. However, it was only in 1952 that import quotas were first employed as an instrument for protection -- for the fledgling footwear industry. And it was not before the mid-1960s that quantitative restrictions were extensively employed as a deliberate policy instrument to influence the general development of local industry.

By the late-1970s, unsettling changes in the government's social and economic policies contributed to the deterioration of the local economy. During that time, quantitative restrictions were motivated less by development policy and more by balance of payment considerations. These restrictions, however, were short-lived. The movement towards economic liberalization, which began in the 1980s, witnessed the removal of most quantitative restrictions by 1986.

The role of tariffs in Jamaica has undergone significant changes over time. From the dawn of emancipation to the dusk of the Great Depression, tariffs were *the* single most important source of central government revenues. During that interim, the contribution of tariffs ranged from a low of 53.4 per cent of total receipts in 1870 to a high of 69.9 per cent in 1850 (Eisner, 1961). In the post-War era, it was not until 1961 before income taxes eclipsed customs duty as a source of revenues. This trend has continued unabated, and by the mid-1970s customs duties contributed a mere 5.06 per cent to the public purse, while income taxes accounted for 28.20 per

cent of the total -- enjoying pride of place as the single largest source of government revenues (Newbery and Stein, 1987).

Perhaps the most central element determining the competitiveness of Jamaican exports is the trade regime under which the economy operates. Jamaica, as a founding member of the Commonwealth Caribbean (CARICOM), subscribes to CARICOM's common external tariff (CET). The CET is a highly differentiated tariff schedule exhibiting a wide dispersion of tariff rates; the maximum rate being applicable to nonessential foods and beverages, soaps, travel goods, consumer durables, and electronic appliances.

The efficacy of the CET has been under review during the 1980s. One of the motivating forces for this is that other non-CARICOM countries in the region have undertaken extensive trade reform programs. Contrary to their historical experience, most of the countries of Central and South America have removed quantitative restrictions on imports and have narrowed, or are still in the process of narrowing, their import tariffs to a range lower than that of CARICOM. In this regard it appears, at least *prima facie*, that CARICOM countries, such as Jamaica, have lagged behind their Latin American counterparts in matters of trade reform.

It is important, however, to recognize that *de facto* and *de jure* tariff rates often do not coincide. This issue is particularly relevant to Jamaica where the official tariff rates are very misleading. Although the published rates, which correspond to the common external tariffs of CARICOM, are relatively high, there are a complex

set of exemption procedures, which ensure that the actual rates paid for broad categories of imports are substantially below published nominal rates. The trade data shows that in 1986, for example, 78% of imports by value were classified as *concession imports*, and thus not liable to the full duty rates. In addition, the average rate of duties collected in 1986 was a mere 3.5%. Weiss (1985) describes a similar situation for 1982 when the average rate of duty collected was 7%. While individual items may pay the published rate of tariff, the degree of concessions means that the average rates applied to Standard International Trade Classifications (SITC) are well below the official rates. For example, using 1982 data Weiss (1985) found for SITC category 85 (Footwear) duties collected were 12%, while the published rates for most footwear items were 25%; similarly for SITC 84 (Clothing) duties collected were at a rate of 20%, while the official tariff schedule ranged from 20% to 45%, with most items eligible for the 45% rate. In fact, for 1982 only six out of the sixty-five 2-digit SITC categories that characterize Jamaica's imports realized an average rate of duty that exceeded 20%: beverages (24.5%), explosives (20.6%), office machines (32%), sanitary plumbing and heating (30.5%), special transactions (32.8%), and firearms (47.3%). Furthermore, the aggregate value of these six categories represented a mere 2.8% of total merchandise imports.

Notwithstanding the foregoing analysis, CARICOM, and especially Jamaica (with much encouragement from the World Bank), embarked upon a two-phase program of tariff reform (reduction). The first-phase covered the period 1987 to

1991, and the second-phase is to take effect from 1993 to 1997. In the first-phase the CET was set at a range from 5% to 45%, while the rates for the second phase are currently under negotiation. The goal of both phases is to broaden the tariff base, while reducing the tariff rates to remain competitive with the tariff regimes that currently prevail in Central and South America.

The first step in the restructuring of the tariff schedule took place in March 1987 and resulted in a 68% maximum aggregate rate of duty. The final set of rates to be applied by the end of the first-phase in 1991 are as follows:

- (1) 10% aggregate on imports of raw materials.
- (2) 20% aggregate on imports of capital goods.
- (3) 30% aggregate on imports of consumer goods.

The preceding rates allowed for a narrow category of special items, such as noncommercial motor vehicles which were subjected to tariffs that exceeded 100 per cent.

The objective of the current research is relatively straightforward, it is to establish the optimal revenue-neutral tariff structure for Jamaica using data for 1986, the year immediately prior to the introduction of tariff reform. The basic notion is to compare the optimal tariff structure generated by a computable general equilibrium

(CGE) model with that of the structure implemented in the first phase of the tariff reform program during the period 1987 to 1991.

General Equilibrium Effects of a Tariff

The general equilibrium impacts of a tariff are well established in the literature, with a lengthy heritage that preceded the seminal endeavors of Adam Smith and David Ricardo. The topic remains a familiar one, gracing just about every level of academic inquiry on trade theory, with a range of scholarship that spans the spectrum from the introductory to the advanced. With this lineage and enduring status -- and the nature of the present research -- academic courtesy (homage?) dictates a brief discussion of the issues. For expository clarity the general equilibrium effects of a tariff will be illustrated using a graphical representation of the two-sector Heckscher-Ohlin-Samuelson (HOS) trade model. Starting from a position of free trade, the model operates under the following assumptions:

- (1) Domestic markets are perfectly competitive.
- (2) All factors of production are fully employed.
- (3) The export price elasticity of supply the import price elasticity of demand are infinite -- the small-country assumption.

- (4) All traded goods are homogenous commodities -- perfect substitutes in use.
- (5) The trade balance is fixed.

Consider the familiar diagram of Figure 2.1, referring to a typical developing country that imports manufactured goods and exports agricultural commodities. The domestic transformation curve is represented by QQ ; the world price line is depicted by $WPL(W_F)$, and its slope W_F , is the exogenous world price ratio for manufactured and agricultural goods. In the absence of trade policy, the world price ratio (W_F), and the domestic price ratio (D_F), are equivalent. Therefore, at prevailing world prices, the country can trade anywhere along $DPL(W_F)$. The free-trade consumption possibilities (absorption), which depends upon the domestic price ratio, occurs along the locus of the income consumption curve $ICC(W_F)$. Given the assumption of perfect competition in domestic markets, and the absence of externalities or distortions, the economy's social welfare is maximized at the free-trade levels of consumption and production. That is to say, under free-trade the economy is at a Pareto optimum. Production under free-trade occurs at P_F where the domestic rate of transformation (DRT) is equal to the foreign rate of transformation (FRT). Similarly, free-trade consumption occurs at C_F where $ICC(W_F)$ intersects $DPL(W_F)$ and where the domestic rate of substitution (DRS) equals the FRT.

tariff, the new domestic price line $DPL(D_T)$ can no longer support the same point of tangency along the production possibility frontier as did the old domestic price line, $DPL(D_F)$, that corresponded with the world price $WPL(W_F)$. That is to say, $DPL(D_T)$ and $WPL(W_F)$ are no longer parallel and overlapping because the tariff introduces a wedge between world and domestic prices.

The economy's consumption possibilities must now reflect the new domestic price regime, however identifying the new consumption point is less straightforward than identifying the new production point. Nevertheless, the process can be simplified by enlisting the following assumptions into the model:

- (1) The economy's expenditures are equal to its income at world prices.
- (2) Domestic users face the tariff-distorted domestic price ratio.
- (3) Tariff revenues are redistributed to consumers via a non-distortionary (lump-sum) transfer.
- (4) Both imports and exports are non-inferior goods.

The economy's new consumption point under the tariff regime lies on a world-price line (assumption 1) through production point P_T (assumption 2) and on an indifference curve tangent to a domestic-price line (assumption 3). Thus, in Figure

2.1, the new consumption bundle is at C_T , a point of tangency for an indifference curve and a domestic-price line parallel to $DPL(D_T)$.

The general equilibrium effects of the tariff on a small-country can now be catalogued as follows:

- (1) The consumption of the import good declines, with both income and substitution effects reinforcing each other; while consumption of the export good may rise or fall, depending upon the relative strengths of opposing income and substitution effects.
- (2) The tariff causes production, and therefore resources, to be shifted from the unprotected sector (agriculture) into the protected sector (manufacturing).
- (3) There is a decline in imports of manufactured goods because of (1) and (2), above.
- (4) There is a fall in consumer welfare (movement to a lower indifference curve) under the tariff compared with free trade.
- (5) Even if the factors of production are immobile between sectors, with production remaining at P_F , there is, nevertheless, a decline in both the consumption and the

importation of the manufactured good. The associated welfare loss is the movement from C_F to C_0 in Figure 2.1. That is to say, ignoring production effects, the tariff diminishes community welfare by distorting the price regime faced by consumers -- consumption loss. The remainder of the welfare loss (from C_0 to C_T when resources are mobile between sectors), is the loss in real income arising from the change in output-mix. This welfare loss is the production loss from the tariff.

- (6) Although income equals expenditure at world prices, it is obvious from Figure 2.1 that total expenditure exceeds the value of total output at domestic prices. That is to say, C_T is tangent to $DPL(D_T^1)$, a domestic price line parallel to, but higher than, $DPL(D_T)$. This is the effect of assumption 3. Actually, there are two parts to assumption 3. First, tariff revenues are rebated to consumers. If this were not so, consumption would occur on a lower indifference curve tangent to $DPL(D_T)$. And second, tariffs are redistributed in a non-distortionary fashion -- $DPL(D_T^1)$ is parallel to $DPL(D_T)$.

- (7) Finally, the economy is no longer Pareto optimal: the equality of the domestic rate of substitution (DRS) in consumption, the domestic rate of transformation (DRT) in production, and the foreign rate of transformation (FRT) in trade, no longer obtains. Instead, with the introduction of a tariff: $DRS = DRT \neq FRT$.

Tariffs and Domestic Distortions

Since Adam Smith, much of the literature on trade theory and policy has been devoted to exploring the welfare benefits that accrue from free trade and the welfare losses associated with protection. The consistent result that emerges from these analyses is that, for a small country with no other economic distortions, restricted trade under a tariff is inferior to free-trade. Even so, casual observation suggests that governments do not always pursue the socially optimal course of action, after all tariffs are a commonplace in most countries, especially developing countries. The fact is, governments are in the business of trading-off the competing demands of various political interest groups -- a process that does not necessarily guarantee efficient economic outcomes.

Most arguments for tariff protection originate with some market failure in the domestic economy where there is a divergence between domestic prices and domestic opportunity costs. However, in most instances, market failure is insufficient to justify

recourse to trade intervention. The first-best policy requires addressing the immediate cause of the divergence to restore the necessary marginal social equalities. It follows, that any distortion that prevents market prices from corresponding to either the marginal social rate of substitution or the marginal social rate of transformation should be corrected by a tax, a subsidy, or a combination of both. The central principle is that any intervention should be as close as possible to the source of the relevant distortion. Therefore, in the presence of domestic distortions, Pareto optimality requires a production subsidy (tax) as the first-best policy in redressing a production distortion, a consumption subsidy (tax) for a consumption distortion, and a factor subsidy (tax) for a factor-market distortion. Where there is a distortion in foreign markets, such as imperfectly elastic foreign demand or supply, Pareto optimality requires the imposition of a tariff (subsidy) to equate the domestic price ratios with the marginal rates of transformation between traded commodities. In nontechnical terms, this is the application of the optimal tariff structure in the large-country scenario; or, in terms of the preceding graphical analysis, the goal would be the establishment of the equalities, $DRS = DRT = FRT$.

Infant Industry Argument

One of the oldest, as well as the most popular, petitions for protection is the infant industry argument. The essence of the infant industry argument is that it is an

appeal for temporary protection to correct a domestic distortion that does not last forever, but disappears gradually with the passage of time.

There are several different justifications for the infant industry argument one of the most common involves dynamic internal economies. Internal economies can arise through an initial learning experience where the benefits accrue entirely within a firm (industry). Since internal economies are neither market failures nor distortions there is no need for intervention. The fundamental reason for this is that internal economies do not by themselves entail a departure from the first-order conditions of Pareto optimality. However, imperfections in capital markets may make the financing of investment in human capital difficult: because of bias against investment in *invisible* capital, or because of high interest rates for long-term investment (due to myopic foresight). If this is the case, the first-best policy calls for intervention in capital markets, where the market failure prevails, perhaps by providing special financing agencies or the like.

Distortions in Factor Markets

Yet another set of arguments that have entertained a large and loyal advocacy for protection, are those that apply to factor immobility, especially sector-specific factors of production. Factor immobility does not by itself entail a market distortion or market failure, it is simply an immutable phenomenon in economics systems. If factor prices are flexible, immobility of factors cannot prevent an economy from

being better off under free trade than under protection. Therefore, even when factors are immobile, as long as factor prices are flexible, factor prices will continue to reflect the true opportunity cost of factors to the economy. The conditions of Pareto optimality are maintained, and there is no domestic distortion in need of remedy.

When distortions are present in factor markets, such as rigid real wages at a level too high to support full employment, the first-best policy calls for addressing the problem at its source. In this instance employment subsidies and not trade protection is the ultimate solution.

Distortions in the Commodity Market

There is yet another group of arguments that appeal for protection, and these are motivated by distortions in domestic output markets. Imperfect competition (monopoly, oligopoly, and monopolistic competition) in commodity markets raise the price of output above their marginal cost of production. Similarly, in instances where external economies or diseconomies are present, marginal private costs appear higher than marginal social costs. Again, as before, the first-best policy is to address the source of the problem: either through the introduction of free trade to end domestic monopoly power or through the application of appropriate taxes (subsidies) if the source of monopoly power is overseas.

The Limitations of Domestic Distortions Theory

In the previous section, various arguments for protection have been considered and have been found wanting. This leads to the conclusion that there is a good case for dismantling existing protective barriers in small countries. However, even the well-motivated theorist or policy maker faces a difficult task. The process of reform must, to some extent, accede to practical considerations that have not yet been included in the current analysis.

According to Corden (1984), a common feature of the standard theory of domestic distortions is the assumptions that lump-sum (non-distortionary) taxes are available to finance the various required subsidies, or alternatively, that the supply elasticity of effort is zero. The implicit assumption associated with this latter issue, is that it is possible to raise lump-sum taxes without creating a distortion relative to leisure. But even if lump-sum taxes are available, many theoretical arguments fail to note there may be practical limits to the amount of revenue that can be raised for redressing distortions. In addition, there is a tendency for the literature to ignore the role of tariffs as primarily a source of government revenues and not as a means of protection. This is particularly so in developing countries, where the ease of assessment, and the facility of collection, makes tariffs one of the major single contributors to the public purse. By contrast, the literature on trade protection is replete with the presumption that tariffs are used exclusively for protection, and their

revenues are remitted to consumers (in lump-sum fashion) rather than relegated to government coffers for other fiscal purposes.

More recently, the literature on trade distortions has been focused on second-best analysis where the issue concerns trade taxes as sources of revenues. According to Corden (1984), one approach is to set a revenue target, assume no prior domestic distortions of any kind, ignore income distribution effects, and then consider the optimal structure of trade taxes. Dasgupta and Stiglitz (1974) and Corden (1974) found that the optimal tariff and export taxes (subsidies) will not be uniform.

This conclusion vitiates the standard rule-of-thumb in development policy that counsels LDCs to equalize their tariff rates across sectors or at least move towards more equal rates by raising the lowest tariffs and lowering the highest ones. A policy of equal tariff rates or a narrow range within which tariffs are applied is intuitively appealing, since it supposedly accords equivalent or near equivalent rates of nominal protection to the relevant domestic industries. This position represents the conventional wisdom at the World Bank (Robinson, 1990) and has been advocated by Belassa et al. (1982), Krueger (1985) and Harberger (1988). The basis for the argument is that if world prices are viewed as the appropriate *shadow prices* of traded goods, then a varied tariff structure represents a distortion. However, if there are other distortions in the economy, then the shadow prices of traded goods in this second-best environment need not equal world prices.

Chambers (1989) provides a survey of the theoretical debate showing that in the presence of non-removable distortionary taxes, such as income and commodity taxes, equalizing tariff rates is not optimal. Dahl, Devarajan, and van Wijnbergen (1986) discuss a theoretical model of the issue and provide an empirical application with a CGE model of Cameroon. Devarajan and Lewis (1989) discuss a similar application with a thirteen-sector CGE model of Indonesia, and Devarajan, Lewis, and Robinson (1989) illustrate the empirical issues using a stylized extension of the two-sector CGE model of an archetypical LDC. From these studies, the conclusion is that, in a second-best world, a policy of equal tariffs across sectors is not optimal.

One of the more interesting results from the now growing body of empirical work is that the costs of engaging in trade protection, or that the gains from removing them, are relatively small. In a recent conference volume, Srinivassen and Whalley (1986) compare studies of trade liberalization in a variety of single country and multi-country models. In their summary, they note that the static welfare gains from trade liberalization are relatively small, less than 1 percent of GNP.

CHAPTER 3.**THE MODEL**

The main objective of this study is the formation of a multi-sector computable general equilibrium model of the Jamaican economy to derive an optimal tariff policy for the island. The relevant issue that will be addressed in this chapter is the choice and the implementation of an appropriate CGE model for the task at hand. The first part of the deliberation will concentrate on general principles of model design and model philosophy. Afterwards, the focus will converge on the practical aspects of model specification.

Types of Economic Models

There are several ways to classify economic models. Robinson (1988) identifies and elaborates on some of these taxonomical endeavors. One approach is by mathematical structure or methodology: optimization or simulation, static or dynamic, and linear or nonlinear. Another is by theoretical type or by the nature of the underlying theoretical paradigm. And finally, models can be classified by policy focus where the modelling enterprise can occupy a range of efforts to include, in order of increasing complexity: analytical constructs, stylized archetypes, and applied models.

Most of the work on multi-sector models of developing countries has been motivated by policy concerns. These concerns have exacerbated the long-standing tension between theoretical simplification and empirical complexity. The tension reflects the continuum of research perspectives that economic models occupy, ranging from the analytic, to the stylized, to the applied.

Analytic models are designed to explore the implications of various sets of theoretical postulates. Their major purpose is to facilitate the mathematical analysis of various properties and policies through modest applications of algebra or geometry. They are, therefore, deliberately simplified to focus attention on important assumptions and causal mechanisms. By necessity, they are designed with the minimal possible assumptions regarding the magnitudes of their parameters where the need for mathematical brevity dictates that the stylized facts are minimized and often exaggerated.

By their very nature, analytic models are limited in their application. Many phenomena that can be isolated in an analytical model can often work in contradictory directions. The resolution of the problem ultimately rests with the designation of a model that can provide solutions with numerical values. Accordingly, whenever an analytical model is insufficient in providing unambiguous results, recourse is often made to a stylized numerical model. Stylized numerical models have two main functions: (1) to analyze the problems that are too intractable for analytical methods, or that have ambiguous implications that can only be resolved by actual parameter

values, and (2) to provide the numerical order of magnitude for various results whose analytic properties are well understood.

Typically, stylized numerical models are more complex than their analytical counterparts. However, since the goal is to explore particular causal mechanisms, stylized numerical models usually do not wander too far from their underlying analytic foundations. The complexity of a stylized model is still, however, a *far cry* from a model that seeks to realistically portray the variety of important effects required by policy analysis.

Applied models distinguish themselves from their stylized counterparts in two very important ways. First, they broaden the range of stylized facts exploited in the modelling exercise. And second, they incorporate a wide range of important variables and features in describing an economic system.

The progression from an analytic construct to a stylized archetype, and ultimately, to an applied model, allows increased institutional specificity. The tradeoff, of course, is that the gain in additional detail and size may obscure the major causal mechanisms that drive the model.

Computable General Equilibrium Models: An Introduction

The development of computable general equilibrium (CGE) systems have significantly transformed the design and complexity of applied, economy-wide models. This capability originates from two important characteristics of CGEs. The

first, is the capacity to indulge a variety of autonomous microeconomic agents operating in an endogenous price system -- one that equilibrates supply with demand. And the second, is the facility to entertain the extreme nonlinearities that are frequently encountered in the mathematical descriptions of most economic relationships. Both characteristics have equipped CGEs to become one of the most elaborate economic tools employed in policy analysis.

The most significant achievement that CGE models have attained over their predecessors is their ability to consistently integrate five important cornerstones into an economic architecture whose foundation supports an endogenous and decentralized price system. These five integrated cornerstones are: autonomous economic agents, their individual motives, the economic signals to which they respond, the institutional framework within which they interact, and finally, a set of system constraints or equilibrium conditions that must be satisfied in the aggregate (Robinson, 1988).

Briefly, several disparate agents are assumed to separately optimize their economic behavior within a variety of constraints. For example, households are assumed to maximize their utility subject to an income constraint, while producers are assumed to maximize profits within the confines of the prevailing production technology. The important distinction in CGE models, is that the optimizing behavior of economic agents is contingent upon the information communicated by price signals -- signals that emanate from the intricate operations of a decentralized price system: a system where relative prices continually equilibrates demand and supply, and a system

where prices themselves can be determined within the model. These price signals, which play an important role in allocating a variety of scarce resources, are generated in institutional environments of either perfect or imperfect competition. In turn, the general structure of the scheme and the independent decisions of individual economic agents, are subject to certain resource and system constraints. The outcome of this simultaneous nexus is a comprehensive economic model replete with autonomous decision-makers; each making decisions within the framework of decentralized factor and commodity markets; and each contributing separately to the ultimate goal of establishing the optimum allocation of scarce resources.

From the perspective of economic planning and policy analysis, CGE models have proven to be useful tools in evaluating the economy-wide impacts of various policies that effect: income distribution, consumption, investment, economic growth, employment, structural transformation, and the patterns of trade. Equally important, because CGE models can entertain autonomous, decentralized decision makers operating within an endogenous price system, they can portray the interdependence among economic agents. Specifically, they can delineate the inherently complex interdependence that constitutes the circular-flow of payments and receipts for goods and services. This latter feature is theoretically significant. Many economy-wide planning models, especially linear-programming models, are not internally consistent with the behavioral rules of microeconomic (individual) agents (Robinson, 1988). There are two major advantages of operating within the apparatus of a fully specified

price system. The first, is that it embraces the essence of the circular-flow. And the second, is that it imposes rigorous compatibility between the data and the underlying macroeconomic and microeconomic assumptions of the model. Such structures then, provide a coherent and integrated picture of the economy. A picture that includes not only the macroeconomic variables that constitute the economic system, but also the behavioral assumptions most commonly associated with decentralized, microeconomic activities in a price endogenous system: utility-maximization, profit-maximization, and cost minimization. CGEs thus provide a comprehensive laboratory for performing and analyzing various policy experiments involving price incentives and price interactions. Policy choices, therefore, occur within a consistent analytical and informational framework not only at the macroeconomic level, but also, and extensively so, at the microeconomic level.

Designing an Applied General Equilibrium Model

In applying general equilibrium analysis to policy questions, a series of initial issues typically arises. These issues are concerned with both the broader theoretical questions of model design, and with the achievement of a model that captures the features of the relevant policies under review. A conspicuous set of issues that immediately confront the model-builder is the widespread practice, albeit generally unacknowledged, of model preselection (i.e. the necessity to choose a specific model before proceeding with the particulars of policy analysis). There are four important

issues encountered in model preselection: model paradigm, model structure, functional forms, and model aggregation. The first issue, model paradigm, is a theoretical one, while the remainder address the more practical aspects of model design.

Model Paradigm

Prima facie, the fundamental difficulty in preselection is the availability of several alternate theoretical models (paradigms) in the literature, each applicable to the policy question at hand, and each yielding a different set of policy implications. Unfortunately, the methodology of applied general equilibrium analysis, per se, does not provide a way of discriminating between alternate models -- the selection process essentially does not involve any form of hypothesis testing in the statistical or econometric sense (Shoven and Whalley, 1992). Therefore, conflicts among alternate economic theories will arise, and it is judicious to acknowledge that there is a large degree of subjective judgement in selecting a particular theoretical structure (Shoven and Whalley, 1992).

Although there are several alternate models to choose from, the literature on trade-oriented general equilibrium models can be divided into three broad schools of thought: the *neoclassical*, the *structuralist* and, for want of a better sobriquet, the *neoclassical-structuralist*.

Neoclassical trade theory is built on the small-country assumption, where each nation is a price taker in international markets. This assumption makes a strong

distinction between two sets of domestically-produced commodities: traded and non-traded goods. The prices of the former are fixed by international markets because domestically-produced traded goods are considered perfect substitutes for imports or exports. By contrast, the prices of non-traded goods are entirely determined by the domestic market. While neoclassical trade theory has many practical applications, especially the role of trade policy in closing foreign exchange gaps, the theory cannot adequately accommodate the empirical reality of *cross-hauling* or two-way trade -- the simultaneous export and import of commodities at the sectoral level.

On the other hand, the structuralist school assumes that the relationship among goods in sectors with international trade is one of perfect complementarity. Accordingly, the degree of substitutability between domestic goods and traded goods within the same economic sector is zero (this is, coincidentally, the assumption in the two-gap model). While the structuralist approach can adequately account for cross-hauling, trade policy has no role to play in closing foreign exchange gaps in its rigid framework.

Finally, there is the neoclassical-structuralist school. Its distinguishing feature is that it avoids some of the more extreme assumptions of both the neoclassical and the structuralists paradigms. The major contribution of the neoclassical-structuralists is the assumption that in sectors with international trade imports or exports are neither perfect substitutes nor perfect complements of domestic production. Instead, the relationship among imports, exports, and their domestic counterparts is one of

imperfect substitutability (complementarity). This approach has certain desirable features: it allows cross-hauling at the sectoral level, and it gives trade policy a central role in closing foreign exchange gaps.

Model Structure

Most applied models currently in use have a similar form. They are typically variants of static, two-factor models that have an established tradition in the literature on public finance and international trade (Shoven and Whalley, 1992). These models involve several producing sectors, where intermediate-transactions are usually incorporated with the assistance of either fixed or flexible-coefficient input-output matrices. Factors of production, on the other hand, are aggregated into two broad categories (labor and capital) which are accommodated in a framework with substantial substitution possibilities (Shoven and Whalley, 1992).

Although it is likely that alternate models with richer structures will gradually appear in the future, Shoven and Whalley (1992) posit three reasons that account for the popularity of the basic two-factor model.

First, many policy issues have already had the benefit of prior theoretical inquiry within a two-factor analytical framework. If the major contribution of empirical investigation is the advancement of research from analytical constructs to applied models, then it is only natural to retain the same basic theoretical structure used in analytical models. Furthermore, the intuition and insights gleaned from

analytical constructs can be used as a guide in applied models since policy issues are simulated within a conceptually similar framework.

Second, most data on which numerical specifications are based come in a form that is consistent with the two-factor paradigm. The widely adopted conventions of national income accounting explicitly identify wages, salaries, operating surplus, and depreciation as major cost components of GDP; this suggests using models with labor and capital as the primary inputs of value-added.

Third, the convenient partition between produced goods and endowed factors contributes to computational simplicity. Because of this, there are significant reductions in the time and the cost of obtaining both initial and counter-factual solutions in large-scale models.

There is yet another reason applied models share a similar form. Input-output tables contribute the major source of data to the modelling exercise (Dixon et al., 1992). In turn, an input-output foundation imposes a particular structure on CGE models. The two most important of these are: joint production as the basis for organizing the provision of sectoral output to satisfy intermediate, consumer, and capital demand (ie. each sector produces a single homogeneous commodity supplied as an intermediate, consumer, or capital good); and second, strong separability of output among sectors (ie. there are no substitution possibilities between the output of different sectors).

Functional Forms

Another important issue in model preselection is the choice of functional forms. The major constraints on specifying demand and supply functions are that they must be both consistent with the theoretical approach and that they must be analytically tractable. The general procedure is to select the functional form that best allows key parameter values, such as elasticities, to be incorporated into the model, while maintaining tractability. This largely explains the use of functions that are so often restricted to the family of first-order (convenient) forms: Cobb-Douglas, constant elasticity of substitution (CES), linear expenditure system (LES), and others (Shoven and Whalley, 1992). These convenient forms could, of course, be relaxed to include second-order approximations with flexible functional forms. However, such specifications would unnecessarily complicate the parameterization of the model since many more cross-elasticities (which are difficult to estimate precisely) would be needed (Melo and Tarr, 1992).

A device widely employed in applied models that complements the use of first-order (convenient) functional forms is to arrange functions in a hierarchical (or nested) pattern. Under this approach, functions can be contained within other functions, and many layers of hierarchy can be employed. The practical benefit of this technique is that it greatly expands the number of parameters that can be calibrated to preexisting elasticity estimates in the literature.

Model Aggregation

The choice of both the level and the extent of aggregation is one of the more difficult preselection issues that preoccupy any prospective modeler. In practice, several considerations enter the choice of aggregation in applied models: the need to accurately capture the main discriminatory features involved in the policy issues under discussion, the limits of data availability, and the need to constrain computer costs by using a model structure that can be manipulated with relative ease (Shoven and Whalley, 1992). This latter point, however, has become less important.

Improvements in both software and hardware have not only removed the domain of programming from the mainframe computer to the personal computer, but have also simplified the coding activities associated with model specification and model manipulation.

According to Shoven and Whalley (1992), there is an increasing tendency towards applying different levels of aggregation to the same data set. In the initial stage of model construction, a highly aggregated data set can be used to reduce development time and simplify model manipulations. For these first-stage models, where only initial broad indications of results are needed, a high degree of aggregation is desirable. Only after the modeler is sure that all development and design problems have been resolved should a more disaggregated presentation be attempted.

A further issue affecting the level and extent of aggregation is the policy orientation of the model itself. Depending upon the focus of the analysis, and the policies in question, some portions of the model may be highly aggregated while others are more disaggregated. Flexible aggregation of this type is often the best accommodation to the various competing concerns that confronts the modelling exercise. As a rule, rather than thinking in terms of a single construct, a modeler should develop a more comprehensive modelling capability. The central idea is the accommodation of several alternate levels of aggregation, and different model variants within the same exercise.

An Overview of the Model

The model is constructed along the traditional paradigm of positive analysis that has come to be widely used in economics. Agents are assumed to optimize their behavior according to some rule. The derived results are then utilized to test a variety of positive hypotheses. In this instance, the focus of the model is not to establish if economic agents behave in an optimal fashion, rather, their optimal behavior is presumed. Consequently, the modelling procedure can be called conditional positive analysis. Conditional, because optimizing behavior is hypothesized but not tested.

By way of a synopsis, the CGE model consists of an economy-wide, simultaneous, multi-sectoral formulation of the Jamaican economy that provides

endogenous solutions for: product prices, profits, the functional distribution of income, sectoral production, imports, exports, employment, consumption, the aggregate price level, and the balance of payments accounts. The core of the system consists of simulated markets for factors and commodities in which all potential demand and supply imbalances are simultaneously reconciled -- either through a price-clearing system (the Walrasian adjustment mechanism), or through a quantity-clearing system (the Keynesian adjustment mechanism). Because tariff rates can differ by end-use within the same sector, each sector will include three distinct categories for domestic absorption: intermediate goods and two final commodities (consumer and capital goods).

A social accounting matrix (SAM) is the organizational framework around which the model is constructed. The SAM provides a consistent reconciliation of the flow-of-funds among the different institutions and agents in the economy. Although the CGE concentrates almost entirely on the real sector, some of the more important financial transactions are also portrayed, albeit in the most part, as exogenous variables. These include: foreign borrowing, social security payments, government transfers, and various taxes.

The model represents a class of CGE models used to analyze issues of trade policies in developing countries. The behavioral rules of the model are sustained by the activities of four distinct categories of economic agents: households, corporations,

the government, and the rest of the world. The activities of these agents are incorporated in a specification that includes the following eighteen sectors:

Sugar Cane Agriculture

Other Export Agriculture

Domestic Agriculture

Livestock Agriculture

Bauxite and Alumina

Food Manufacturing

Beverage and Tobacco Manufacturing

Sugar Manufacturing

Other Manufacturing

Petroleum Refining

Chemicals and Other Intermediate Manufacturing

Fabricated Metals, Machinery, and Equipment

Electricity and Water

Construction and Installation

Distributive Trades

Transportation and Communication

Real Estate and Financial Services

Personal and Miscellaneous Services

In order to provide a more thorough understanding of the model, its principal features are derived and discussed below. This is followed by a lengthy recapitulation that will be used to cement the various disparate ideas into a unified body of thought. Afterwards, there is a discussion on the derivation of the model's parameters. And finally, a necessary caveat is issued regarding the uses and limitations of economic models.

International Trade

Most applied, trade-focused policy models are based upon the comparative advantage framework associated with Heckscher, Ohlin, and Samuelson -- trade is determined by the factor intensities of production and by the relative factor abundance among countries.

A characteristic common to most applied trade-focused models is the so-called Armington assumption. A premise, which unlike that of the traditional Heckscher-Ohlin-Samuelson (HOS) model, treats traded goods as heterogeneous rather than homogeneous commodities. The reasons for this approach reflect the inherent tension between theory and application that continually confronts the empirical modeler, and the need, ultimately, to reconcile these tensions in a way that is both theoretically plausible and pragmatically functional. There is substantial evidence of two-way trade or cross-hauling at the sectoral level of aggregation employed in most applied models. However, early modelling endeavors using the HOS model had a problem with

maintaining a realistic degree of two-way trade when changes in trade policy occurred (Shoven and Whalley, 1992). In any effort to overcome this problem, most multi-sector computable general equilibrium models include product differentiation at the national level, along with constant-returns-to-scale technology and perfect competition at the firm level. National product differentiation requires the following assumptions for commodities associated with the same economic sector:

- (1) Domestically produced and imported goods are imperfect substitutes -- the Armington assumption.
- (2) Domestically produced goods sold on the domestic market differ from those sold on the export market.

An additional assumption, unrelated to the cross-hauling problem but appropriate to the Jamaican situation, is also incorporated in the model:

- (3) The economy purchases and sells its imports and exports at the prevailing world prices -- the small-country assumption.

Import Demand

The Armington assumption requires that both domestic and imported goods, associated with the same economic sector, be treated as imperfect substitutes for each other, and that they be aggregated to produce a third and distinct good (a composite commodity). The underlying behavioral assumption dictates that the cost of combining the relevant commodities is kept at a minimum -- cost minimization. More specifically, it is assumed that domestic users minimize the cost of consuming a composite commodity consisting of both a domestic good and its corresponding import and where the two goods are also subject to a constant elasticity of substitution (CES) aggregation function.

For example, with intermediate-goods, imports (VM_i^d) and domestic goods (VD_i^d) are combined in consumption to create a composite good (QV_i^d) to satisfy intermediate-absorption (demands). The behavioral assumption is that demanders establish the minimum cost for any level of consumption, given the aggregation function and the prices of domestic and imported goods:

$$\begin{aligned}
 \text{Minimize:} \quad & PM_i^v \cdot VM_i^d + PD_i^v \cdot VD_i^d \\
 & VM_i^d, VD_i^d \\
 \text{S.T.} \quad & QV_i^d = CES(VM_i^d, VD_i^d)
 \end{aligned} \tag{1}$$

The first order conditions yield the intermediate-import demand equation:

$$VM_i^d/VD_i^d = f_i(PM_i^v/PD_i^v) \quad (2)$$

where PM_i^v and PD_i^v are the respective prices for imported (VM_i^d) and domestic intermediates (VD_i^d).

Figure 3.1 shows how the assumption of national product differentiation establishes, through relative prices, the optimal allocation of total demand between domestic use and imports. The CC curve depicts an isoquant derived from the import aggregation function, where the combination of domestic use and imports is consistent with the supply of the composite commodity. The model calibrates the import aggregation function on base-year data for a given trade substitution elasticity. That elasticity establishes the shape of the curve around the initial point, A, which represents a tangency between the composite commodity's isoquant and the price line,

$$PM_i^v \cdot VM_i^d + P_i^d \cdot VD_i^d \quad (3)$$

When the price of the imported good is lowered by removing the tariff, for example, the initial price ratio will change from $(P_i^d/PM_i^v)^0$ to $(P_i^d/PM_i^v)^1$. Economic agents attempting to minimize the cost of purchasing the composite good will shift the new equilibrium point to *B*, representing a higher import to domestic use ratio. The change in the price ratio is also reflected as a change in the price of the composite

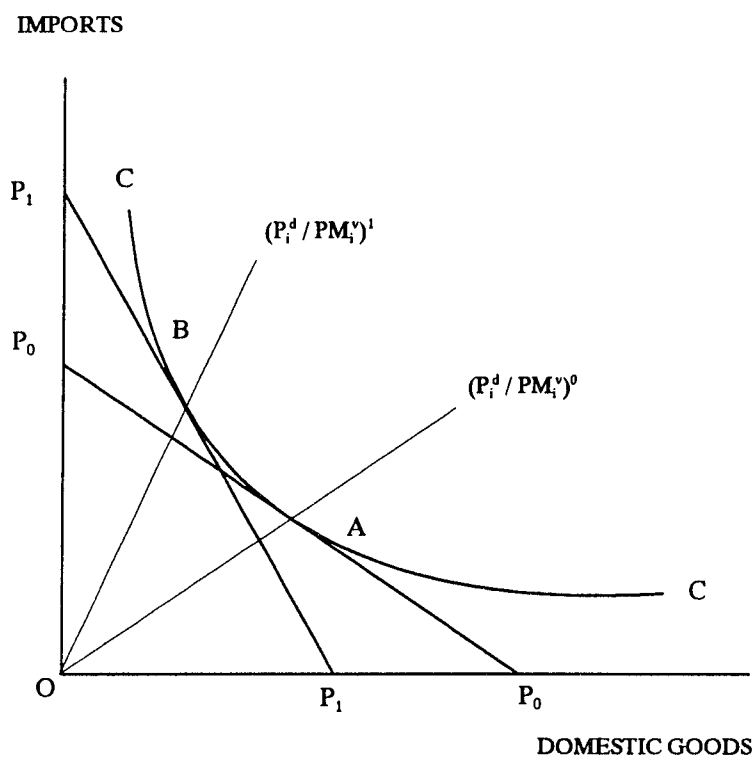


Figure 3.1: Determination of import demand

commodity. Because the aggregation function is linearly homogeneous, the composite commodity price can be represented as a weighted average (linear combination) of the respective prices of its domestic and the imported components,

$$P_i^q = \frac{PM_i^v \cdot VM_i^d + P_i^d \cdot VD_i^d}{QV_i^d} \quad (4)$$

The notion of national product differentiation in import markets is not a completely innocuous one. Besides its original intention, that of vitiating the cross-hauling problem, national product differentiation assumes both two-stage budgeting and a weakly separable aggregation function. It also implies that the price of domestic goods, P_i^d , and their corresponding domestic prices for imports, PM_i^v , need not be rigidly linked via trade policies and the exchange rate, such that:

$$PM_i^v = PM_i^{s^v} \cdot (1 + TM_i^v) \cdot r \quad (5)$$

While equation (5) still holds true under the Armington assumption, the equality between P_i^d and PM_i^v need not obtain. Although P_i^d is now endogenous, the price-taking assumption (small country assumption) is retained in the import market where PM_i^v continues to be linked to $PM_i^{s^v}$, the exogenously specified world price of Jamaican imports; TM_i^v , the tariff rates in sector i ; and r , the conversion factor between U.S. and Jamaican prices (determined exogenously in the model).

The extent to which world prices can influence domestic prices is a function of the elasticity of substitution between domestic goods and their imported counterparts. Two polar examples illustrate the point. Whenever the elasticity of substitution approaches infinity, the composite commodity's isoquants become increasingly linear -- indicating that VD_i^d and VM_i^d are becoming perfect substitutes in use. In turn, as the isoquants become more linear, cost minimization can only accommodate limited

divergences between domestic and world prices. Conversely, when the elasticity of substitution approaches zero, the composite commodity's isoquant becomes increasingly Leontief -- indicating that VD_i^d and VM_i^d are approaching perfect complements in consumption. Again, as the isoquants become more curvilinear, cost minimization can accommodate greater divergence between domestic and world prices.

Export Supply

The extension of the Armington assumption to the export market is a relatively simple task. It requires the presumption that export sectors face a constant elasticity of transformation (CET) production possibility frontier for both exports E_i^s , and domestic sales D_i^s . In addition, it is also assumed that entrepreneurs wish to maximize the total revenues from sectoral output X_i^s , by supplying these disparate markets in the following manner:

$$\begin{aligned}
 \text{Maximize:} \quad & P_i^e \cdot E_i^s + P_i^d \cdot D_i^s \\
 & E_i^s, D_i^s \\
 \text{S.T.} \quad & X_i^s = \text{CET}(E_i^s, D_i^s) \qquad (7)
 \end{aligned}$$

the ensuing first order conditions provide the structural equation that determines the ratio of export supply to domestic output:

$$E_i^s/D_i^s = f_2(P_i^e/P_i^d) \quad (8)$$

where P_i^d is commodity i 's endogenous domestic price, and P_i^e , its corresponding export price (in Jamaican dollars) which is stipulated as:

$$P_i^e = P_i^{se} (1 + T_i^e) . r \quad (9)$$

where T_i^e is the export subsidy rate, and P_i^{se} is the world price of Jamaican exports. Analogous to the import demand situation, the small-country assumption dictates that P_i^{se} is exogenously specified.

Figure 3.2 shows how the assumption of national product differentiation can be employed to determine, through changes in relative prices, the allocation of total output supplies between domestic and export markets. The TT curve represents the CET production possibility frontier derived from the output aggregation function,

$$X_i^s = CET(E_i^s, D_i^s) \quad (10)$$

where the combinations of domestic and export supply are consistent with the level of total output. The elasticity of transformation establishes the shape of the frontier

DOMESTIC GOODS

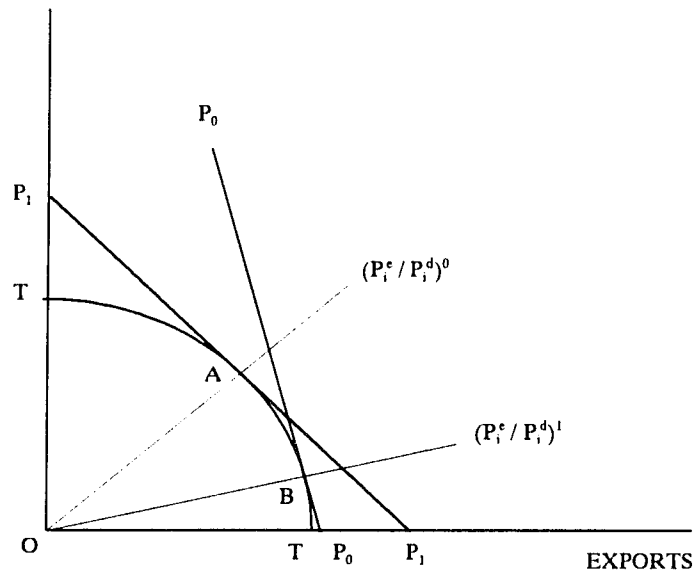


Figure 3.2: Determination of export supply

around the initial equilibrium point, A, which represents a point of tangency between the production possibility frontier and the revenue line,

$$P_i^e \cdot E_i^s + P_i^d \cdot D_i^s \quad (11)$$

with initial equilibrium price ratio, $(P_i^e / P_i^d)^0$.

When the export price of a commodity increases because of an increase in the world price, for example, the initial equilibrium at point *A* that supports the price ratio $(P_i^e/P_i^d)^0$, will face to a new price regime, say, $(P_i^e/P_i^d)^1$. Suppliers attempting to maximize sales revenues from domestic and export markets will shift the new equilibrium point to *B* representing a higher export to domestic use ratio. This causes the withdrawal of supply from the domestic market to the export market, which in turn exerts upward pressure on the domestic market price. The change in the price ratio is also reflected as a change in the price of the composite output supply. Because the CES aggregation function is linearly homogeneous, the composite price can be represented as a weighted average (linear combination) of the respective prices of its domestic and the exported components,

$$P_i^x = \frac{P_i^e \cdot E_i^s + P_i^d \cdot D_i^s}{X_i^s} \quad (12)$$

As with the case of imports, the rigid link between the domestic prices of export and domestic sales need not hold; the divergence between the two prices depends on the elasticity of transformation. For example, if the elasticity of transformation were to assume a relatively high (elastic) value of, say five, then it would only require a 1.0% change (divergence) in the relative price of exported to

domestic goods to induce a 5.0% change in the ratio of exported goods to domestic goods supplied by the producers of the composite output.

Household Consumption

The model embraces a single representative household with a *nested* utility function that consists of, at the upper level, a Cobb-Douglas specification. The resulting constant shares are expended, by economic sector, on composite consumer commodities. These composites are derived, at the lower level of the nesting procedure, by aggregating consumer imports and consumer domestic goods according to a CES utility function.¹ Households are assumed to maximize utility by consuming a basket of composite consumer commodities C_i^d , subject to a post-tax (T^h), post-savings (*mpsh*), household budget constraint, Y^{H*} . This creates demand functions for consumer goods and services that are responsive to variations in relative prices and incomes. The price response is derived from the substitution possibilities between consumer imports and consumer domestic output associated with the Armington aggregation process. By comparison, the income response comes from variations in labor incomes, which are established in factor markets and by exogenous income transfers from other economic agents within the system.

Mathematically, the representative household's optimizing problem can be stipulated as:

¹This is described in greater detail in the section: **Import Demand**.

$$\begin{aligned}
 \text{Maximize:} \quad & U^H = U(C_i^d) \\
 & c_i^d \\
 \text{S.T.} \quad & \sum_i PQ_i^c \cdot C_i^d = Y^H(1 - T^H) \cdot (1 - mpsh) \quad (13)
 \end{aligned}$$

the resulting first order conditions generate household demands for goods and services that are homogeneous of degree zero in prices and income:

$$C_i^d = C_i^d(Y^{H*}, PQ^c.) \quad (14)$$

where:

$$\begin{aligned}
 PQ_i^c &= \text{Price of Composite Consumer-Commodity } i. \\
 C_i^d &= \text{Quantity of Composite Consumer-Commodity } i. \\
 Y^H &= \text{Household Income} \\
 PQ^c &= \text{N x 1 Vector of Composite Consumer-Commodity Prices}
 \end{aligned}$$

Government Demand

In most CGE models, government spending is usually broken down into transfers and expenditures. The latter are typically maintained at constant real levels relative to a base year. That is, government is treated as a separate consuming agent procuring private goods and services. Usually the derivation of the demand for public goods and services is not dealt with, although in a few cases models have been used with public goods in household utility functions (Shoven and Whalley, 1992).

Basically, the government exercises discretionary fiscal policy by taxing a variety of incomes and transactions; the proceeds are then spent on goods and services, or disbursed as transfer payments. In the latter instance, this includes: government salaries for public administration and, transfer payments to businesses, households, and foreign parties. The government is assumed to keep the real levels of expenditures on each commodity fixed at the base year level, therefore, the government's sectoral demand for a given commodity G_i^d , is:

$$G_i^d = g_i \cdot GDTOT \quad (15)$$

In equation (15), $GDTOT$ is the government's exogenously specified aggregate level of real expenditures, while g_i is the fixed-share spent on good i in the base year.

Taken together these shares sum to unity over all commodities.

Output Supply and Factor Demands

In order to reduce the data requirements, while maintaining theoretical consistency and empirical plausibility, it is assumed that each productive sector consists of a representative corporation whose activities reflect the aggregate or sector-wide decision of producers. It is also postulated that corporations abide by the rule of profit-maximization in a competitive environment, thereby giving rise to factor demands and commodity supply.

In most CGE models, the structure of intermediate demand (V_i^d) follow a Leontief specification:

$$V_i^d = \sum_j a_{ij} X_j^s \quad (16)$$

the a_{ij} 's represent input-output coefficients, while the X_j^s 's are gross sectoral outputs. From equation (16), it is evident that there is no substitution possibilities between the various sectoral components of intermediate-demand. However, within a given intermediate-sector, the aggregate level of domestic and foreign intermediate goods are imperfect substitutes according to the dictates of the Armington assumption, where a CES function is employed in the aggregation of the respective local and imported components.

The derivation of output supply is based upon a two-stage optimization process. In the first stage, firms minimize the total cost (TC_i) of producing output (X_i^s) employing two factors of production capital (K_i^d) and labor (L_i^d). The relationship between factors and output is given by a constant-returns-to-scale, CES value-added function:

$$X_i^s = CES(K_i^d, L_i^d) \quad (17)$$

The total cost of production is determined by the factor prices: denoted by R_i for the price of capital, and W_i for the price of labor:

$$TC_i = W_i \cdot L_i^d + R_i \cdot K_i^d \quad (18)$$

Mathematically, the least-cost combination of factors is found by choosing the levels of capital and labor that solve the cost-minimization problem:

$$\begin{aligned} \text{Minimize:} \quad & TC_i = W_i \cdot L_i^d + R_i \cdot K_i^d \\ & \quad \quad \quad \kappa_i^d, L_i^d \\ \text{S.T.} \quad & X_i^s = CES(K_i^d, L_i^d) \end{aligned} \quad (19)$$

the resulting conditional factor demands have the usual property of homogeneity of degree zero in prices and take the form:

$$K_i^{d*} = L_i^*(X_i^s, W_i, R_i) \quad (20)$$

$$L_i^{d*} = L_i^*(X_i^s, W_i, R_i) \quad (21)$$

and the corresponding optimal-valued cost function can be written in the usual manner as:

$$\begin{aligned}
TC_i^* &= W_i \cdot L_i^{d*} + R_i \cdot K_i^{d*} \\
&= TC_i^*(X_i^s, W_i, R_i)
\end{aligned} \tag{22}$$

In the presence of constant-returns-to-scale (linearly homogeneous) technologies, equations (20) through (22) can be expressed exclusively as functions of factor prices multiplied by the level of output, accordingly:

$$K_i^{d*} = K_i^{d*}(W_i, R_i) \cdot X_i^s \tag{23}$$

$$L_i^{d*} = L_i^{d*}(W_i, R_i) \cdot X_i^s \tag{24}$$

$$TC^* = TC^*(W_i, R_i) \cdot X_i^s \tag{25}$$

where Equation (25) be easily manipulated to show the coincidence of marginal and average costs associated with constant-returns-to-scale cost functions.

At the second stage of the optimization process, producers attempt to choose the level of output that maximizes total profits (Π_i). Representing the product price by the variable P_i^x , firms :

$$\text{Maximize}_{X_i^s} \Pi_i = P_i^x \cdot X_i^s - TC_i^*(W_i, R_i) \cdot X_i^s \tag{26}$$

However, it is not possible to find the profit-maximizing level of output X_i^s , in the usual manner, by setting the derivative Π_{iX} , equal to zero. Output is simply not an argument of the derivative Π_{iX} . Thus displaying the familiar result that (in the presence of constant-returns-to-scale technology) the rate of change of profit with respect to changes in output supply is, interestingly, not a function of the level of output, but rather, a function of only factor prices and the output price.

Profit maximization and perfect competition induce marginal revenue (output price) to be equated to the marginal cost of production which, with linearly homogeneous functions, is also the average cost of production. Since output price and average cost are equal, the level of profits is zero -- the zero-profit condition.

With linearly homogeneous technology, supply functions are perfectly elastic -- they do not relate levels of output to the price of the product. Therefore, profit maximizing behavior by producers does not lead to a unique relationship between the quantity of a good supplied and its corresponding price. The rationale for this is straightforward, given existing prices, if an activity is profitable at one level of output, then profits can be doubled by merely doubling the level of output. There is, therefore, an indeterminate number of profit maximizing output levels compatible with a given set of relative prices. That is to say, any profit making firm with a constant return to scale technology would be in a state of perpetual and unending expansion. Conversely, at a given set of prices, if production is not profitable at the existing level of output, then it will not be profitable at any other level of output. Only with

zero profits can a firm with a constant-returns-to-scale technology be in equilibrium, and this equilibrium is compatible with any of the set of possible output levels.

The zero profit condition is incorporated into the model by defining a firm's profits as:

$$\Pi_i = P_i^x \cdot X_i^s - W_i \cdot L_i^d - R_i \cdot K_i^d - \sum_j a_{ij} \cdot X_j^s \cdot PQ_i^v - ITAX_i \quad (27)$$

where $ITAX_i$ represents indirect taxes, net of subsidies. The zero-profit condition implies that:

$$P_i^x \cdot X_i^s = W_i \cdot L_i^d + R_i \cdot K_i^d + \sum_j a_{ij} \cdot X_j^s \cdot PQ_i^v + ITAX_i \quad (28)$$

Typically, it is convenient to define indirect taxes as per unit commodity taxes, such that:

$$ITAX_i = T_i^D \cdot X_i^s \quad (29)$$

Substituting equation (29) into equation (28) and dividing through by X_i^s gives the price (cost) per unit of output.

$$P_i^x = (W_i \cdot L_i^d + R_i \cdot K_i^d) / X_i^s + \sum_j a_{ij} \cdot PQ_i^v + T_i^D \quad (30)$$

The term:

$$(W_i L_i^s + R_i^k K_i^d) / X_i^s \quad (31)$$

represents value-added per unit of output, often referred to in the literature as the value-added or net price (P_i^n). Making the appropriate substitutions equation (30) becomes:

$$P_i^x \cdot (1 - T_i^D) = P_i^n + \sum_j a_{ij} \cdot P Q_j^v \quad (32)$$

This expression shows that the zero profit condition implies that the unit cost of output is solely determined by both primary and intermediate factor costs. Equation (30) is usually rewritten in terms of (P_i^n) to give:

$$P_i^n = P_i^x \cdot (1 - T_i^D) - \sum_j a_{ij} \cdot P Q_j^v \quad (33)$$

In the model, productive capital is assumed to be sector-specific (immobile across economic sectors), therefore, in a perfectly competitive environment, any excess of revenues over labor and intermediate-costs is treated as a return to the sector-specific factor. That is to say, whenever the stock of capital is fixed and output prices function as the equilibrating variable, as in a Walrasian adjustment

mechanism, profits are decided residually after payments for labor services and intermediate-inputs.

Persistent high rates of unemployment are a hallmark of labor markets in Jamaica. While there are an established and growing repertoire of theories to explain this chronic situation in LDCs, the model will embrace the simple convention of maintaining a perfectly elastic labor supply over the proposed range of experiments. In other words, sectoral wage rates (W_i) are assumed to be constant.

With the stock of capital fixed, immobile, and fully employed, labor inputs determine the level of output. Using the definition of value-added price, the aggregate economic activity of each sector can be characterized by an archetypal corporation whose short-run profit maximizing endeavors are represented as follows:

$$\underset{L_i^d}{\text{Maximize:}} \quad P_i^n \cdot CES(K_i^s, L_i^d) - W_i \cdot L_i^s - R_i \cdot K_i^s \quad (34)$$

the reduced form solution gives the derived demand for labor expressed in terms of the value-added price, and factor prices:

$$L_i^d(P_i^n, W_i, R_i) \quad (35)$$

Finally, substituting equation (33) into the value-added function, gives the level of output supply.

Savings and Investment

Due to the absence of explicit capital and financial markets, the savings decisions of private economic agents (households and enterprises) are exogenously specified as fixed rates. Total government savings, *GOVSAV*, is determined residually as the government's budget surplus (deficit), while foreign savings, *FSAV*, is treated as a completely exogenous variable.

Household Savings

Households are assumed to save a fixed fraction, *mpsh*, of their after-tax income, $Y^H(1 - T^H)$, such that aggregate household savings, *HHSAV*, can be defined in the following manner:

$$HHSAV = Y^H(1 - T^H).mpsh \quad (36)$$

Enterprise Savings

Similarly, in the aggregate, enterprises are also assumed to save a fixed fraction, *mpse*, of their after-tax income, $Y^E(1 - T^E)$, where enterprise savings is defined as:

$$ENTSAV = Y^E(1 - T^E).mpse \quad (37)$$

In addition, enterprises also generate savings by applying fixed rate depreciation charges, $depr_i$, to the current value of capital stocks, PK_i, K_i^s . Aggregate depreciation, $DEPRECIA$, is then defined as:

$$DEPRECIA = \sum_i depr_i \cdot PK_i \cdot K_i^s \quad (38)$$

Total Savings

The total volume of saving is derived from the independent thrift activities of private individuals (households and enterprises), the public sector, and foreign investors ($FSAV.r$). These are depicted below as:

$$\begin{aligned} SAVINGS = & HHSAV + ENTSAV + DEPREC + GOVSAV \\ & + FSAV.r \end{aligned} \quad (39)$$

Investment

Since the model is a static specification, investment does not add to the existing stock of productive capital. However, for accounting purposes, but more so for the purpose of calculating the price of capital goods, it is useful to establish the

origin and the destination of capital goods within the economic system. This requires a capital-flow matrix in which the row-totals represent the aggregate demand for capital goods by sector (type) -- construction, metals, machinery, equipment, and so forth -- while the column-totals show the exogenously stipulated quantity of investment undertaken by each sector.

New productive capital is assumed to be a fixed-proportion aggregation over the relevant composite capital goods (QK_i^k). The fixed-proportions correspond to the coefficients (k_{ij}) of a capital-composition matrix which is derived, in input-output fashion, from the capital-flow matrix. Accordingly, the price of capital (PK_i) is obtained by aggregating the appropriate elements (k_{ij}) from the capital-composition matrix, then multiplying them by the corresponding price (P_i^k) of composite capital goods:

$$PK_i = \sum k_{ij} P_i^k \quad (40)$$

Recapitulation

As this juncture, a review of the entire system will be implemented. The goal is to bring together all the disparate transactions and diverse assumptions of the model into a unified system of equations. Following Devarajan, Lewis, and Robinson (1991), the process will be facilitated by organizing all equations into five mutually exclusive categories: (1) price equations; (2) quantity equations; (3) income equations;

(4) expenditure equations; and finally; (5) market clearing equations and macroeconomic closure conditions. Afterwards, Appendix A will provide a dictionary of all the variables and parameters that occur throughout the model.

Price Equations

Table 3.1 presents the various equations defining the price relationships in the model. In equations (1) through (4), the domestic price of tradeables is the tariff- or subsidy-inclusive world price multiplied by the exchange rate, r . The *small-country* assumption implies that world prices for exports (P_i^{*e}) and imports (PM_i^{*c} , PM_i^{*k} , PM_i^{*v}) are exogenous.

Equations (5) through (8) describe the prices for composite commodities as weighted averages of their respective components. The quantities, QV_i^s , QC_i^s , and QK_i^s represent the CES aggregation of the three different categories of sectoral imports with their corresponding domestic counterparts (intermediate goods, consumer goods, and capital goods). X_i^s is gross sectoral output, which is a CET aggregation of goods supplied to the export market (E_i^s) and goods sold on the domestic market (D_i^s).

Equation (9) defines the sectoral value-added price, or net price (P_i^n), while equation (10) gives the price (PK_i) of a unit of capital installed in sector i . The price is sectorally differentiated, reflecting the fact that capital used in different sectors is a heterogeneous commodity.

Table 3.1: Price Equations

$$(1) \quad PM_i^v = PM_i^{Sv} \cdot (1 + TM_i^v) \cdot r$$

$$(2) \quad PM_i^c = PM_i^{Sc} \cdot (1 + TM_i^c) \cdot r$$

$$(3) \quad PM_i^k = PM_i^{Sk} \cdot (1 + TM_i^k) \cdot r$$

$$(4) \quad P_i^e = P_i^{Se} \cdot (1 + T_i^E) \cdot r$$

$$(5) \quad P_i^v = \frac{PM_i^v \cdot VM_i^d + P_i^d \cdot VD_i^d}{QV_i^s}$$

$$(6) \quad P_i^c = \frac{PM_i^c \cdot CM_i^d + P_i^d \cdot CD_i^d}{QC_i^s}$$

$$(7) \quad P_i^k = \frac{PM_i^k \cdot KM_i^d + P_i^d \cdot KD_i^d}{QK_i^s}$$

$$(8) \quad P_i^x = \frac{P_i^e \cdot E_i^s + P_i^d \cdot D_i^s}{X_i^s}$$

$$(9) \quad P_i^n = P_i^x (1 - T_i^D) - \sum_j a_{ij} \cdot P_j^q$$

$$(10) \quad PK_i = \sum_j k_{ij} \cdot P_j^k$$

Quantity Equations

Table 3.2 contains the equations that establish the principal supply relationships in the model. Equation (11) define the CES value-added technology, the demand for labor, equation (12), is derived from profit maximization while equation (13) details the demand for intermediate factors. Equation (14) contains the CET transformation functions that combine domestic sales with exports, and equation (15) describes the corresponding export supply functions that ensue from revenue maximization. Equations (16), (18), and (20) give the CES aggregation functions for the three categories of composite commodities (intermediate, consumer, and capital, respectively). The corresponding import demand functions are specified in equations (17), (19), and (21) where cost minimization dictates that these functions depend on the price ratio between imports and domestic goods.

The production process is define by a nesting process. At the upper level, output is a Leontief production function between real value-added and intermediate inputs. Real value-added, in turn, is a CES function that exhibits substitution possibilities between capital and labor.

Capital input is a fixed-coefficient aggregation over composite capital goods, but only the aggregate is shown in the production function of equation (11). Capital is assumed to be sector-specific (fixed and immobile across sectors), therefore capital in each sector enjoys differential marginal rates of return. The structure of capital markets dictates that, in the short-run, there are diminishing returns to the variable

Table 3.2: Quantity Equations

$$(11) \quad X_i^s = CES(K_i^d, L_i^d)$$

$$(12) \quad L_i^d = L_i^d(W, R, P_i^n, K_i^s)$$

$$(13) \quad V_i^d = \sum_{ij} a_{ij} X_i^s$$

$$(14) \quad X_i^s = CET(E_i^s, D_i^s)$$

$$(15) \quad E_i^s/D_i^s = f_1(P_i^e/P_i^d)$$

$$(16) \quad QV_i^s = CES(VM_i^d, VD_i^d)$$

$$(17) \quad VM_i^d/VD_i^d = f_2(PM_i^v/P_i^d)$$

$$(18) \quad QC_i^s = CES(CM_i^d, CD_i^d)$$

$$(19) \quad CM_i^d/CD_i^d = f_3(PM_i^c/P_i^d)$$

$$(20) \quad QK_i^s = CES(KM_i^d, KD_i^d)$$

$$(21) \quad KM_i^d/KD_i^d = f_4(PM_i^k/P_i^d)$$

factor, labor. The non-agricultural labor markets, in turn, reflect the institution of downward-rigid nominal wages.

Intermediate factor demand, equation (13), is described by a Leontief aggregation function for each supplying sector. There is, therefore, no substitution possibilities among the various additive components of intermediate factor demand. However, within a given sector, domestic and foreign-produced intermediate inputs are imperfect substitutes according to a CES aggregation function between the respective local and imported components.

By extending the Armington assumption to the export market, the model sustains the empirical reality of two-way trade, or cross-hauling, at the sectoral level. In equation (14), aggregate gross output (X_i^s) is supplied to domestic (D_i^s) or foreign (E_i^s) markets. Although these three commodities (X_i^s , D_i^s , and E_i^s) have the same sectoral classification, they are each distinct goods, with separate prices. Similarly, imports (VM_i^d , CM_i^d , and KM_i^d) and their corresponding domestic counterparts (VD_i^d , CD_i^d , and KD_i^d) are also distinct from their respective composites (QV_i^s , QC_i^s , and QK^s), each having separate sectoral prices.

Income Equations

Table 3.3 details the equations that describe the flow of income generated by value-added which are subsequently distributed, circuitously, to the various economic agents in the model: enterprises, the government, and households. Due to the

Table 3.3: Income Equations

$$(22) \quad Y^L = \sum_i W_i \cdot L_i^d$$

$$(23) \quad Y^K = \sum_i R_i \cdot K_i^d$$

$$(24) \quad Y^E = Y^K + GENT - DEPREC$$

$$(25) \quad Y^H = Y^L + GSAL + HHT - SST \\ + (Y^E - ENT TAX - ENT SAV)$$

$$(26) \quad TARIFF = \sum_i PW_i^{sv} \cdot TM_i^v \cdot VM_i^d \cdot r + \sum_i PW_i^{sc} \cdot TM_i^c \cdot CM_i^d \cdot r \\ + \sum_i PW_i^{sk} \cdot TM_i^k \cdot KM_i^d \cdot r$$

$$(27) \quad IND TAX = \sum_i P_i^x \cdot X_i^s \cdot T_i^x$$

$$(28) \quad HHTAX = Y^H \cdot T^H$$

$$(29) \quad ENT TAX = Y^E \cdot T^E$$

$$(30) \quad GR = TARIFF + IND TAX + HHTAX + SSTAX + ENT TAX$$

$$(31) \quad DEPREC = \sum_i depr_i \cdot PK_i \cdot K_i^s$$

$$(32) \quad HHS AV = Y^H \cdot (1 - T^H) \cdot mpsh$$

$$(33) \quad ENT SAV = Y^E \cdot (1 - T^E) \cdot mpse$$

$$(34) \quad GOV SAV = GR - \sum_i P_i^c \cdot GD_i - HHT - GENT$$

$$(35) \quad SAVINGS = HHS AV + ENT SAV + GOV SAV + DEPREC \\ + FSAV \cdot r$$

absence of financial markets, the model precludes the various endogenous behavioral relationships that govern financial transactions. That is to say, financial variables are set exogenously: specified as fixed quantities or by simple share or multiplier relationships.

Equations (22) and (23) describe the flow of factor incomes, which in turn are distributed to enterprises and households in equations (24) and (25). Equation (24) shows that, in addition to factor income, enterprises also receive transfer payments from the government (*GENT*) and incur depreciation (*DEPREC*) expenses. Because households are the ultimate owners of enterprises, the after-tax (*ENTTAX*) and after-savings (*ENTSAV*) income from enterprises accrues to households as entrepreneurial revenue. This is shown in equation (25), where households also receive salaries (*GSAL*) and transfer payments (*HHT*) from the government, and are subject to social security (*SST*) taxes.

Equation (30) is the sum of equations (26) through (29) which determine the government's revenues from: tariffs (*TARIFF*), indirect taxes (*INDTAX*), household income taxes (*HHTAX*), and corporate income taxes (*ENTTAX*), respectively.

Equations (31) through (34) delineate the components of domestic savings. These include: financial depreciation (*DEPREC*), corporate savings (*ENTSAV*), household savings (*HHSAV*), and government savings (*GOVSAV*). The domestic private sector, firms and households, save fixed proportions of their respective incomes. On the other hand, savings by the public sector is determined by the

government's budget surplus or deficit, defined as the residual after total expenditures and total receipts. Aggregate savings (*SAVINGS*), equation (35), includes savings derived from domestic sources, plus foreign savings expressed in domestic units of account (*FSAV_r*), where foreign savings represents the capital inflows required to balance international payments, i.e. net foreign savings.

Expenditure Equations

Table 3.4 provides the equations that describe the demand for goods by the economic agents in the model. Private domestic consumption (C_i^d), equation (36), ensues from maximizing a CES utility function; while the government is assumed to keep the real levels of expenditure on each commodity (G_i^d), equation (37), fixed at the base year level.

Changes in the value of inventory accumulation -- inventory demand (DST_i) -- is determined by individual firms, equation (38), using fixed-shares of gross output ($dstr_i$). Aggregate nominal productive investment ($FXDINV$) is calculated, in equation (39), as total investment ($INVEST$) minus the value of inventory accumulation. Aggregate productive investment is converted into real investment by sector of destination (DK_i), in equation (40), using fixed-shares ($kish_i$), which sum to unity over all sectors. Finally, the capital composition matrix (b_{ij}), equation (41), translates the value of investment by sector of destination into final demand for capital goods by sector of origin (ID_i^d).

Table 3.4: Expenditure Equations

$$(36) \quad P_i^c \cdot C_i^d = \beta_i \cdot Y^H \cdot (1 - mpsh) \cdot (1 - T^H)$$

$$(37) \quad G_i^d = g_i \cdot GDTOT$$

$$(38) \quad DST_i = dstr_i \cdot X_i^s$$

$$(39) \quad FXDINV = INVEST - \sum_i P_i^k \cdot DST_i$$

$$(40) \quad PK_i \cdot DK_i = kshr_i \cdot FXDINV$$

$$(41) \quad ID_i = \sum_j b_{ij} \cdot DK_j$$

Market Clearing Conditions, Macroeconomic Closure, and the Numéraire

In an economic model, markets with endogenous prices and quantities require three equations: a supply equation, a demand equation, and a market clearing condition (often referred to in the general equilibrium literature as a commodity balance equation). Table 3.5 contains the commodity balance equations along with the system constraints that the model must satisfy.

There are four commodity markets at the sectoral level: domestic goods (D_i), composite intermediate-goods (QV_i), composite consumer-goods (QC_i), and composite capital goods (QK_i). The supply and demand equations for each of these markets

Table 3.5: Market Clearing Conditions and Macroeconomic Closure

$$(42) \quad QV_i^s = V_i^d$$

$$(43) \quad QC_i^s = C_i^d + G_i^d$$

$$(44) \quad QK_i^s = ID_i^d + DST_i^d$$

$$(45) \quad D_i^s = VD_i^d + CD_i^d + KD_i^d$$

$$(46) \quad L_a^d = L_a^s \quad a = \text{agricultural sectors}$$

$$(47) \quad \sum_i PW_i^e . E_i^s = FSAV - \sum_i PW_i^{sv} . MV_i^d - \sum_i PW_i^{sc} . MC_i^d \\ - \sum_i PW_i^{sk} . MK_i^d$$

$$(48) \quad SAVINGS = INVEST$$

have already been given in Tables (3.2) and (3.4), thus only the market clearing equations need to be delineated. Although the model is a general equilibrium representation of the Jamaican economy, the small-country assumption implies international markets (imports and exports) can be modelled in a partial equilibrium context. Accordingly, there is no need to specify market clearing conditions for imported or exported commodities.

Equations (42) through (44) show that sectoral supplies of composite commodities must equal their respective demands, thus defining market-clearing equilibrium in the composite markets for intermediate, consumer, and capital goods. Similarly, total domestic supply must equal total domestic demand. Accordingly, equation (45) provides the market clearing conditions for domestic goods.

The equilibrating variables for equations (45) through (48) are sectoral prices. There are fifteen prices in the model that have sectoral subscripts: P_i^x , P_i^y , P_i^c , P_i^* , P_i^d , PM_i^y , PM_i^c , PM_i^k , P_i^e , PM_i^{sv} , PM_i^{sc} , PM_i^{sk} , P_i^{se} , P_i^a , PK_i . The world prices (PM_i^{sv} , PM_i^{sc} , PM_i^{sk} , P_i^{se}) are exogenously specified, and of the remaining eleven prices, ten are dependent variables -- they appear on the left-hand side of price equations in Table (3.1) -- leaving P_i^d as the only independent price variable that can freely adjust.

Equation (46) defines equilibrium in the agricultural labor market with wages acting as the equilibrating variable. By contrast, because the price of labor in the non-agricultural labor market is exogenously fixed, the demand for labor becomes the equilibrating variable. Fixed capital stocks imply that the demand for capital is equal to the fixed supply, therefore, there is no need for a market clearing condition in capital markets. In the absence of factor mobility, however, the return to capital will differ across sectors.

An interesting property, peculiar to general equilibrium models without money, is the interpretation of prices. It is natural to think of prices as expressed in *units of account*, such as £, \$, ¥, or Fr. However, economic models without monetary

systems can only provide solutions for equilibrium prices as rates of exchange, and not in units of account. That is to say, the absolute price level in a general equilibrium model without money is indeterminate. The monetary factors that establish the absolute price level do not enter the system, and only relative prices (price ratios) can be determined. Although a particular model may only determine a set of relative prices, any price within the system can be used as a unit of account, a numéraire. Accordingly, it is necessary to arbitrarily fix the level of one price and then solve the system for all the other prices so that the ensuing prices are now expressed in terms of the numéraire. The choice of the model's numéraire which is related to closure rules is discussed below.

Equations (47) and (48) describe the two system constraints that the economy must satisfy: the trade balance, and the savings-investment balance. There are several different variables that can be chosen to equilibrate these equations, that is to say, there are alternate ways to close the model.

Closure rules arise from the problem of deciding which prices and quantities must be made exogenous to derive a model where the number of equations is equal to the number of variables. Closure rules usually involve the complex interaction among the savings-investment balance, the trade (or current account) balance, and the government deficit (surplus).

Traditionally, there are two standard closure rules for clearing the savings-investment balance in models without financial markets. The first is the investment-

driven model where total investment (*INVEST*) is exogenous, and the current account deficit (*FSAV.r*) is treated as a residual. The second is the savings-driven model where the current account deficit is treated as the exogenous variable and total investment becomes the residual -- adjusting to the supply of savings. The paramount significance of the savings-investment balance is that the determination of the numéraire depends crucially on whether the model is either investment-driven or savings-driven. The actual criterion for choosing between these two models depends upon the prevailing institutional arrangements in the economy.

The implicit assumption in an investment-driven model, where the current account deficit is treated as a residual, is that the economy is completely and unconditionally open; that is to say, there are no restraints on the supply of foreign exchange. In this case, the exchange rate (*r*) can be used as the numéraire, and all prices will then be measured relative to world prices.

On the other hand, when the current account deficit is treated as an exogenous variable, as in savings-driven models, the implicit assumption is that a fixed amount of foreign exchange is available. Accordingly, the exchange rate is assumed to be endogenous (floating) and adjusts to equilibrate the demand with the supply of foreign exchange. In this circumstance, a general price level is often used as the numéraire. Whenever this occurs, the domestic price level is essentially exogenous.

A model of the Jamaican economy should preferably be savings-driven because Jamaica has very limited access to supplies of foreign exchange. An interesting

variation on the savings-driven model, which is employed in the present research, is to restrict the trade balance as the difference between exports and imports, while using the exchange rate (r) as the numéraire. All prices are then measure relative to the exchange rate (the conversion factor between U.S. and Jamaican prices), and the overall price level depends completely on the value of the numéraire. Finally, government consumption is exogenously specified in the model, implying that government savings (the budget surplus or deficit) is the equilibrating variable.

Having selected the macro closures and designated the numéraire, careful counting of the equations and variables in the model show that the number of equations in Tables (3.1) through (3.5) is one more than the number of endogenous variables listed in Table (3.6).² This obvious imbalance can be resolved by appealing to Walras' Law.

The implication of Walras' Law is that in a model with m economic agents and n markets, if all economic agents satisfy their budget constraints and $(n-1)$ markets are in equilibrium, where the quantity demanded equals the quantity supplied, then the n -th market will automatically be in equilibrium. In more practical terms, if a model consists of a system of n equations, then there are only $(n-1)$ independent equations. This means that only $(n-1)$ variables can be solved, implying that one equation can be eliminated from the system. In this case, the last equation, the savings-investment

²The easiest way to count the variables is to set the number of sectors (i) equal to one.

3.6 List of Endogenous Variables

Prices:

$PM_i^v, PM_i^c, PM_i^k, P_i^e, P_i^v, P_i^c, P_i^k, P_i^s, P_i^n, P_i^d, PK_p, W_i$

Quantities:

$X_i^s, L_i^d, V_i^d, E_i^s, D_i^s, QV_i^s, QC_i^s, QK_i^s,$

$VM_i^s, CM_i^s, KM_i^s, VD_i^s, CD_i^s, KD_i^s$

Income:

$Y^L, Y^K, Y^E, Y^H, TARIFF, INDTAX, HHTAX, ENTAX,$

$GR, DEPREC, HHS AV, ENTS AV, GOV SAV, SAVINGS$

Expenditures:

$C_p, G_p, DST_p, FXDINV, INVEST, DK_p, ID_i$

equation, can be eliminated, although the choice of which particular equation to delete has no effect on the solution of the model.

Alternatively, rather than eliminating an equation, it is convenient to add a slack variable to the equation which would otherwise be dropped. The slack variable

can then be used to check the consistency of the model. In equilibrium, the value of the slack variable must be zero.

Model Calibration

There are two approaches to generating parameter values for functional forms in applied general equilibrium models: the calibration or deterministic approach, and the econometric or stochastic approach. The two procedures reflect the trade-off between intricate economic specification on the one hand, and sophisticated statistical estimation on the other.

The prominent feature of the econometric approach, is that the structure of the economic model is often simplified to allow for substantial richness in statistical specification. While in the calibration approach, the procedure is quite the opposite. The richness of the economic structure is compatible with less sophisticated statistical methods that, in the case of bench-marking to a single year's data, becomes completely deterministic.

In more practical terms, there are three significant reasons that preclude complete econometric specification and estimation of general equilibrium systems (Shoven and Whalley, 1992). First, in some applied models the specification includes several hundreds of parameters, and the simultaneous estimation of all the model parameters using the time-series methods would require either unrealistically large numbers of observations or the imposition of excessively severe identifying

restrictions. Second, even when models are partitioned into independent sub-models (such as demand and supply systems) to render the number of estimates tractable, partitioning does not fully incorporate all the equilibrium restrictions that can be accommodated in calibration procedures. Finally, not all national accounts data are available as separate price and quantity observations, making it difficult to sequence equilibrium observations with consistent units through time, as would be required for time-series estimation.

Calibration relies on the prior construction of a bench-mark equilibrium data set for a particular model under investigation. A social accounting matrix is usually employed for this purpose. The SAM provides a snapshot of the economy at a single point in time. It documents the income and outflow (in value terms) in each and every market and for each and every economic agent. Each row of a SAM provides information on the sources of income to a specific account, while the columns portray the expenditures incurred by an individual account to other accounts. A SAM is considered balanced when the row aggregates and the corresponding column aggregates give the same values. This symmetric balance implies:

- (1) Demands equal market supplies for each commodity.
- (2) Production costs (including distributed earnings) exhausts revenues -- industry earns nonpositive profits.

- (3) Expenditures (including savings) and incomes of domestic agents are identical. That is to say, all agents (including the government) have demands that satisfy their budget constraints.
- (4) The economy is in external sector balance.

Calibration is most easily understood as the requirement that the model be capable of reproducing an observable base-year equilibrium solution. The methodology of calibration is not to solve the model for an equilibrium, but rather to use the observed equilibrium data to solve for the model parameters.

Typically, calibration involves only one year's data, accordingly, bench-mark data cannot identify a unique set of values for certain parameters such as the model elasticities. Particular values for the relevant elasticities are required, and are usually exogenously specified prior to the actual calibration exercise. The specification of elasticities prior to calibration is most easily thought of as determining the curvature of isoquants and indifference surfaces around an initial position given by the bench-mark equilibrium data (Shoven and Whalley, 1992).

Uses and Limitations of Economic Models

No modelling exercise is complete without issuing a caveat on the very model under consideration. The use of economic models for policy simulation and economic

analyses, in official and semi-official circles, has a recent history in LDCs. Despite their limitations (and there are several), economic models are a valuable addition to the tools employed in development planning and policy analysis. Their recent introduction to the planning and policy-making arena has, however, often led to misconceptions and abuses regarding their uses and limitations.

Beyond their role as instruments for providing coherence among various seemingly unrelated economic variables, and as a framework within which policy experiments can be performed, economic models can have an essentially forecasting purpose. The present model is not intended for strict forecasts or projections of the economy into the future. The accuracy, as opposed to the consistency, of such projections will depend on embodying the historical characteristics of the economy in the model. This can be an extremely difficult task, especially when the multi-sectoral structure of the model and the amount of the accompanying variables and equations can, and does, impose severe challenges to the available econometric techniques (Mansur and Walley, 1984).

On the other hand, the model is intended to provide both an internally consistent simulation of the Jamaican economy and the capability to analyze changes in existing policies. The CGE under consideration, therefore, is a structural model designed for policy analysis and cannot be used to make unconditional projections or forecasts. The model is structural because its form is dictated by the underlying economic theory (Pindyck & Rubinfeld, 1991). Structural models stand in stark

contrast to their temporally disaggregated, macroeconomic forecasting counterparts. Most important, they avoid specifications that rely upon lagged endogenous variables and reduced-form equations to capture the role of expectations and frictions in the economy (Dervis et al., 1982). The significance of the dichotomy between structural policy models and traditional reduced-form forecasting ones can best be described in the following manner. First, it is often difficult to trace the causal mechanisms at work in traditional forecasting models since a reduced-form equation may be compatible with several different structural forms (equations). And second, models with lagged endogenous variables and reduced-form equations may be useful in predicting the future, provided that existing policy rules are maintained, but they cannot be used for policy evaluation -- the *Lucas critique*.

Economists, especially policy modelers, have found it useful to implement some important considerations in addressing the major contentions raised by the Lucas critique. The first, and more epistemological consideration, is to base macroeconomic analysis on a consistent foundation validated by the choice theoretic framework of microeconomics. The distinct advantage of exploiting a choice theoretic framework is that reduced-form and *ad hoc* equations can be eschewed in favor of the first-order conditions that ensue from appropriately specified constrained optimization processes. In essence, first-order conditions are structural equations involving, in most instances, a market constraint and, in all instances, a set of behavioral equations that contain policy invariant (structural) parameters such as tastes

and technology. Consequently, policy analysis or counter-factual simulations became an exercise in changing the market constraints faced by economic agents. After all, structural parameters are, by definition, policy invariant, and are assumed neither to reflect nor to embody past or present policies. The significance of implementing a choice theoretic framework to describe economic behavior should not be understated. Because the model's key parameters are not influenced by past policies, or for that matter current simulation experiments, a structural model imparts a greater degree of confidence and validity to the policy simulation endeavor.

Counter-factual simulations involve the changing of a few policies at any given time while maintaining the vast array of existing policies under the umbrella of *ceteris paribus*. This essential characteristic of counter-factual simulations helps to define the requirements of another, and more procedural ingredient in addressing the Lucas critique. It necessitates the explicit specification of the structural equations that govern the particular policies of interest, along with the designation of the relevant policy variables in the appropriate subsidiary equations throughout the model. Consequently, changes in policy, through the exogenous modification of the policy variables in the relevant structural equations, will affect the optimizing behavior of individual economic agents and ultimately influence the entire economic system.

There still must be a degree of confidence that policy changes will not affect the true values of structural parameters, so that estimates or calibrations from previous sample periods remain stable under different proposed policies. After all, it

is plausible that elasticities of response to current variables in structural equations can be altered by changes in policy. At the present time, economists have not focused much attention in resolving this particular problem. Even so, a second best solution, by way of a sensitivity analysis, can ameliorate the situation. A sensitivity analysis would require the application of exogenous changes in key elasticities whenever policy simulations are performed, thereby validating the model's robustness.

Given the task at hand, that of modelling and analyzing changes in the existing magnitude of current policy variables. A conscious effort is applied in making the mechanisms governing the model as transparent and simple as possible, and at the same time, adhering to received economic theory. Transparency and theoretical plausibility are the crucial hallmarks that any simulation exercise, including an empirical general equilibrium model, must engross if it is to provide a credible and effective framework for experimentation, economic analysis, and policy choice.

CHAPTER 4.

MODEL VALIDATION AND SIMULATION

The purpose of this chapter is to determine the *optimal* tariff structure for Jamaica, in the presence of pre-existing tariff distortions, where tariffs are constrained to satisfy the non-efficiency objective of revenue generation. Using data for 1986, the year immediately prior to the introduction of tariff reform, this paper will attempt to establish the *second-best* revenue neutral tariff structure for the island. There are, however, two academic errands that need to be discharged before addressing this specific issue. The first errand, is the presentation of a simplified version of the model so that the forces that drive the system are made eminently transparent. And the second errand, is the substantiation of the model's validity. This latter task will be accomplished by subjecting the system to a short-run forecasting exercise.

A Basic One-Sector CGE Model

In order to make the simulation exercise more meaningful and understandable, this section will present an analytical version of the model developed in the preceding chapter. A major advantage of working with analytical models is that they require relatively simple and transparent specifications which facilitate tractable algebraic or graphical solutions.

The current exposition follows that of Melo and Robinson (1987), Devaragan, Lewis, and Robinson (1990), and Melo and Tarr (1992). Consider a small country with two producing sectors and three goods. One sector produces a traditional exportable commodity while the other a final consumer good. Factor markets are ignored, albeit labor and capital are assumed to be fully employed (later, this assumption will be modified). The problem of income distribution is also ignored by postulating a collective utility function. Outputs are net of intermediate goods -- that is, outputs are produced for final consumption. The following assumptions describe the model in detail:

- (1) The two locally produced commodities are an export good, E^x , which is sold exclusively to the rest of the world, and a home good, D^x , used solely for domestic consumption.
- (2) The third good is an import, M^d , which is not produced domestically but is an imperfect substitute, in use, for the home good, D^d -- the Armington assumption.
- (3) Domestically produced goods sold on the domestic market differ from those sold on the export market.

- (4) The economy purchases and sells its imports and exports at the prevailing world prices -- the small-country assumption.
- (5) The model has three economic agents: a producer, a household, and the rest of the world.

In Table 4.1, equation (1) is a constant returns to scale CET function which defines the economy's production possibility frontier (PPF) -- the maximum achievable combination of goods E^s and D^s supplied by producers. Output X^s is fixed because all primary factors are fully employed, and since there are no intermediate goods, X^s also corresponds to real GDP. The sole producer in the model attempts to maximize revenues from sales of both D^s and E^s , subject to the CET aggregation function. From the first-order conditions, Equation (4) gives the efficient ratio of exports to home goods (E^s/D^s) as a function of their relative prices. Equivalently, the family of iso-revenue lines with slope (P^e/P^d) that are tangent to the PPF, determine the optimal allocation of M^d and D^d . Equation (9) defines the price of the composite commodity X^s which is a weighted average of the domestic prices of its export and home components.

Following the approach suggested by Armington (1969), equation (2) defines a composite commodity, Q^s , made up of D^d and M^d . The composite commodity is given by a constant returns to scale CES aggregation function. The single household

Table 4.1: A Basic One-Sector CGE Model

Quantities

$$(1) X^s = CES(E^s, D^s)$$

$$(2) Q^s = CES(M^d, D^d)$$

$$(3) Q^d = \frac{Y}{P^d}$$

$$(4) E^s/D^s = f_1(P^e/P^d)$$

$$(5) M^d/D^d = f_2(P^m/P^d)$$

Income

$$(6) Y = P^x X^s + B.r$$

$$(7) P^m = PW^{m,r}$$

Prices

$$(8) P^e = PW^{e,r}$$

$$(9) P^x = \frac{P^e.E^s + P^d.D^s}{X^s}$$

$$(10) P^q = \frac{P^m.M^d + P^d.D^d}{Q^s}$$

Table 4.1 (Continued)

Numéraire and Market Clearing Conditions

$$(11) \quad r \equiv 1$$

$$(12) \quad D^d - D^s = 0$$

$$(13) \quad Q^d - Q^s = 0$$

$$(14) \quad PW^m M^d - PW^e E^s = 0$$

minimizes the cost of consuming the composite commodity, subject to the CES aggregation function. Cost minimization generates equation (5), the demand for imports as a ratio of home to imported goods. Equation (10) defines the price of the composite commodity Q^d as a weighted average of the price of the home and imported goods.

Equation (6) shows that the household receive all the exogenous foreign transfers, in addition to all the endogenous income ($P^x X^s$) generated by the economic system. Equation (3) defines household demand such that all income is spent on the composite good.

There are seven price relationships in the model: the exogenously fixed world prices for E^s and M^d (PW^e and PW^m); the domestic prices for E^s and M^d (P^e and P^m); the prices for the two composite commodities, X^s and Q^d (P^x and P^q), and *the*

conversion factor between domestic and foreign prices, r . Because equations (1) and (2) define linear homogeneous functions which are incorporated in optimization processes (cost minimization or revenue maximization) the resulting demand and supply functions are homogeneous of degree zero in prices. Doubling all prices, for example, will double incomes but leave the real import and export ratios unchanged -- only relative prices matter. In order to obtain the absolute price level a numéraire is required, and for this purpose the conversion factor, r , is set equal to one.

Equations (12) through (14) define the market-clearing equilibrium conditions. Supply must equal demand for commodities D and Q , and the balance of trade constraint must be satisfied. The complete model has fourteen equations and thirteen endogenous variables. The three equilibrium conditions, however, are not all independent. Any one of them may be dropped and the resulting model is fully determined.

The model is simple enough for its properties to be shown graphically. Figure 4.1 presents a four-quadrant diagram that captures the essential features. The production possibility frontier PP , equation (2), and a tangent price line with slope (P^d/P^e) is shown in quadrant 4. At any given price ratio, the point of tangency of the price line with the PPF determines the equilibrium production level (P^*) of both the home and exported goods.

For convenience, the exogenous world prices for both exports and imports are normalized at unity while B , net foreign capital inflows (outflows), is assumed to be

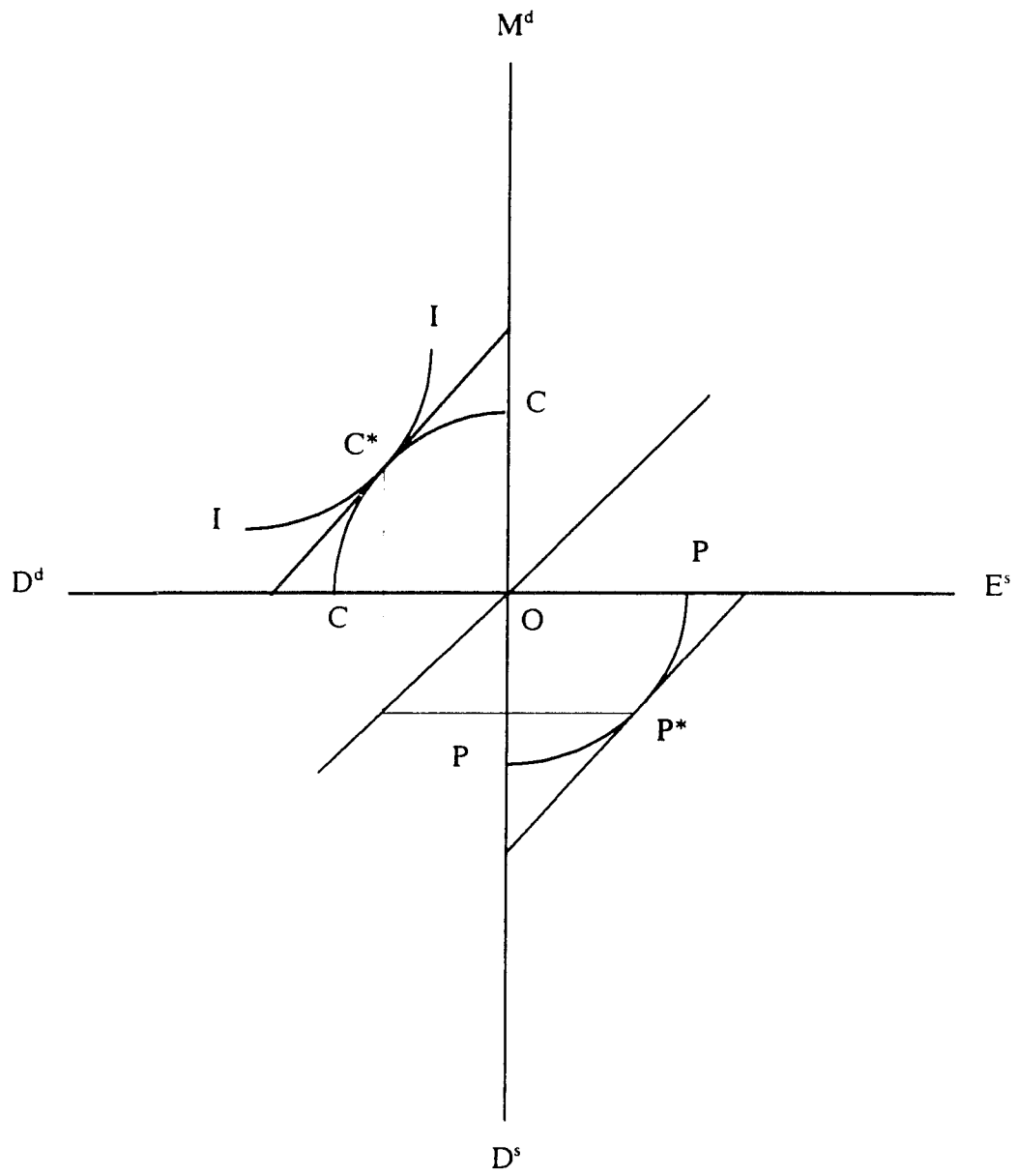


Figure 4.1: Equilibrium in a basic one-sector model

zero. In this case the balance of trade equation defines the foreign offer curve and is graphically represented as a 45-degree line through the origin in quadrant 1.

Quadrant 3 has a 45-degree line which simply indicates the locus of equilibrium in the home good market -- $D^s = D^d$.

At any given production level of good E^r , the balance-of-trade constraint determines how much of the imported good the country can purchase. The reason for this is that with no capital inflows ($B = 0$), the only source of foreign exchange is exports. Quadrant 4 shows the concave curve, CC , the *consumption possibility frontier*, which is the locus of points that simultaneously satisfy the balance of trade constraint in quadrant 1 and the production possibility frontier in quadrant 2. When world prices of imports and exports are set at unity (are equal) and trade is balanced ($B = 0$) the consumption possibility frontier in quadrant 4 is a mirror image of the production possibility frontier, PP , in quadrant 2.

Equation (2) in Table 4.1 defines domestic absorption, the tangency between the iso-absorption curves and the consumption possibility frontier will determine the amount of D^d and M^d the consumer will demand, at price ratio (P^d/P^m).

In quadrant 4, the import aggregation function, equation (1), generates a series of iso-goods curves, II , analogous to indifference curves. Consumer equilibrium is achieved at the point of tangency with the consumption possibility frontier. Finally, the economy produces at point P^* and consumes at point C^* where the equilibrium price ratios faced by consumers (P^d/P^m) and producers (P^d/P^e) are equal.

Tariffs, Resource Reallocation, and National Product Differentiation

In the previous section the free-trade levels of production and consumption are P^* and C^* , respectively. Under this allocation pair the usual conditions of Perato optimality are satisfied since the marginal rate of substitution (MRS) in consumption and the domestic marginal rate of transformation (MRT) in production are both equal to the foreign rate of transformation (FRT).

Now suppose an *ad valorem* tariff is imposed on M^d at rate t . The FRT which is defined by world markets, is unchanged, however, consumers, who face a budget constraint in which the relative price of the import good has risen, will optimize by altering their purchases such that a unit of the import good is valued relatively more than a unit of the home good, that is $MRS = P^d/PW^m(1 + t)$. But since the export price of producers remain un-distorted, producers will optimize their production decisions where $MRT = P^d$. This implies that a reallocation of resources can increase welfare.

The relevant question is, when the price of an imported good raises because of a tariff, will the demand for its domestic counterpart increase? Usually, but not always. The reason is that there is a trade-off between two distinct effects -- weak separability and two-stage budgeting. As discussed in Chapter 3, the Armington assumption requires weak separability and two-stage budgeting. In the first-stage, cost minimizers choose the optimal combination of domestic and foreign components in producing composite commodities. In the second-stage, economic agents optimize

composite commodity purchases subject to predetermined expenditure constraints.

When a tariff causes the domestic price of an import to raise, given the assumption of imperfect substitutability at the first-stage, this also increases the price of the domestic counterpart commodity. Since the prices of both its components have risen, the price of the composite commodity also raises leading to the inevitable decrease (at the second-stage) in the quantity demanded of the composite good. However, because the home commodity is an imperfect substitute for its imported counterpart, the price of the home commodity does not fully appreciate to the level of the imported good (Milner, 1992). Consequently, the home good is now relatively cheaper than its imported counterpart, cost minimizing agents (at the first-stage) will substitute the home good for the imported commodity, subject to the pre-determined expenditure limits encountered in the second-stage maximization process. In summary, the first-stage increases the quantity demanded of the home good, while the second-stage decreases it. Which of the two effects dominates defines whether the goods are gross substitutes or gross complements.

In the limiting cases, where goods are perfect complements in use (i.e., the Leontief paradigm, where the elasticity of substitution is zero in the first-stage), any increase in the quantity demanded of a composite good results in an equi-proportionate increase in the quantity demanded for the domestic and imported components.

For imported and home goods to be gross substitutes, the elasticity of substitution in the first-stage (the trade substitution elasticity) must be larger than the elasticity of composite good demand in the second-stage (the own-price elasticity of demand for the composite commodity). That is to say, a rise in the domestic price of an imported good causes an unequivocal increase in the quantity demanded for its domestic counterpart. In the current study the range of elasticities are chosen to reflect that home and imported goods are gross substitutes in use.

Having dispensed with the necessary preliminaries, the analysis of a tariff on gross substitutes can be fully summarized. The summary will assume the typical labor market environment in LDCs, like Jamaica, where the labor supply in the non-agricultural sector is perfectly elastic. That is, agricultural labor is fully employed while unemployment exists in the non-agricultural sectors.

- (1) The tariff causes the domestic price of both the import and home good to rise. However, because both goods are gross substitutes, the consumption of the import good declines while the consumption of the home good increases. On the other hand, consumption of the export good may rise or fall, depending upon the relative strengths of opposing income and substitution effects.

- (2) The increased consumption of the home good stimulates both the levels of output and employment in the home good sector.
- (3) Although employment and output has increased, the price of the home good has also increased. And given that the nominal wage is fixed, the increase in the price of the home good causes the real wage to fall.
- (4) Finally, because the production of composite output has increased, and because labor is unemployed, it cannot be ascertained, *a priori*, if the tariff induces a net shift in resources away from the non-protected export sector to the protected import sector. That is to say, the change in export volume is indeterminate.

Model Validation and Elasticity Scenarios

The model is validated by updating the exogenous variables from 1986 to 1987 and re-solving the system with the new data set. The aim of the exercise is to establish the extent to which the model can derive accurate short-term forecasts that correspond to the observed history of the economy.

There are three major constraints on the validation exercise, all of which arise from limitations on the available data. The first constraint derives from the intrinsic

nature of calibration which precludes performing statistical procedures on the forecasts. The second constraint stems from the lack of data on capital stocks and the scarcity of information regarding the demand for investment by sector of destination. This latter set of deficiencies make it difficult to assess the model's ability to forecast at the sectoral level. Accordingly, the validation exercise is restricted to forecasts of the macroeconomic variables: consumption, investment, government spending, exports, and imports. Finally, because of the poverty of previous empirical research on the sectoral demand and supply of traded goods in Jamaica, a range of trade elasticities are incorporated in the validation exercise. Specifically, both a low and a high elasticity scenario are simulated. Following the example of Dervis et al. (1982), the high elasticity scenario uses elasticity values that are three times that of the low elasticity scenario. The absolute-values of the own-price elasticity of demand for composite commodities are listed below in Table 4.2. These values reflect the assumption of Cobb-Douglas utility functions for composite consumer goods by

Table 4.2: Own-Price Elasticity of Composite Demand

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
Import Sectors	0.0	1.0	0.0

households and the government; and Leontief demand structures for composite intermediate and capital goods.

The choice of values for the low and the high elasticity scenarios are arbitrary, however, since imported goods and their domestic counterparts are assumed to be gross substitutes, the absolute-value of the relevant import elasticities have to be larger than the corresponding absolute-value of the own-price elasticity of demand for composite goods. The values for the low elasticity scenario are given in Table 4.3.

The high elasticity scenario is also given in Table 4.4 and exhibit values that are three times those of the low elasticity scenario. In both instances, while these arbitrary values reflect prevailing data constraints, they are assumed to be representative of the actual values that obtain.

Analyzing the results from the validation experiment, it is evident from Table 4.4 that the model's solution variables differ from the observed history of the

Table 4.3: Sectoral Import Trade Elasticities by Scenario

Scenario	Type of Commodity		
	Intermediate	Consumer	Capital
Low Elasticity	0.30	1.25	0.30
High Elasticity	0.90	3.75	0.90

Table 4.4: Comparison of Simulated Versus Actual Macroeconomic Results for 1987 (Actual 1987 results = 100.0)

Categories	Elasticity Scenario	
	Low	High
Private Consumption	99.5	99.6
Government Consumption	100.0	100.0
Gross Capital Formation	101.6	100.7
Exports	98.5	99.1
Imports	102.0	101.8
Gross Domestic Product	99.9	99.3

economy by not more than two per cent. This would indicate, that in the short-run, the model can provide a reliable portrait of the actual economy.

The Simulation Results

This paper is concerned with second-best policies in the presence of trade distortions. In particular, it determines *optimal* tariff rates in the presence of pre-existing distortions (indirect taxes, tariffs, and rigid nominal wages) using a model with: (1) imperfect substitutability between domestically produced outputs and their imported counterparts; (2) imperfect substitutability between domestic output and

exports; (3) unemployment in the non-agricultural sectors; and (4) a fixed balance of trade. The analytical framework is of relevance to the debate on partial trade policy reform in developing countries, where existing tariffs are constrained to satisfy the non-efficiency objective of revenue generation.

Beyond the data limitations expressed in the previous section, there is yet another constraint relevant to the simulation exercise, and that is, the model's inability to capture specific tariffs imposed on individual items. Unless a model with several thousand sectors is contemplated, any model with smaller dimensions will only depict trade taxes as average tariff rates applicable to a broad range of commodities.

In the policy experiments, choice is introduced by redefining parametric tariffs as policy variables. Optimal tariffs are determined by optimizing consumers' welfare (direct utility function) subject to the equations of the CGE model plus the government's revenue constraint. Because the model is a static representation of the Jamaican economy, the results from the initial simulation indicated that all tariffs on consumer and intermediate goods should be removed and the tax burden placed entirely on capital goods. As a consequence, both the rates of return to capital and the level of investment declined precipitously. The situation was remedied by the addition of a side-constraint stipulating that investment by sector of destination could not fall below the base year results. When this was implemented, it was found that the government's revenue constraint could be completely relaxed and, depending upon the elasticity scenario, the optimal tariff regime changed the bench-marked budget

Table 4.5: Actual Tariff Rates by Sector, 1986

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	per cent		
Food Manufacturing		0.148	
Beverages and Tobacco		0.106	
Other Manufacturing	0.029	0.083	
Petroleum Products		0.074	
Chemicals	0.017		
Equipment		0.825	0.077

surplus of J. \$2.02 million to a deficit ranging from J. \$3.76 million to J \$5.47 million.

The initial tariff rates and tariff revenues for 1986 are displayed in Tables 4.5 and 4.6, respectively. It is obvious that, except for consumer imports in the equipment category, tariff rates in Jamaica during 1986 were applied in relative moderation (at least, in the context of an 18-sector model). Furthermore, in 1986, Jamaican commercial policy apparently contained the foundations of an optimal tariff structure. First, the major sources of tariff revenues are derived from consumer imports, followed by capital imports, with tariff revenues from intermediate imports making the smallest contribution to the public purse. Second, actual tariff rates also emulate a similar pattern of dispersion: the highest rates being applied to consumer

Table 4.6: Actual Tariff Revenues by Sector, 1986

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
J. \$million			
Food Manufacturing		53.517	
Beverages and Tobacco		3.330	
Other Manufacturing	16.700	26.819	
Petroleum Products		1.111	
Chemicals	10.709		
Equipment		66.453	41.928

goods, the lowest to intermediate commodities, while capital goods enjoyed a rate that fell between the two extremes.

The results for both the low and the high elasticity scenarios are detailed in Tables 4.7 through and 4.10. Sectoral tariffs which yielded less than J. \$1 million in revenues are eliminated from the tables as they are probably uneconomical to administer. In addition, the optimal tariff rates were restricted to merchandise imports, since initial results indicated that the model tended to place tariffs on the category *miscellaneous services*. While this is plausible it is usually not a widespread practice, especially since it is extremely difficult to assess or collect duties on such services.

Table 4.7: Optimal Tariff Rates by Sector (Low Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
per cent			
Food Manufacturing	0.011	0.324	
Sugar Manufacturing		0.047	
Other Manufacturing		0.061	
Chemicals		0.124	
Equipment		0.039	0.077

Table 4.8: Optimal Tariff Revenues by Sector (Low Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
J. \$million			
Food Manufacturing	6.379	101.854	
Sugar Manufacturing		1.445	
Other Manufacturing		20.286	
Chemicals		14.616	
Equipment		5.148	41.990

Table 4.9: Optimal Tariff Rates by Sector (High Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	per cent		
Food Manufacturing		0.406	
Other Manufacturing		0.003	
Chemicals		0.190	
Equipment			0.077

Table 4.10: Optimal Tariff Revenues by Sector (High Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	J. \$million		
Food Manufacturing		120.662	
Other Manufacturing		1.081	
Chemicals		21.226	
Equipment			42.317

The four major conclusions that ensue from the optimization exercises as exhibited in Tables 4.7 through 4.10 are that:

- (1) Given the existence of other distortions in the economy (indirect taxes, and rigid nominal wages) the optimal tariff policy is one with highly variegated rates. This confirms the findings of Devarajan, Lewis, and Robinson (1990) who derive similar policy lessons using small, two-sector, general equilibrium models of archetypical developing countries. The simulations also indicate that the optimal pattern of tariffs requires the imposition of the highest tariff rates on consumer goods, the lowest on intermediate goods, while the rates for capital goods should abide between those two extremes. Moreover, the results call for a significant reduction of the tariff base on intermediate goods by either reducing the taxable sectors to one (low elasticity scenario) or totally eliminating duties on intermediate imports (high elasticity scenario).
- (2) The optimal tariff rates for capital imports are relatively indifferent to the elasticity scenarios. This is clearly not the case with consumer or intermediate imports. Even so, the sources of tariff revenues are relatively indifferent to the elasticity scenarios. And in either scenario, total tariff revenues fall.

- (3) Tariff reform has very little impact on the macroeconomic performance of the economy. There are several reasons that explain this result. First, actual versus published tariffs are already low in Jamaica, even by the standards of developed countries; therefore, changes in tariff rates can be expected to have a negligible impact upon the economy. Second, the existing tariff structure already exhibits several optimal features: high tax rates on consumer goods, low taxes on intermediate goods; a broader tax base on consumer goods through the taxation of more items, and a narrower tax base for intermediate goods covering fewer sectors. Third, the underlying model and the experiments are comparative static in nature, and do not allow for the dynamic impact of tariffs rates or tariff structure. Fourth, tariff revenues make up a small fraction of government revenues (less than 6% in 1986) and even smaller percent of GDP (less than 2% in 1986). Given that the experiments call for a revenue-neutral tariff structure, tariff changes would have very little impact at either the microeconomic (sectoral) level or at the macroeconomic level. Finally, as indicated by Devarajan, Lewis, and Robinson (1990), the total welfare gains from implementing optimal tariffs in a second-best world are small because substitution possibilities in production, consumption, and trade endow

the economy (model) with a large degree of flexibility that can vitiate the effects of policy reform.

- (4) Except for the equipment sector, tariff reform also has very little impact on the microeconomic performance of the economy. In the equipment sector the tariff on consumer imports falls from an initial level of 82.5 per cent to a level of 3.87 per cent for the low elasticity scenario and to zero in the high elasticity scenario. The tariff decline causes consumer imports of equipment to raise by 65.2 per cent in the low elasticity scenario and by 69.9 per cent in the high elasticity scenario. In addition, because imports and home goods are gross substitutes, the tariff decline, which causes a decline in the home good price, also causes production of the home good to fall.

Actually, the situation described in (4) above is quite unrealistic. The majority of consumer imports (by value) in the equipment sector are for automobiles; and other island economies such as Bermuda and Singapore have already placed severe restrictions on automobile imports due to environmental considerations and the geographic limitations of space. Partially because of this, but more so because of the revenue potential, the new tariff regimes initiated in 1987 and 1993 allow for a narrow category of special items, such as noncommercial motor vehicles, which are

subject to tariffs that exceeded 100 per cent. Accordingly, a second set of simulations were performed in which the original tariff rate for equipment was maintained at the base year rate of 82.5 per cent. The resulting tariff rates and tariff revenues are displayed in Tables 4.11 through 4.14.

Unlike the previous experiments, the optimal tariff rates on all categories of imports were relatively insensitive to the elasticity scenarios. However, as before, both the microeconomic and macroeconomic effects of the tariffs are quite insignificant. Even with the tariff on consumer equipment, the optimal tariff structure remains relatively similar to the previous set of simulations: no tariffs on intermediate imports, the highest rates on consumer goods, and an intermediate rate on capital goods.

Table 4.11: Constrained Optimal Tariff Rates by Sector (Low Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
per cent			
Food Manufacturing		0.259	
Other Manufacturing		0.012	
Chemicals		0.078	
Equipment		0.825	0.074

Table 4.12: Constrained Optimal Tariff Revenues by Sector (Low Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	J. \$million		
Food Manufacturing		85.687	
Other Manufacturing		4.068	
Chemicals		9.506	
Equipment		66.559	40.408

In addition, Tables 4.15 through 4.17 compares the effects of the unconstrained and the constrained optimal tariff policies under both elasticity scenarios. The sectoral GDP results (Table 4.15), the sectoral labor demand results (Table 4.16) and the macroeconomic results (Table 4.17) exhibit a remarkable similarity across tariff policies and elasticity scenarios.

Finally, Table 4.18 reinforces the similarity of outcomes across tariff policies and elasticity scenarios. Both aggregate employment and total consumer utility, the *metric*, derived by substituting real consumer demand into the consumer's direct utility (Cobb-Douglas) function, are practically invariant across tariff policies and elasticity scenarios.

Table 4.13: Constrained Optimal Tariff Rates by Sector (High Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	per cent		
Food Manufacturing		0.269	
Chemicals		0.091	
Equipment		0.825	0.074

Table 4.14: Constrained Optimal Tariff Revenues by Sector (High Elasticity Scenario)

Sector	Type of Commodity		
	Intermediate	Consumer	Capital
	J. \$million		
Food Manufacturing		88.386	
Chemicals		10.995	
Equipment		66.560	40.418

**Table 4.15: Change in Sectoral GDP by Tariff Policy and Elasticity Scenario
(Base Year = 100.00)**

Sector	Unconstrained Tariffs		Constrained Tariffs	
	High	Low	High	Low
Sugar Cane Agriculture	99.98	99.91	100.04	100.03
Other Export Agriculture	99.98	99.91	100.04	100.03
Domestic Agriculture	99.98	99.91	100.04	100.03
Livestock Agriculture	99.98	99.91	100.04	100.03
Bauxite-Alumina	100.00	99.93	100.06	100.05
Food Manufacturing	100.05	100.01	100.12	100.11
Sugar Manufacturing	99.98	99.91	100.04	100.04
Beverages and Tobacco	100.36	100.28	100.44	100.43
Other Manufacturing	100.12	100.11	100.20	100.20
Petroleum Refining	99.99	99.92	100.06	100.05
Chemicals	100.03	99.90	100.02	100.00
Equipment	98.85	98.94	100.12	100.11
Utilities	100.01	99.93	100.11	100.10
Construction	100.04	99.96	100.13	100.12
Distributive Trades	98.80	98.94	99.59	99.58
Transportation	100.06	100.00	100.13	100.12
Business Services	100.11	100.00	100.20	100.19
Misc. Services	100.08	99.93	100.15	100.14

Note: (1) Constrained tariffs refer to the preservation of base year tariff rates in the equipment sector.

(2) High refers to the high elasticity scenario.

(3) Low refers to the low elasticity scenario.

Table 4.16: Change in Sectoral Labor Demand by Tariff Policy and Elasticity Scenario (Base Year = 100.00)

Sector	Unconstrained Tariffs		Constrained Tariffs	
	High	Low	High	Low
Sugar Cane Agriculture	100.00	100.00	100.00	100.00
Other Export Agriculture	100.00	100.00	100.00	100.00
Domestic Agriculture	100.00	100.00	100.00	100.00
Livestock Agriculture	100.00	100.00	100.00	100.00
Bauxite and Alumina	100.11	100.12	100.08	100.08
Food Manufacturing	100.18	100.25	100.20	100.20
Sugar Manufacturing	100.00	100.00	100.00	100.00
Beverages and Tobacco	100.68	100.66	100.71	100.70
Other Manufacturing	100.27	100.39	100.30	100.32
Petroleum Refining	100.26	100.20	100.36	100.36
Chemicals	100.16	99.97	99.94	99.90
Equipment	97.98	98.25	100.13	100.13
Utilities	100.16	100.09	100.31	100.31
Construction	100.12	100.10	100.17	100.17
Distributive Trades	100.16	100.11	100.20	100.20
Transportation	100.19	100.19	100.20	100.20
Business Services	100.25	100.19	100.29	100.29
Misc. Services	100.12	100.02	100.12	100.12

Note: (1) Constrained tariffs refer to the preservation of base year tariff rates in the equipment sector.
(2) High refers to the high elasticity scenario.
(3) Low refers to the low elasticity scenario.

Table 4.17: Change in Macroeconomic Variables by Tariff Policy and Elasticity Scenario (Base Year = 100.00)

Variable	Unconstrained Tariffs		Constrained Tariffs	
	High	Low	High	Low
Consumption	100.54	100.38	100.11	100.09
Investment	100.05	100.05	100.04	100.04
Inventory	99.94	99.96	100.08	100.08
Government	100.00	100.00	100.00	100.00
Exports	99.87	99.94	99.98	99.99
Imports	101.09	101.01	100.22	100.22
GDP	99.71	99.69	99.99	99.98

Note: (1) Constrained tariffs refer to the preservation of base year tariff rates in the equipment sector.

(2) High refers to the high elasticity scenario.

(3) Low refers to the low elasticity scenario.

Table 4.18: Change in the Level of Aggregate Consumer Utility and Aggregate Employment by Tariff Policy and Elasticity Scenario (Base Year = 100.000)

Variable	Unconstrained Tariffs		Constrained Tariffs	
	High	Low	High	Low
Consumer Utility	100.410	100.007	100.143	100.126
Employment Level	100.063	100.052	100.140	100.141

Note: (1) Constrained tariffs refer to the preservation of base year tariff rates in the equipment sector.
 (2) High refers to the high elasticity scenario.
 (3) Low refers to the low elasticity scenario.

CHAPTER 5.**SUMMARY AND CONCLUSIONS**

The role of tariffs in Jamaica has undergone significant changes over time. From the dawn of emancipation to the dusk of the Great Depression, tariffs were *the* single most important source of central government revenues. In the post-World War II era, it was not until 1961 before income taxes eclipsed customs duties in their contribution to the public purse. This trend has continued unabated, and by the mid-1970s customs duties contributed a mere 5.06 per cent to government revenues, while income taxes accounted for 28.20 per cent of the total.

Perhaps the most central element determining the competitiveness of Jamaican exports is the trade regime under which the economy operates. Jamaica, as a founding member of the Commonwealth Caribbean (CARICOM), subscribes to CARICOM's common external tariff (CET). The CET is a highly differentiated tariff schedule with a wide dispersion of tariff rates that are relatively high in comparison with most of the neighboring countries in Central and South America.

Reform of the CET has become one of the central issues within CARICOM. The tariff reform program is part of the continuing process of reorganizing the trade regime to achieve the twin objectives of restructuring industry and facilitating exports. The general objective is the achievement of increased efficiency of production in the

manufacturing sector and increased efficiency of resource allocation in the economy.

Specifically, the tariff reform program (P.I.O.J., 1988) seeks to:

- (1) Encourage production in the domestic and export sectors by reducing biases in trade against these sectors.
- (2) Simplify the tariff system by narrowing the number of levels of tariff rates and removing arbitrary powers of intervention by the authorities.
- (3) Broaden the tariff base and separate revenue collection from product protection.
- (4) Enable exporters to obtain inputs at world prices.

It is important, however, to recognize that in trade policy *de facto* and *de jura* tariff rates often do not coincide. This issue is particularly relevant to Jamaica where the official tariff rates are very misleading. There are a complex set of exemption procedures, which ensure that the actual rates paid for broad categories of imports are substantially below published nominal rates.

This paper is concerned with second-best policies in the presence of existing distortions. In particular, it determines *optimal* tariff rates in the presence of pre-existing distortions (indirect taxes and rigid nominal wages) using a model with: (1) imperfect substitutability between domestically produced outputs and their imported

counterparts: (2) imperfect substitutability between domestic output and exports; (3) unemployment in the non-agricultural sectors; and (4) a fixed balance of trade. The analytical framework is of relevance to the debate on partial trade policy reform in developing countries, where existing tariffs are constrained to satisfy the non-efficiency objective of revenue generation.

The current research finds that during 1986, the year immediately prior to the imposition of tariff reforms, Jamaican trade taxes exhibited substantial elements of an optimal structure with optimal rates. In addition, it found that tariff reform did not lead to increased exports. On the contrary, it led to small increases in imports and concomitantly small decreases in exports. In the Jamaican setting, therefore, tariff reform should not be viewed, as it has often been, as an export panacea.

Given that existing tariffs exhibit a high degree of optimal structure, trade reform in Jamaica should be directed at implementing improvements in trade administration. There are obvious benefits to be derived from two areas of administrative reform. The first is the consolidation of the published tariffs rates with that of the actual rates; and the second is the abolition of arbitrary powers of intervention in trade policy by the authorities. Beyond these measures, however, there is little scope for much significant economic improvements at either the macroeconomic or the microeconomic level.

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APPENDIX A.

VARIABLES AND PARAMETERS OF THE MODEL

Endogenous Variables

C_i	Final demand for private consumption
CD_i	Domestic consumer good
CM_i	Imported consumer good
D_i	Domestic sales of domestic output
$DEPREC$	Total depreciation charges
DK_i	Investment by sector of destination
DST_i	Inventory investment by sector
E_i	Exports
$ENTSAV$	Enterprise savings
$ENTTAX$	Enterprise tax revenue
$FXDINV$	Total fixed capital investment
G_i	Government final demand
$GOVSAV$	Total government savings
GR	Total government revenue
$HHSAV$	Household savings
$HHTAX$	Household income taxes
ID_i	Final demand for Investment good by sector of origin
$INDTAX$	Total indirect tax revenue
$INVEST$	Total investment
KD_i	Domestic capital good
KM_i	Imported capital good
L_i	Labor
P_i^d	Domestic sales price
P_i^e	Domestic price of exports
P_i^c	Price of composite consumer good
P_i^k	Price of composite capital good
P_i^v	Price of composite intermediate good

Endogenous Variables (Cont'd)

P_i^x	Price of gross output
P_i^n	Net (value-added) price
PK_i	Price of a unit of capital in each sector
PM_i^c	Domestic price of imported consumer good
PM_i^k	Domestic price of imported capital good
PM_i^y	Domestic price of imported intermediate good
QC_i	Composite consumption good
QK_i	Composite capital good
QV_i	Composite intermediate good
<i>SAVINGS</i>	Total savings
<i>TARIFF</i>	Total tariff
V_i^d	Intermediate input demand
VD_i	Domestic intermediate good
VM_i	Imported intermediate good
W_i	Wage rate
X_i^s	Gross output
Y^E	Enterprise income
Y^H	Household income
Y^K	Capital income
Y^L	Labor income

Exogenous Variables and Parameters

a_{ij}	Input-output coefficient
k_{ij}	Capital composition matrix coefficient
$depr_i$	Depreciation rate
<i>FSAV</i>	Foreign savings
<i>GDTOT</i>	Total real government consumption
K_i	Stock of productive capital
$kshr_i$	Investment destination shares

Exogenous Variables and Parameters (Cont'd)

$mpse$	Enterprise savings rate
$mpsh$	Household savings rate
p_i^{se}	World price of export good
PM_i^{sc}	World price of imported consumer good
PM_i^{sk}	World price of imported capital good
PM_i^{sv}	World price of imported intermediate good
r	Exchange rate
T^E	Enterprise income tax rate
T^H	Household income tax rate
TM_i^c	Tariff rate on consumer imports
TM_i^k	Tariff rate on capital imports
TM_i^v	Tariff rate on intermediate imports
T_i^x	Indirect tax rate

APPENDIX B.**UPDATING THE JAMAICAN INPUT-OUTPUT TABLE**

Many studies have confirmed that input-output coefficients are not stable over time and require periodic updating (United Nations, 1973). The frequency with which input-output tables are completely estimated and balanced is constrained by the considerable amount of time and resources that must be expended on the endeavor. The ideal is the construction of annual input-output tables completely integrated with the estimation of national accounts as in the Netherlands and Norway (United Nations, 1973). Because the ideal is instituted in very few instances, it has become necessary to update input-output tables using techniques that are less demanding of the full-fledged survey procedures that were engaged in the preparation of the original construct. This situation is particularly applicable to Jamaica which has had a long history of association with input-output tables. Starting with its first input-output table in 1958, it was not until 1980 before the second, and current, table was compiled. Unfortunately, in both instances, a minimum of effort was invested in updating either table even when situations clearly warranted such action.

In the remainder of this appendix, the discussion will focus on the problem of coefficient stability in the context of the 1980 input-output tables; and the procedure employed in the current research to update the coefficients to 1986.

Coefficient Stability and Jamaica

Inter-temporal variations in the values of input coefficients are usually associated with three important causal mechanisms:

- (1) Changes in relative prices.
- (2) Technical changes.
- (3) Imperfect data.

Dramatic changes in prices have become a commonplace in the recent economic life of Jamaica. For the relevant period in question, 1980 to 1986, the Jamaican economy experienced massive price increases brought about by two salient factors:

- (1) Devaluation of the local currency by magnitudes in excess of 205 per cent.
- (2) Far-reaching economic liberalization which eliminated price controls and subsidies on a wide range of commodities.

Both of these events have had significant impact on the economy. Gross domestic product measured in current prices increased by 183 per cent while real GDP

increases by a mere 2.0 per cent. Furthermore, economic liberalization and the removal of price controls have precipitated substantial changes in profit rates. These in turn, have led to transformations in input coefficients. For example, in the utilities sector, the ratio of profits to gross output increased from 13.2 per cent to 35.92 per cent while in the transportation sector the increase was from 7.9 per cent to 20.9 per cent. These increases in capital income caused the relevant column totals of the input coefficients matrix to decline and the primary input coefficients to increase.

Concomitantly, the corresponding row coefficients for these sectors demonstrated significant increases which in some instances resulted in the doubling of some values.

Moreover, economic liberalization of trade policy have also lead to changes in coefficients. The removal of quantitative restrictions on imports and the removal of other non-tariff barriers have effected the coefficients in the import matrix.

The distortionary effects caused by changes in relative prices can be completely eliminated by presenting input-output data in constant prices. Unfortunately, not all the requisite data are available for constructing a constant price input-output table.

The other important contributing factor to coefficient variation is technical change. The speed and extent of technical change in the modern sectors of developing economies is one of the main reasons why input coefficients change over time. In the case of Jamaica, the most drastic technologically induced change in coefficients have occurred in the bauxite-alumina sector. From 1980 to 1986, energy

use per unit of alumina production declined, in real terms, by 37.76 per cent (Petroleum Corporation of Jamaica, 1988a). It is crucial, therefore, that technological changes be incorporated in input-output tables with frequent regularity. This is especially important, since technology is the most significant contributor to changes in input coefficients that lay beyond the domain of statistical remedy.

Finally, input-output coefficients can change because of imperfect information. Much of the problem associated with coefficient changes due to imperfect data ensue from classification difficulties. This can be reduced, though not entirely eliminated, if care is exercised in classifying commodities on the basis of the homogeneity principle so that changes in the product-mix within a given grouping is insignificant. In the current exercise, the classification problem was not considered important especially since a pre-existing list for categorizing imports and exports by economic sector was available.

Updating input-output coefficients

In the absence of constant price input-output tables, the problem of updating is regarded as a statistical procedure of adjusting a matrix to fit new column and row sum constraints. This is the basis of the widely used RAS procedure. The RAS method consists of finding a set of multipliers to adjust the rows of an existing matrix, and a set of multipliers to adjust the columns, so that the cells in the adjusted matrix will sum to the required row and column totals of the proposed updated

construct. In mathematical terms, if A_0 is the existing base year input-output table and A_1 is the proposed updated table, then:

$$A_1 = R.A_0.S$$

where R and S are the respective diagonal matrices of row and column multipliers.

From the perspective of economists, the RAS method assumes that each element, a_{ij} , of the matrix A_0 , is subject to two effects:

- (1) The substitution effect.
- (2) The fabrication effect.

The substitution effect, expressed by the R -matrix, measures the extent to which the i -th commodity has been replaced by, or substituted for, other commodities in industrial production. While the fabrication effect expressed by the S -matrix, measures the extent to which the j -th industry has altered the ratios of input usage in its production process. The method further assumes that each effect works uniformly. The simple RAS method will normally fail to produce an accurate estimate of A_1 , since the assumption that the row and the column effects work uniformly along rows and columns is not justified. Because of this, the RAS method has been modified to improve its accuracy. The modification requires the inclusion of exogenous data on

the coefficients of the new table. It should be noted that in using the modified RAS method no economic significance can be attached to the values of the row and the column multipliers. In which case, it may be preferable to regard the modified RAS method as a purely statistical tool for adjusting matrices.

Finally, in developing countries such as Jamaica, the modified RAS method can be used as an efficient technique to economically updated input-output tables. Since key coefficients are often determined by a few large establishments from whom statistics are regularly available (sugar manufacturing, petroleum refining, public utilities, and alumina production), the amount of exogenous data that can be incorporated into the modified RAS method is quite substantial and the quality of the data is usually very accurate. In this context, the updated results, obtained from additional information about pre-selected major coefficients, are substantially improved.