

Modelling the U.S. Sweetener Sector in MONASH-USA

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Abstract

MONASH-USA (also known as USAGE-ITC) is a detailed dynamic general equilibrium model of the U.S. being developed by the Centre of Policy Studies in collaboration with the U.S. International Trade Commission. This paper reports on the preliminary results of an ongoing project aimed at enhancing the modelling of the sweetener sector (sugar, corn-derivative sweeteners, and related sectors such as ethanol and sugar-containing products). This project seeks to (a) add detail to the industry and commodity classification of the relevant sectors and (b) create a detailed modelling structure for the U.S. trade and industry-support policies that affect these sectors. This paper: (i) briefly outlines the structure of the U.S. sweetener industries and the significant related sectors, and the current trade and support policies; (ii) describes the various adjustments made to the model's database; (iii) describes the modelling techniques used to capture the various components of the trade and support policies directed at these industries or which influence them indirectly; and (iv) reports on the results of some preliminary simulations using MONASH-USA involving changes to components of the various policy tools modelled. A second theme of the research is the development and application of methods for modelling complementarity relationships in a large-scale general equilibrium framework.

* We wish to gratefully acknowledge the assistance and advice of Douglas Newman of the USITC, Office of Industries.

1 Introduction

MONASH-USA (also known as USAGE-ITC) is a highly disaggregated, dynamic, computable general equilibrium (CGE) model of the United States developed at the Centre of Policy Studies (CoPS) in collaboration with the U.S. International Trade Commission (USITC). The model distinguishes over 500 industries and commodities, 51 regions (the 50 states plus the District of Columbia), over 700 occupational categories, multiple household categories and disaggregates international trade by the destinations and sources of exports and imports respectively. MONASH-USA is able to run dynamically with either backward-looking (recursive) or forward-looking expectations.

In initial applications at the USITC, concerns were raised about the model's treatment of this import sensitive industry. Particular areas of concern were (a) the level of detail captured in the industry and commodity classifications and (b) the theoretical structure of the industry and trade policies. In light of these concerns, a program of development was undertaken to address these issues, the results of which are reported in this paper.

In the first part of the paper, the structure of the U.S. sweetener industries and the significant indirectly-related sectors is described, as well as the trade and support policies applied to these sectors.

Next, there is a theoretical analysis of the U.S. sugar program, placed in the context of conventional trade analysis under tariff rate quota (TRQ) regimes. This discussion suggests that care is needed in applying broadly defined theoretical norms to real-world policy regimes, and that regime-specific approaches are often required.

Next, a description is provided of the various adjustments made to the model's database and dimensional structure. The database is disaggregated to identify the various stages of sweetener-related agriculture and down-stream milling and refining, as well as the transformation possibilities available at the various stages of these processes (for example, corn-based stock feeds, corn starches and ethanol production). Sugar imports into the U.S. are also disaggregated by source.

In the third section of the paper, a description is provided of the modelling techniques used to capture the various components of the trade and support policies directed at these industries. Of particular interest is that modelling of the TRQs and domestic programs is achieved via a set of nested complementarity relationships focused on quantities rather than tariff-equivalent price wedges. Furthermore, the TRQs are differentiated by source and enter the model via series of CES and CRESH nests, beginning at the bottom-level with a CRESH regional-source nest.

In the final section, the results of some illustrative simulations are provided and discussed, using MONASH-USA and involving changes to various policy tools that have been added to the model. These simulations provide an indication of some of the potential effects of changes to these support mechanisms, and highlight some areas for focus in ongoing model development that would further enhance the credibility of this theoretical structure in policy analysis. These simulations are labelled "preliminary" in the sense that development of the model is ongoing – particularly with regard to the database. This section is provided at the conference session as a handout, and is also available at the Centre of Policy Studies website in the working paper series.

The exposition of the theory developed for the project and its implementation in MONASH-USA is condensed for this paper. A more comprehensive discussion, including a deeper analysis of some of the numerical and mathematical underpinnings, is provided in a Centre of Policy Studies working paper¹.

2 U.S. Sugar and Corn Industry Policy

2.1 The U.S. Sweetener Sector

2.1.1 Sugar

The U.S. sugar and corn-sweetener industries comprise what will hereafter be referred to collectively as the U.S. sweetener industries. These industries are both competitors and allies in the market for sweetener products in the United States, as will be explained below.

The U.S. sugar industry is made up of the cane sugar and beet sugar industries. Unlike most sugar producing nations, the U.S. has the geographical and environmental scope and sufficient market size to support both types of sugar manufacturing, and does so only for domestic consumption purposes. The U.S. is not a direct exporter of sugar, although it does indirectly export sugar through sugar-containing products.

The cane sugar sector can be characterised as comprising three broad sub-sectors,

1. sugar cane farming,
2. sugar cane milling, and
3. cane sugar refining.

Each of these sub-sectors produces a distinct product:

1. Sugar cane farming is an agricultural activity that produces sugar cane;
2. Sugar cane milling is an industrial process that uses sugar cane as an input and produces raw cane sugar, as well as by-products such molasses and sugar syrups;
3. Cane sugar refining takes raw cane sugar as an input and produces refined cane sugar.

Cane sugar is grown in Florida, Hawaii, Louisiana and Texas. The U.S. sugar cane crop currently totals around 33 million metric tons per annum, of which about 90 percent is grown Florida and Louisiana. 2004.

The beet sugar sector can be characterised as involving two distinct activities,

1. sugar beet farming, and
2. beet sugar refining,

and two distinct products,

1. sugar beets, and
2. refined beet sugar.

¹ See Winston (2005).

Sugar beet farming is categorised by the USDA² into cost-of-production regions: in no particular order, these are (1) Great Lakes (Michigan, Ohio), (2) Upper Midwest (Minnesota and North Dakota), (3) Great Plains (Colorado, Montana, Nebraska, New Mexico, Texas, Wyoming) and (4) Far West (California, Idaho, Oregon, Washington State).

Total U.S. sugar production in 2004 was approximately 7.83 million metric tons raw value (MTRV³). This is comprised of around 4.25 million MTRV of beet sugar and 3.58 million STRV of cane sugar. The U.S. ranks 4th or 5th in the world as sugar producer depending on the season in question – for example, 2005 is expected to be low crop year due to the four hurricanes that hit Florida in 2004. Imports of all sugar products totalled 1.56 million MTRV, made up mostly of raw sugar under the TRQ and NAFTA programs totalling approximately 1.17 million MTRV, making the U.S. the world's 4th largest raw sugar importer. The rest of the import volume comprises refined sugar, sugar syrups and indirect consumption of sugar in sugar containing products. Sugar containing products are also regulated by a TRQ policy based on a complicated set of formulae calculating the equivalent sugar content of imported products. The U.S. imports from 40 countries under the TRQ system, of which the largest suppliers (in order) are the Dominican Republic, Brazil, the Philippines and Australia.

The U.S. sugar industry generates a variety of products, but the vast bulk of its revenue is derived from raw and refined sugar production. Other products, which are mostly by-products of sugar milling and refining, include bagasse, molasses, ethyl alcohol, rum, animal feed particle board and paper board.

Sugar cane must be milled soon after harvesting or its sugar yield falls as it dries out. Similarly, beets must be processed very soon after harvesting or they lose potency. This means that cane farms and sugar mills, and beet farms and beet-sugar refineries, must be located close to each other. Regional sugar markets in the U.S., therefore, tend to face low competition from other regions, and cane prices can vary substantially between states and even districts. Refined cane and beet sugar are chemically indistinct forms of fructose, and in this sense enter the market as a single, truly homogenous product. At the end of the production chain, therefore, refined sugars from the two sectors compete purely on price. The intermediate sugar milling sub-sector of the cane sugar industry is the focus of the sugar program, and is most vulnerable to import competition.

Raw sugar prices in the U.S. tend to be around 46 cents per kilogram, with the domestic support price under the agricultural loans program for sugar at around 39.6 cents per kilogram. The world sugar price, although historically volatile and variable through a wide range, is currently around 17 cents per kilogram.

2.1.2 Corn

The U.S. corn industry is a major agricultural producer and export commodity for the US, with annual total production in 2004 in excess of 10 billion bushels⁴, or around 254 million metric tons. This makes the U.S. far-and-away the largest producer of corn in the world, producing around 100 million tons more than the next largest producer (China). Around 50 million metric tons of U.S. corn is exported annually to a range of countries including Japan, Mexico, Taiwan and Egypt. Most corn grown in The

² See, for example, any recent issue of *'Sugar and Sweetener Situation and Outlook'*, USDA, ERS.

³ A short ton is 2000 pounds, compared to a metric ton of 1000kg – 1 metric ton equals 1.102311 short tons. "Raw value" refers to a standard measure for sugar that takes into account the two levels of processing in cane sugar compared to the single level in beet sugar. One ton of refined sugar is equivalent to 1.07 tons of sugar, raw value.

⁴ A bushel of yellow corn weighs 56 pounds.

U.S. is yellow corn, a variety not grown for direct human consumption (unlike sweet corn), but used for stock feeds and in wet and dry milling plants to produce a variety of products. Around 80 percent of the corn crop is used for stock feeds, with the rest being used in value added industries mostly involved in the output of wet- and dry- corn milling products like sweeteners, corn starches and ethanol. The use of corn in the U.S. wet-milling industry is divided about equally between these three uses.

The U.S. corn sweetener industry produces high fructose corn syrups (HFCS), glucose syrups and dextrose in wet-milling plants, of which around 70 percent of industry activity is devoted to HFCS. Corn sweetener production has expanded rapidly in recent years, and these products now account for around 55.7 percent of total sweetener deliveries to industry and final consumption in the U.S. by weight, having overtaken sugar in recent years. Notably, the U.S. beverage industry has almost entirely moved into using HFCS, while, to a lesser extent, manufacturers of baked goods like breads and cookies have increasingly switched to corn sweeteners.

2.2 The U.S. Sugar Support Program

2.2.1 Background

The current sugar program in the U.S. is built on the foundation of the Jones-Costigan Act of 1934. This instigated a program of management for the U.S. domestic sugar market that involved (1) the determination of U.S. domestic demand on an annual basis, (2) the use of quotas as a means to formally allocate a proportion of the market to domestic and foreign suppliers, (3) the instigation of marketing allotments (domestic production quotas) and (4) a formal program of acreage management designed to facilitate (3). The Jones-Costigan Act was replaced with the Sugar Acts of 1937 and 1948, which carried the underlying principles of the earlier legislation through to the early 1970's. In 1974, the U.S. Congress repealed the Sugar Act of 1948 which led almost immediately to large production increases and plummeting domestic sugar prices. In 1977, the Food and Agriculture Act was passed, which re-instigated a program of sugar industry support, and introduced the initial loan program.

The Agriculture Act of 1979 introduced a system of price supports to sugar processors that operated through a loan scheme and federal agency sugar purchases, aimed at offering a stable price to growers and millers and intervening in the sugar supply to manage U.S. market prices. This was essentially a buffer-stock scheme by another name.

In the Food and Agriculture Act of 1981, the loans scheme was adjusted to provide loans on a nonrecourse basis (see below), and was continued essentially unchanged in the Farm Act of 1990. The 1996 Farm act again continued the program, but limited the ability of the authorities to intervene in markets and maintain prices above the loan rate due to number of policy developments including, notably, U.S. commitments to the WTO and the NAFTA agreement. The 1996 Act also changed the nature of loans to recourse loans in all cases except where imports were allowed to exceed 1.336 million MTRV – the penalties instigated were 1 cent per pound for raw cane sugar and 1.072 cents per pound for refined sugar on any forfeitures (explained below). Most recently, 2001 Agricultural Appropriations Act eliminated the TRQ trigger for nonrecourse loans and removed all provision for loans to be granted on a recourse basis.

The two most important components of the current U.S. sugar support program are the loan scheme and the TRQ program.

2.2.2 The Loan Scheme

Essentially, loans are taken out against raw sugar production at the “loan rate” using the sugar as collateral, and are taken for maximum term of 9 months. Initially, this “loan rate”, or support price, was set at 16.75 cents per pound for raw sugar and 19.7 cents per pound for refined beet sugar, but has since been increased to 18 cents and 22.9 cents per pound, respectively. Loans must be repaid with any interest charges by September 30 in any given year. Cane mills share the interest expense with their growers, but beet refineries cannot, and must therefore recover the entire additional cost of interest from the revenue generated by sugar sales – this in part explains the differences in the loan rates, along with the fact beet sugar is typically sold at a 2 percent cash discount.

The loans are offered by the Commodity Credit Corporation (CCC) directly to sugar cane mills and beet sugar refineries, who qualify for the scheme by agreeing to offer sugar cane and sugar beet growers a minimum price for their produce of around 60 percent of the loan rate. As U.S. trade commitments under the WTO and NAFTA are fixed, the marketing allotments are the policy tool used by authorities in the first instance to limit the supply of sugar and maintain a target “minimum” price. This intent of the minimum price is to avoid sugar forfeitures by covering the loan rate plus a small margin that accounts for mill-to-refinery transport costs and other distribution costs (plus, in some instances, location discounts imposed by refiners on mills) in the case of sugar mills, and exactly the loan rate in the case of beet refiners (as there is no second stage to processing and no additional costs are incurred post-refinery). Thus, the idea is make it more profitable for sugar mills and beet refineries to sell their output onto the market and repay the loans, rather than forfeit the crop and keep the loan money. According to Haley (2001), in 2000 the minimum prices required to forestall sugar forfeitures were 19.86 cents per pound for raw cane sugar, and 24.78 cents per pound for beet sugar.

2.2.3 The TRQ Program

Under its obligations to the WTO set down in the Uruguay Round Agreement on Agriculture (URAA) of 1994, the U.S. agreed to import a minimum of 1.139 million MTRV of sugar in each marketing year (defined as running from October to September), including a specific allocation of 24,251 MTRV of refined sugar. The allocation of TRQs to the 40 recipient countries occurs on a historical basis, calculated against the share of each country’s supply to the U.S. during the period 1975-81 when trade in sugar was relatively free.

In chapter 17 (heading 1701) of the U.S. Harmonised Tariff Schedule (HTS), the in-quota and over-quota rates applied to sugar, as negotiated under the URAA, are *excise* rates set (in general) at 1.4606 and 33.87 cents per kilogram respectively. The U.S. HTS allows for different rates for special cases, including zero in-quota rates for the Caribbean Basin Economic Recovery Act (CBERA) nations and those covered by the Generalized System of Preferences (GSP) – this, in effect, means that most of the 40 nations holding TRQ rights can supply sugar duty free on in-quota amounts. Countries are issued

Additional quotas over-and-above any allotments the TRQ program are allocated to Canada and Mexico under NAFTA. Canada supplies small quantities of beet sugar to the U.S. market, while Mexico supplies both refined and raw cane sugar. These quotas are discussed further below.

3 Changing the MONASH-USA Theory to Model Tariff Rate Quotas

3.1 Introduction

The general theory of TRQs has been well-covered in the literature. While informative, this literature has relied on fairly simple approaches that are not truly transferable to a realistic analysis of trade and

support policy structure like that in the United States sweetener sector. Furthermore, they don't lend themselves readily to a true welfare analysis. In an application, like that in this paper, to an analysis of policies imposed on an agricultural industry with annual production cycles and significant lags between production decisions and revenue receipts, special attention should be given to the industry supply response and the implications of the resulting shifts in market power.

3.2 The Microeconomic Foundations of Tariff Rate Quotas

The nature of U.S. sugar supply in a given period differs from that of a "generic" commodity. A series of diagrammatical analyses is developed below that begin with, and then extend and refine, the conventional approach to TRQs to incorporate the detail of U.S. sugar programs.

Denote: the in-quota and over-quota *ad-valorem equivalent* (see below) tariff rates by t_i and t_o respectively; the quota by Q ; imports by M ; the world price (in U.S. dollars) by P_w ; the U.S. customs-insurance-freight (CIF) price by P_{CIF} ; the U.S. landed-duty-paid (LDP) price by P_{LDP} ; and the rent per-unit (or premium) due to the quota boundary by ϕ .

It is assumed that applied tariff rates are *ad-valorem equivalent* unless otherwise noted. Denoting the excise rate (using the in-quota value for this example) by t_i^e , the *ad-valorem equivalent* is determined by recognising that any level of revenue generated by an excise tax has an equivalent value-based rate implied by the following equality -

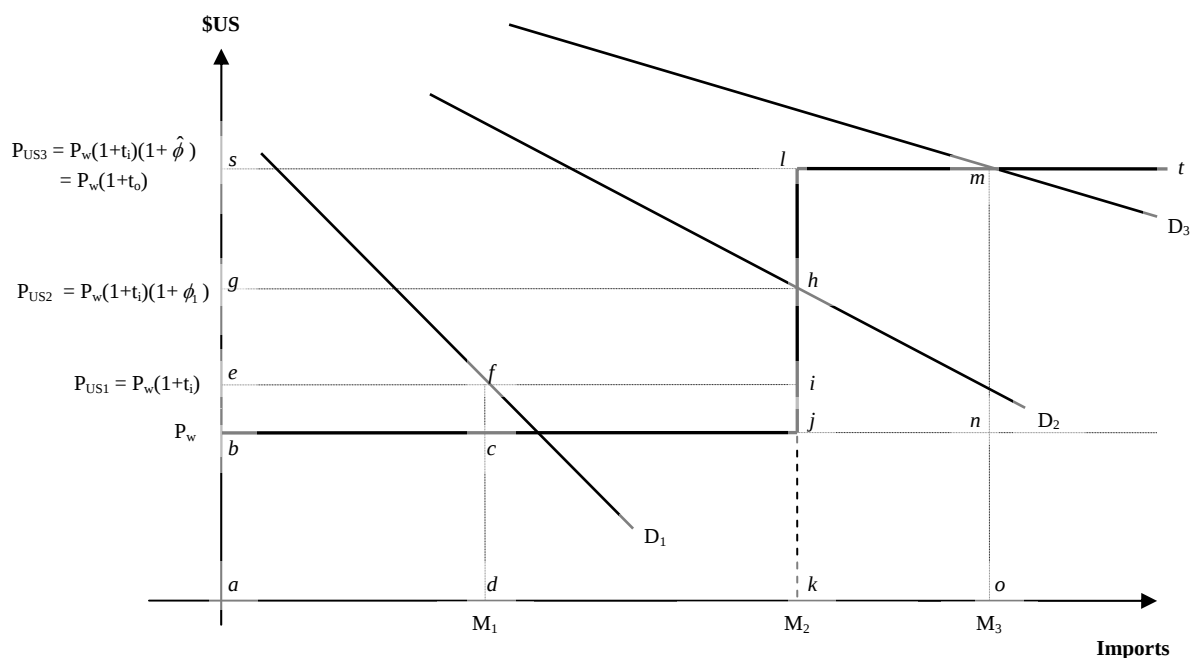
$$t_i^e M = t_i P_{CIF} M$$

which implies

$$t_i = \frac{t_i^e}{P_{CIF}}. \quad (1)$$

When the *powers* of the tariffs (i.e. equal to the *ad-valorem* tariff rate *plus* 1) are applied in this paper, this also allows us to insert the multiplier below or above the rent rectangle in our diagrams by using the appropriate price variable (i.e. P_{CIF}) in the denominator. The CIF price is basically equal to the world price plus rents. Diagrammatically, it also means that the tariff-revenue rectangle remains a constant size as either of these prices varies, which is particularly useful in the case of the rent-inclusive CIF price when analysing on-quota imports.

Figure 1



$\hat{\phi}$ denotes the maximum value of ϕ . In what might be called a standard or “generic” TRQ analysis, figure 1 highlights the important underlying features of this type of trade policy. Given the values of the two *ad-valorem* tariff rates and the sugar quota, three different levels of demand for sugar create the following outcomes:

Firstly, with a level of demand denoted by demand schedule D_1 , sugar imports occur at an in-quota level M_1 , attracting the in-quota tariff and generating no rents (as the quantity constraint imposed by the quota is not binding). The US CIF price is equal to the U.S. dollar world price, the CIF value of imports is $abcd$, and the LDP value is $ae fd$, with tariff revenue $befc$. The LDP price – the *basic* price to U.S. agents represented along schedule D_1 – in this case is P_{US1} .

Demand schedule D_2 generates an *on-quota* level of imports, M_2 , equal to the quota, Q . As the quantity constraint becomes binding, a rent accrues to the foreign exporter and the CIF price rises accordingly. Under these circumstances, the CIF value of imports increases to $aghk$ minus tariff revenue $eijb$, and now involving a rent given by the area $ghie$. These values are generated by the on-quota level of imports, the LDP price P_{US2} (inclusive of a rent and tariff wedge) and a CIF price equal to $P_{US2}/(1+t_i)$. As demand expands, the tariff revenue remains constant and the rents generated by the quota boundary expand proportionately with the CIF price (i.e. *not* proportionately with the LDP price). In this example, excess demand at P_{US1} is generating a per-unit rent of ϕ_1 , which we’ll assume accrues to the foreign country due to the quota “licence” being held by a foreign agent.

In the case of demand schedule D_3 , imports increase to an over-quota level M_3 , the LDP price increases to P_{US3} , the CIF price at the margin *falls* to $P_{US3}/(1+t_o)$ – again equal to P_w – on the over-quota import quantity (M_3-Q). Tariff revenue now comes in two parts – a fixed component given by the in-quota tariff rate t_i and the quota Q (area $eijb$), and a second component given by the over-quota tariff rate t_o and the level of over-quota imports (M_3-Q) (area $lmnj$). As demand drives the LDP price to reach P_{US3} , the per-unit rent reaches a maximum value of $\hat{\phi}$, but this is only applicable to sugar imported under the

quota. Thus, as the level of imports goes *over-quota*, the total value of rents has reached a maximum also, given by area *slie*.

This type of TRQ analysis, while informative, is somewhat incomplete. We can explain this in two steps.

Firstly, ignore the specific characteristics of sugar production and assume a generic commodity. Unless the imported good is a distinct commodity that is not substitutable for a U.S. version, the three demand schedules must be interpreted as *excess demand* schedules for the “generic” commodity. If so, the diagram cannot be used for an analysis of the effect of trade policies on domestic economic welfare, as it entirely ignores the implications of policy for (a) domestic production of the substitute and (b) consumption behaviour. It seems unlikely that a protective trade policy would be applied to a good that had no domestic substitutes and, thus, logically the diagram is incomplete. Figure 2 below addresses some of these issues.

Figure 2

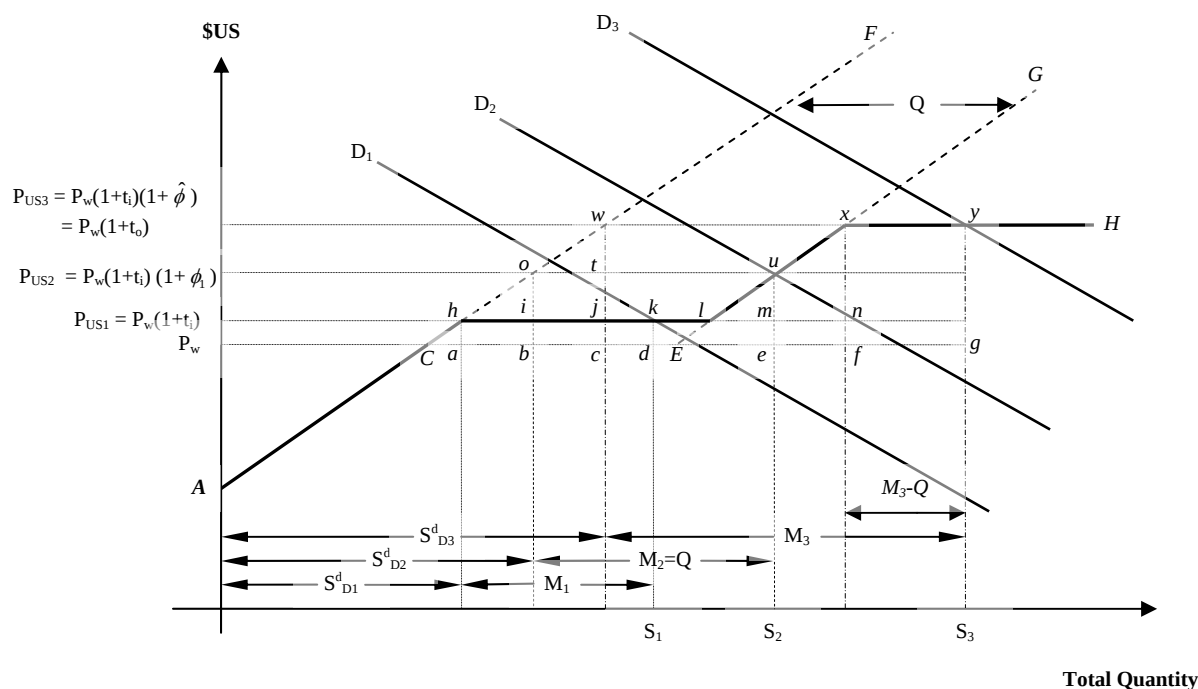


Figure 2 is the implied underlying market diagram that generates figure 1, presuming that a domestic substitute exists. In this case, the demand curves plot the underlying demand schedules that are partly responsible (along with the domestic supply schedule AF) for generating the *excess demand* curves of figure 1. It is helpful in reconciling these two diagrams to recognise that (1) the curve S^d in figure 2 is equivalent to the vertical axis in figure 1, and that (2) the curve S^{TOT} (or $BCxE$) in figure 2 is equivalent to bjl in figure 1. The “total” supply schedule – the horizontal sum of domestic and foreign supply at every price – is given by line ACg in the absence of any trade policies. With the TRQ system in place, line $AhlxH$ describes the supply curve, with segment $hlxH$ being equivalent to the import supply curve plotted in figure 1. As a demand schedule is shifted to the right and passes through point l , imports are restricted by the quota and domestic production responds to the increase in price as excess demand materialises. The increase in the domestic price at the quota boundary is also passed to the foreign supplier of the import quota as a rent, and the supply curve changes as the line segment hl slides up the underlying

domestic supply curve AF . Once demand is sufficient to generate LDP price P_{US3} at point x , buyers are able to purchase as many units of the good as desired from foreign suppliers at this price, equal to the world price P_w plus the over-quota tariff – as such, from this point on, all increases in demand are met by an increase in imports, and domestic production has reached a maximum. At point x and beyond, the line segment that previously represented the quota ceases to “slide” along AF and, instead, attaches to point w and extends out to the right of the diagram.

Figure 2 lacks the simplicity of figure 1, but (therefore) includes much of the detail obscured in a diagram that focuses on excess (domestic) demand and imports. A comprehensive welfare analysis using figure 2 and including the consumer surplus areas will not be conducted at this stage. Rather, a comparison of figures 1 and 2 will be made. With all three demand curves plotted on figure 2, the diagram is somewhat cluttered and a welfare analysis would require some effort to follow, and so an examination of the full welfare consequences of the TRQ scheme will be conducted below in a separate exercise. Welfare analysis is not possible in figure 1 unless, as mentioned, there is no substitutability between the imported good and a domestic commodity, in which case there would be no “figure 2”. Of most importance, in the event that substitutability *does* exist, is that the domestic supply response is included in a diagram like figure 2, so that it is possible to examine how consumer and (total) producer surplus areas are redistributed by changes in policy variables.

With demand schedule D_1 , total supply is S_1 , comprising domestic production S_{D1}^d and in-quota imports M_1 , generating tariff revenue $ahkd$. As the level of imports lies below the quota (hl) by the amount kl , there are no rents generated for the foreign exporter. This was assumed implicitly in figure 1 also, and, it should be noted, this is not always true – the discussion of the U.S. sugar program below will highlight the circumstances under which this assumption does not hold. For now, keep in mind that the quotas in figure 2 are not interpreted as import *commitments* by the importer, and that domestic supply is truly responsive to current market conditions.

Under demand conditions represented by D_2 , imports have reached the quota boundary and rents are being generated. In this case, total demand and supply occurs at S_2 , where supply is composed of domestic production S_{D2}^d and imports M_2 , equal to the quota (also represented by line segment ou in this case). Tariff revenue is given by area $bime$, and rents by $ioum$. Compared to the previous case, this higher level of demand stimulates an increase in domestic output by hi , and an increase in (domestic) producer surplus of area hio - this is absent from figure 1, as is the change in consumer surplus due to increased consumption of the domestic variety and the transfer of surplus from consumers to domestic producers caused by the price increase (both of which we ignore for now in figure 2).

Demand curve D_3 generates a total level of demand and supply S_3 , comprised of domestic output S_{D3}^d , and imports M_3 , equal to the quota plus over-quota imports (M_3-Q) along line segment xy . Total tariff revenue is now a function of two components, (1) imports at the in-quota tariff rate generating revenue $cjnf$ on quantity wx (i.e. the quota) plus (2) imports at the over-quota tariff rate generating revenue $fxyg$ on quantity xy . Once the LDP price has reached P_{US3} and the level of imports has gone over-quota, the total value of rents reaches a maximum value of $r_{\max}Q$, captured in figure 2 by area $jwxn$. Compared to the outcome associated with demand schedule D_1 , curve D_3 has generated an increase in the domestic price from P_{US1} to P_{US3} , and stimulated (1) an increase in domestic output hj and (2) domestic producer surplus $hjwt$, larger than the case of curve D_2 by ij and $ijwo$ respectively.

3.3 The Theory of Tariff Rate Quotas under the U.S. Support Programs

3.3.1 Supply in the U.S. Sugar Industry

With the current price and quantity measured along the vertical and horizontal axes respectively of figures 1 and 2, this assumes an immediate supply response from all sectors of the market in all situations where the quota is not binding. This assumption is not defensible in the U.S. sugar market.

In any given year, *that* years output is highly inelastic with regard to *that* year's *actual* sugar price. As discussed in section 2.2 above, the U.S. sugar program applies domestic production quotas – known as “marketing allotments” – and a loans scheme to the domestic industry in order to maintain an implicit price floor of approximately 39.6¢/kg. The aim of the program is to avoid loan default and sugar forfeitures, and so it is reasonable to assume that sugar stocks do not systematically accumulate (as discussed above). A forecast is generated for the total U.S. demand for sugar at about this price floor plus a margin for error, from which the import commitments under WTO obligations are subtracted and the residual is allocated to the domestic industry as production quotas. Like many agricultural commodities, sugar production is characterised by long lags between decision making and outcomes - production decisions are made on the basis of *expected* prices well before the output is released onto the market and revenue streams are generated. Therefore, except for the real possibility of over-quota imports from Mexico at the lower NAFTA over-quota tariff rate, supply *above* the price floor *at the time of harvesting* is highly inelastic. Supply is also very inelastic below the price floor because costs are sunk at the time of harvesting and the beginning of the marketing cycle, and, in fact, if the variable costs of growers and millers cannot be covered in the event of extremely low prices, crops may be abandoned and mills left idle – the equivalent of the “shutdown” point. Some limited supply response is afforded the authorities through the loans scheme, as it is in their power to withhold forfeited sugar from the market if demand forecasts have been too optimistic.

Figure 3

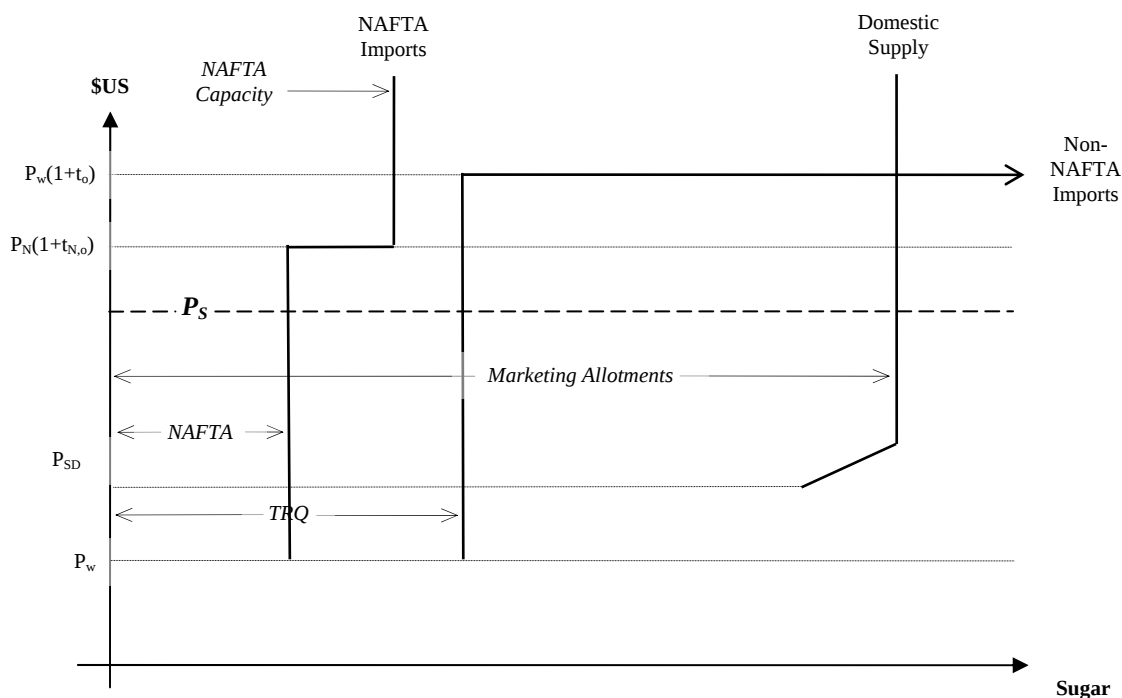


Figure three plots the components of total U.S. sugar supply at the time the marketing cycle begins.

At the time of marketing – when WTO commitments are binding, sugarcane has been harvested and mills are processing sugar – domestic supply is effectively exogenous at the sum of the marketing allotments. As mentioned, very low prices may stimulate crop abandonment and create excess capacity in sugar mills, and - at the limit - supply could potentially fall to zero. This is a situation unlikely to eventuate in reality, as it would require large and unlikely errors in the expectations of cane growers, sugar processors and the federal authorities who set the marketing allotments. The domestic supply schedule in figure 3 is drawn to show that U.S. production costs are higher than both the world price inclusive of the in-quota tariff and the NAFTA duty-free price. The diagram defines a “shutdown” price P_{SD} for domestic production – at prices slightly higher than this, profits are likely to be negative but some fixed costs are covered, while below it a grower or firm cannot even cover variable costs.

The TRQ curve plots the U.S. WTO commitments for imported sugar. This amount must be imported, and so is also autonomous with respect to market prices during the marketing cycle. At a domestic price below the tariff inclusive world price, no sugar would be offered for sale by foreign exporters, although – again – WTO commitments in effect oblige the U.S. to purchase this amount at (*at-least*) the world price.

The NAFTA supply schedule is also drawn to be very inelastic. Under the NAFTA agreement, Mexico receives an additional quota allocation over-and-above the U.S. WTO obligations. This amount is calculated, on a year-by-year basis, as a function of the estimated Mexican sugar surplus of production over consumption, up to a maximum amount of 250 000 metric tons (but is usually much less). The curve is then perfectly elastic at the Mexican over-quota tariff rate (reflecting that Mexican sugar production costs are significantly less than this implied price) and again becomes inelastic at the point that capacity is reached (a function of acreage and sugar yield per acre) for a given season. The quota can be filled with any combination of raw and refined sugar. Furthermore, this sugar enters the U.S. duty free within the quota allocation, and at a relatively low over-quota tariff rate of around 10 per kilogram in the event that the quota allocation is exceeded. In the year from which the data was drawn for the simulations reported below, Mexico imported more sugar at world prices than it exported to the U.S. at the U.S. price, effectively making a healthy arbitrage profit on its quota allocation. As the quotas and duties are to be removed in 2008 under NAFTA, this highlights an issue of concern for U.S. trade policy makers. Rules of origin apply currently to combat this type of behaviour, but this does not limit the ability of a country to export its own product while consuming imported sugar.

Combining these functions generates the U.S. effective supply curve for sugar in any given year, relating current prices and production – this is plotted in figure 4 below. Note that the two axes in each of figures 3 and 4 are not drawn to scale, and are meant only to allow qualitative comparisons.

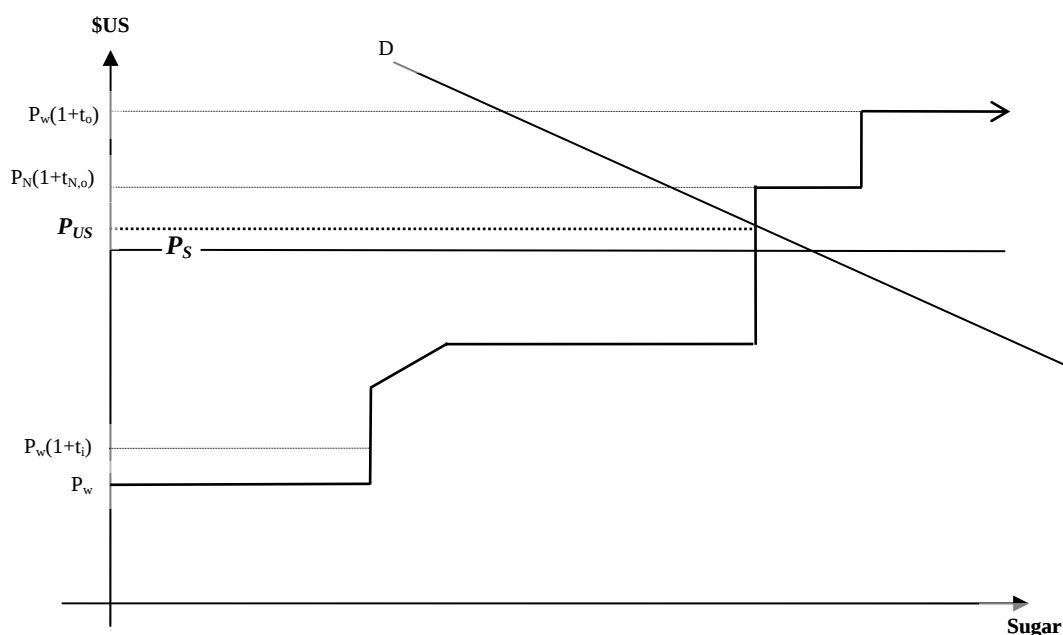
Figure 4

Figure 4 indicates that the supply of sugar in the U.S. during the marketing cycle is very inelastic throughout a wide range of prices, and only involves some price-responsiveness at very low prices (due to crop abandonment, etc) and at prices sufficient to stimulate over-quota imports from Mexico or the rest of the world. This supply curve indicates the opportunity cost of sugar to the various supply-side agents *once the commitment has been made* to supply the various quantities above – in that sense, it is not truly a “supply” function, as it tells us little or nothing about the resource allocation decisions underlying these amounts. Furthermore, due to these limitations, it is not possible to conduct a true behavioural analysis on the basis of these diagrams.

We can adjust figure 4 to provide additional information by taking a slightly different perspective. If we are concerned with allocative-efficiency, and the behavioural and welfare outcomes of production decisions in the sugar industry (both domestic and foreign), we need to relate the expected market price of sugar to the underlying production functions and the opportunity cost of resources allocated to this use.

production is just covered and there are no incentives for domestic producers to expand output (if they could).

Under a free trade regime, figure 5 suggests that no domestic raw sugar is produced. Equilibrium output and consumption is determined at S_2 at a price of se , generating total expenditure $apse$. Total welfare is given by area ysf , of which consumer surplus xsp accrues to domestic agents and producer surplus psf to foreign producers. This outcome has obvious upstream consequences for sugar cane growers that are not captured in this diagram, but, offsetting this to some degree, it is likely that cheaper raw sugar will induce a demand response from upstream users – sugar refineries and end users of raw and refined sugar – and an expansion in their activity.

Under the current U.S. support programs, industry activity occurs at S_1 at the support price P_s , generating total expenditure $auxd$, a change of $drse$ minus $puxr$. Which of these expenditure change areas is the larger depends on the arc elasticity of demand around line segment xs ; however this is likely to stimulate an increase in expenditure based on the econometric evidence of relatively inelastic raw sugar demand in the U.S. Total welfare derived production and consumption is represented by area $yxlgvt$, comprising consumer surplus yxu to domestic consumers, uvt to producer surplus to domestic producers, tariff revenue $kmnl$ accruing to the domestic government, and some foreign surplus areas: these foreign surplus areas can be divided into $mwxn$ in rents to ROW producers, $jvwk$ in rents to NAFTA producers, and producer surplus area jlg going to both in proportions determined by their share in the total quota, bc/bd for NAFTA and cd/bc for ROW (assuming identical production functions). The outcome for the foreign producers depends on the relative sizes of the loss in producer surplus from the decrease in volume and the addition of the rent rectangles, while the outcome is unambiguous for the U.S. – a loss of total welfare $ptvxs$ minus $kmnl$ (the tariff revenue). The loss to the U.S. is comprised of a deadweight production-side loss, due to the increased cost of domestic production over foreign acquisition, of $ptvq$, a deadweight demand-side loss due to the increase in price and reduction in consumption of rxs , and a transfer of consumer surplus to foreigners as rents $qvxr$.

A good way to assess the efficacy of a TRQ and support price program is to compare it to a tariff equivalent policy with an *ad valorem* tariff that would generate the same price and total volume outcomes, as with the dashed foreign supply curve in figure 5. The tariff enables the domestic government to accrue all of the rents as tariff revenue plus (as the diagram is drawn in this case) stimulate no domestic production and thus suffer no production-side deadweight loss. Of course, underlying this analysis is the assumption that factor markets will clear and the resources freed up by import supply are utilised in more valuable uses elsewhere. While this is not likely in the very short run in the presence of wage floors and market frictions (e.g. search costs, information asymmetries, location-related issues, etc) it is a well accepted lesson of economic theory and practical experience that trade policy is a poor substitute for labour market programs in generating full employment in the medium to long term.

Figure 5 generates some outcomes from the TRQ policy that are not typical of this type of trade analysis. Of significant influence in this matter is the fact that enough foreign-sourced sugar can be supplied at a lower cost than the first unit of domestic production, implying that the domestic industry ceases to exist without trade restrictions. However, this is partly generated by some simplifications, perhaps most importantly the assumption of a low price elasticity for import supply across the relevant range. The U.S. is committed to around 1.5 million metric tons of sugar imports out of total global trade in sugar of around 35 million metric tons. This is a relatively small part of the total, but not insignificant, particularly in the event that it chose to increase sugar imports significantly – the capacity constraints generated by the nature of sugar production also apply to foreign producers in a given year, and so the U.S. would need to move world prices to divert significant quantities of sugar from other destinations. It is clear, though, that the U.S. cane growers and raw sugar milling installations would suffer greatly from a free and open sugar market in the United States. This is not the end of the story for total U.S. economic welfare, however, as the rest of this paper shows.

4 Simulating a Change in U.S. Sugar Policy

4.1 Introduction

Modifying MONASH-USA required the completion of two large tasks (1) data collection, and the related modifications to the database, and (2) generating a modelling theory, and its implementation in the model.

The first part of this section provides a brief overview of changes to the dimensional structure and database of MONASH-USA. A number of new industries and commodities were added to the model, requiring that some existing industries and commodities were split and redefined. These new structures also required some decisions be made regarding appropriate nesting structures, but this issue is best left to the discussion of the model's theory below. More detail can be found in Winston (2005).⁶

To simulate the U.S. sugar program realistically, it is necessary to impose some inequality constraints (for the TRQ quotas) and non-differentiable functions (for tariff revenue and quota rents). These can all be represented by complementarity functions that relate the values of two or more variables in various states and under various conditions. Generally speaking, applications of general equilibrium models to analyse quantity restrictions like quotas and TRQ policies have utilised implicit price premiums to proxy for the required inequality constraints. The GEMPACK software developed at the Centre of Policy Studies by Pearson *et al* to solve very large systems of non-linear equations in general equilibrium models has recently been enhanced with dedicated sub-routines that enable explicit quantity restrictions and discontinuous functions to be modelled in a theoretically rigorous way. In the following section, the application of these sub-routines and some complementary numerical methods to the modelling of the U.S. sugar market is described. Part of the application explained below is based in earlier work by Elbehri and Pearson (2000) and Harrison *et al* (2001), with some added extensions and refinements developed to capture the specifics of the U.S. sugar program.

4.2 Adjustments to the Database

The data required for this task was sourced from the Economic Research Service (ERS) of the U.S. Department of Agriculture, and from unpublished proprietary databases at the U.S. International Trade Commission (USITC). Space considerations have led us to keep this section very brief and only illustrative in nature, but more information available from the authors and the CoPS working paper cited a number of times throughout this paper.

4.2.1 Changes in Industry Sets

Old Industries:

- | | |
|------------------|----------------------------------|
| • I7 Feedgrains | Corn, barley, sorghum, oat crops |
| • I13 Sugarcrops | Sugar cane and sugar beet crops |

⁶ We acknowledge here the use of the program DAGG created by Mark Horridge at the Centre of Policy Studies, which made the disaggregation of the numerous relevant rows and columns of the huge MONASH-USA data arrays a relatively painless process – more information on DAGG and other excellent database utilities written by Mark are available on the Centre of Policy Studies website.

- I75 Wetcornmill HFCS, other corn sweeteners (glucose and dextrose), corn starch, corn (ethyl) alcohols – all at wet milling plants
- I79 Sugar Sugar milling and refining, cane and beet

Total industries in old database **513**

New Industries:

- I7 CornCrops Corn crops
- I8 OthFeedgrain Barley, sorghum, oat crops
- I14 SugarCane Sugar cane crops
- I15 SugarBeets Sugar beet crops
- I77 WetCornMill HFCS, other corn sweeteners, corn starch
- I81 RawSugarMill Process sugar cane into raw sugar
- I82 CaneSugarRef Process raw cane sugar into refined cane sugar
- I83 BeetSugarRef Process sugar beets in refined sugar

Total industries in new database **517**

4.2.2 Changes in Commodity Sets

Old Commodities:

- C7 Feedgrains Corn (>80 percent), barley, sorghum, oats
- C13 Sugarcrops Sugar cane and sugar beets
- C74 Wetcornmill HFCS, other corn sweeteners (glucose and dextrose), corn starch, corn (ethyl) alcohols
- C78 Sugar Raw sugar, refined sugar, sugar refinery by-products (molasses etc)

Total commodities in old database **503**

New Commodities:

- C7 Corn Corn
- C8 OthFeedgrain Barley, sorghum, oats
- C14 SugarCane Sugar cane
- C15 SugarBeets Sugar beets
- C76 WetMillSweet HFCS, dextrose, glucose syrups
- C77 WetMillStarch Corn starches
- C78 Ethanol Currently only from corn (wet milling)
- C82 RawCaneSugar Raw cane sugar
- C83 RefCaneSugar Refined cane sugar and by-products
- C84 RefBeetSugar Refined beet sugar and by-products

Total commodities in new database **509**

4.2.3 The Nesting Structure

The following diagrams capture the way that these new industries and commodities are related in the model's structure. Only a brief diagrammatical overview is provided here – more information is available in Winston (2005).

Figure 6

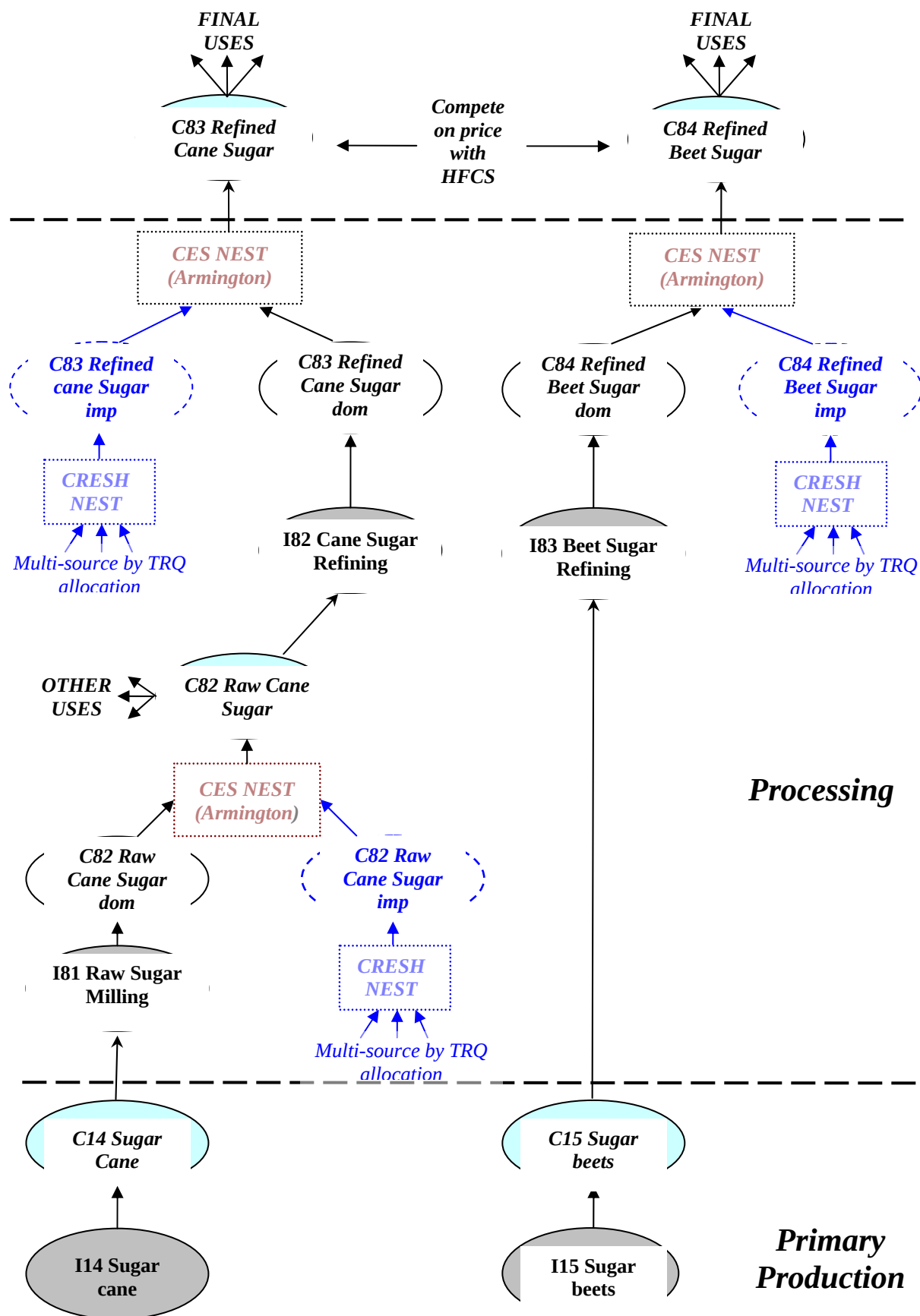


Figure 7

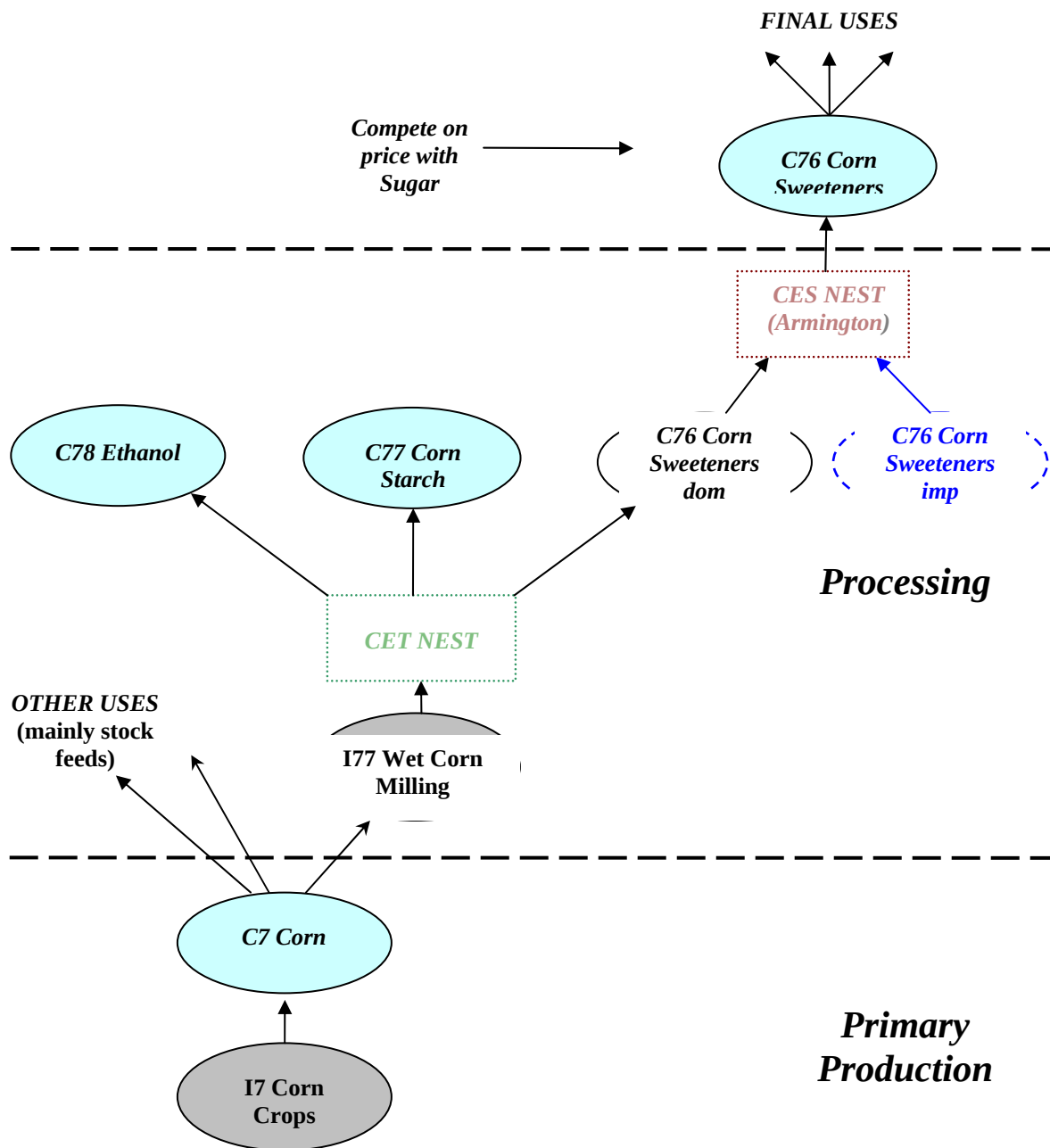
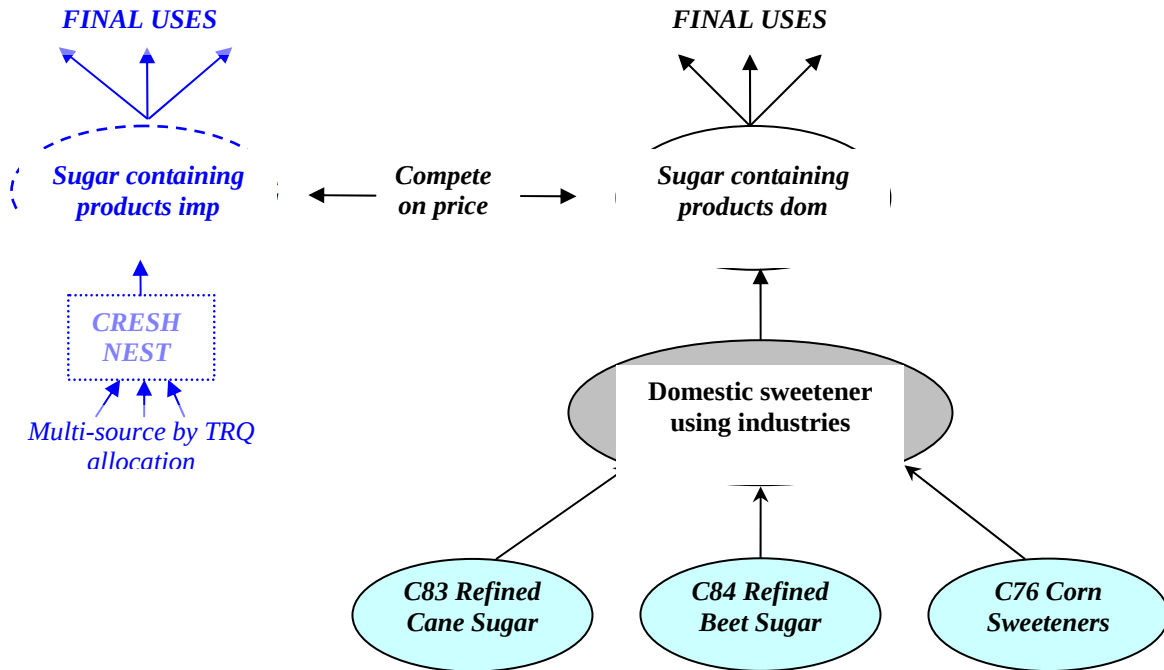


Figure 8



4.3 A Generalised Complementarity Relationship

This section is a brief summary of elements of chapter 16 in GEMPACK documentation, and readers are referred to this text or Harrison *et al* (2002) for more detail.

Complementarity relationships describe the state that a variable takes when some other condition – perhaps an expression – takes one of a set of values. Denote the “complementarity variable” by X , the “complementarity expression” by EXP , and lower and upper bounds on X by L and U respectively. Mathematically, a generalised complementarity relationship takes the form

$$L \leq X \leq U \perp EXP. \quad (2)$$

Equation (2) is notation for the set of relationships like

$$\begin{array}{llll} \text{Either} & X = L & \text{and} & EXP > 0 \quad [\text{state 1}] \\ \text{or} & L < X < U & \text{and} & EXP = 0 \quad [\text{state 2}] \\ \text{or} & X = U & \text{and} & EXP < 0. \quad [\text{state 3}] \end{array}$$

This three-state complementarity can also take the form of one of two dual-state relationships [which are really special cases of (2)] with either (a) a single lower bound where

$$\text{Either} \quad X = L \quad \text{and} \quad EXP > 0 \quad [\text{state 1}]$$

or $X > L$ and $EXP = 0$ [state 2]

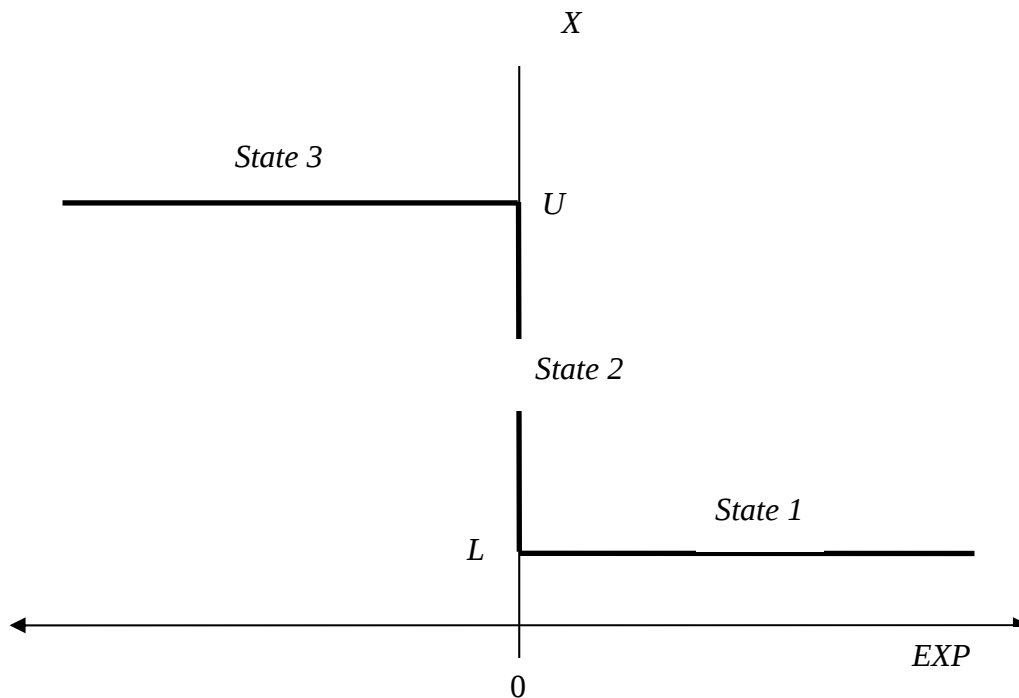
or (b) a single upper bound, where

Either $X < U$ and $EXP = 0$ [state 2]

or $X = U$ and $EXP < 0$. [state 3]

These relationships can be summarised diagrammatically as follows:

Figure 9



The two-state complementarity relationships are represented on figure 9 by simply removing *state 3* and U for the lower-bound-only case, and *state 1* and L for the upper-bound-only case.

Two of the applications below (for calculating the total value of quota rents and tariff revenue under the TRQ regime) utilise another characteristic of complementarities that is worth briefly describing here. Generally, a complementarity with a single bound (a dual-state complementarity) can be expressed as a MAX (maximum) or MIN (minimum) expression. A complementarity with only a lower bound can be equivalently stated as

Either $X - L = 0$ and $EXP > 0$ [state 1]

or $X - L > 0$ and $EXP = 0$ [state 2]

which is the same as

$$\text{MIN}(X - L, \text{EXP}) = 0, \quad (3)$$

and for the upper bound case, by the same logic, we can reformulate and restate the relationship by

$$\text{Either} \quad X - U \leq 0 \quad \text{and} \quad \text{EXP} = 0 \quad [\text{state 2}]$$

$$\text{or} \quad X - U = 0 \quad \text{and} \quad \text{EXP} < 0. \quad [\text{state 3}]$$

and

$$\text{MAX}(X - L, \text{EXP}) = 0. \quad (4)$$

In our application to the modelling of the U.S. sugar sector in MONASH-USA, all three complementarity types are utilised.

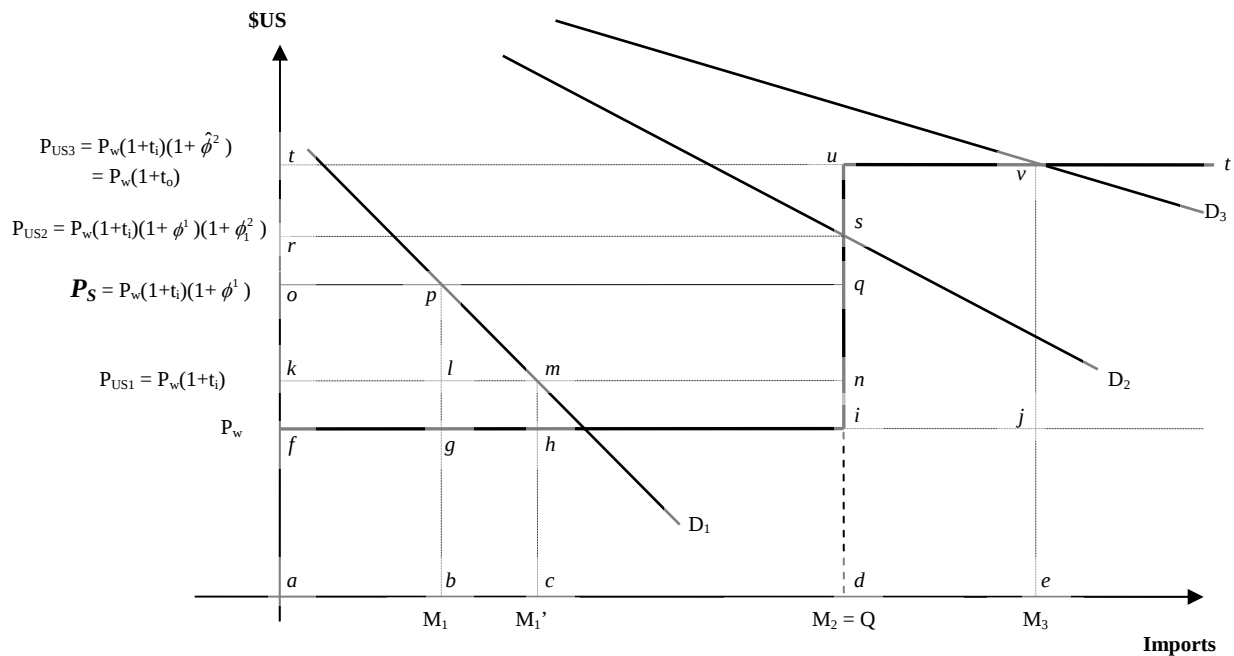
4.4 The MONASH-USA Theory of the U.S. Sweetener Sector

4.4.1 Introduction

The basis of the methodology developed in this section is found in earlier work by Elbehri and Pearson (2000) and Harrison *et al* (2002). As a rule-of-thumb, the Elbehri and Pearson and Harrison *et al* approaches are more closely related to an analysis like that captured in figure 1, while the application described here is more closely related to figure 5.

In this study, the rents generated under the U.S. policies are divided into two components – a “first tier” rent per unit related to the support price, and a “second tier” rent per unit generated by the quantity constraint at the quota boundary. An import diagram like figure 1, but slightly modified, can highlight these concepts.

Figure 10



In figure 10, the notable additions are that now there are *three* types of per-unit rent variable, ϕ^1 , ϕ^2 and $\hat{\phi}^2$, and a support price, P_s . The variables ϕ^1 denotes the rent on a unit of sugar due to the support price (or “first-tier” rent), variable ϕ^2 denotes a variable rent per-unit caused by the quota boundary (or “second-tier” rent), and $\hat{\phi}^2$ now represents the maximum value of ϕ^2 specifically. The underlying theory of the TRQ in figure 10 is slightly different from that in figure 1. This is due to a number of sugar-industry specifics, and also some errors that stem from using a model like that detailed in figure 1 to capture an agricultural TRQ program:

1. The existence of the loans scheme and support price;
2. the existence of the domestic marketing allotments;
3. the *obligation* to import imposed on the U.S. by its WTO commitments;
4. TRQ quota allocations are multi-source commitments;
5. the lag between production decisions for growers and the setting of price in the final market *for* their product;
6. the implied lack of a domestic substitute for the imported good, and
7. the administration of U.S. TRQ quota allocation is by proportional historical allocation.

These points combine to create two important outcomes for the current study:

1. At the time of the marketing cycle, *all* market power is in the hands of foreigners, and therefore
2. foreign suppliers accrue rents on all in-quota units of supply, even if they do not reach the quota boundary.

Let's revisit the nature of the U.S. loans scheme again for an explanation.

The trade policy represented by the TRQ program is subsumed within the overall support program, and particularly the loans scheme. The U.S. sets a support price that, in effect, guarantees growers and millers a minimum return on their activity and which, because of the forfeiture clause, acts much like a buffer stock scheme. However, as stocks do not systematically accumulate, and because they *must* be released onto the market in the following year, these can be ignored for an analysis of systematic producer behaviour. The demand function is autonomous from the perspective of the U.S. price setting authority, and so *given* the demand curve and a target price floor, the authority must control supply. As the world price of sugar is much lower than the support price, a trade policy aimed at quantity restrictions on imports must be a component of the overall support program. However, because the U.S. commitments under the WTO require that a certain quantity of imports is allowed to enter the U.S. market, the free variable from the authorities' perspective becomes the level of domestic supply.

Now assume that the various quantities have been determined, and cane is ready for harvesting at the end of the growing cycle. At this point, supply to the U.S. market is very inelastic, as discussed in regard to figures 3 and 4. Point one is now brought to light – as domestic producers do not export sugar, and as foreign producers (a) have alternative markets, (b) know that the U.S. has obligations that require it to import sugar and (c) that these obligations are country specific at this time as they are entrenched in the U.S., quota allocations under the TRQ regime, it is in the power of importers to move the domestic price by restricting supply and sending their sugar elsewhere. They would certainly receive a lower price in other markets, but they also face a quite inelastic demand schedule in the U.S., so their net revenue position is unclear. It is true that doing this may jeopardise their future TRQ allocations, and so a game (in the economic sense) is being played.

The outcome of this is that foreign suppliers accrue rents on all units of imports up to the quota boundary *even if they do not reach the constraint*. Thus, if one foreign supplier delivers less than their total quota allocation, they still receive the U.S. market price of at least P_s , but probably more. In figure 10, the current U.S. situation is depicted by demand curve 2, but the 3 demand curves of figure 1 are again applied for comparative purposes.

With D_1 , imports are in-quota at M_1 , generating tariff revenue $fk lv$ (the *ad-valorem* equivalent rate) and total rents at the support price of $kopl$. As a reminder, the *ad-valorem* equivalent tariff rate is a function of the CIF price of imports, which in this example is equal to the LDP price (P_s for D_1) minus the tariff, or pb minus lg . In figure 1, D_1 generated an outcome measured against import quantity M_1' and LDP price P_{US1} , involving more tariff revenue (by area $lghm$) and no rents.

Given schedule D_2 , the level of demand is sufficient to fill the quota and generate a second-tier rent above the support price at a market price of P_{US2} . Tariff revenue reaches an in-quota maximum of $fk ni$ while the total rent $krsn$ is now comprised of two parts, the maximum possible first-tier rent $kopn$ plus a second-tier rent of $orsq$. In MONASH-USA, the two rents are modelled separately, with the second-tier taking the form of a complementarity, and as the value of *total* rents is determined by (in the language of Pearson) a "piece-wise linear function" (explained below), these are modelled using a technique that relies on the MAX and MIN equivalency of complementarity relationships that was briefly outlined above (again, discussed below).

Demand schedule D_3 is not affected by the different focus taken here.

Point 7 above (quota administration by proportional historical allocation) raises an issue that can potentially lead to errors in the modelling of policies like the U.S. support program for sugar if not

addressed. In a more general approach like that in Pearson and Elbehri (2000), import sources are implicitly treated as distinct suppliers for quantities up to and including the quota boundary. One foreign supplier can then be supplying in-quota and not be accruing rents while another is on the quota boundary and is accruing rents. This means that the two sources of supply are treated as comprising distinct commodities that cannot be easily substituted for one another. Consider the following thought experiment:

Take a multi-country TRQ allocation like that in the U.S., but assume for this example that there are only two suppliers. Suppose that supplier 1 – let’s say Brazil – is on-quota and deriving rents, while supplier 2 – let’s call this one Australia – is in-quota and receiving the world price, supplying 10 metric tons less than its quota allocation. From the U.S. point of view, this is a sub-optimal outcome that can be improved by doing the following – reducing its imports from Brazil by (let’s say) 5 metric tons and increasing the imports from Australia by 5 metric tons. The total level of imports does not change, but now *all* sugar is imported in-quota at the world price, saving the U.S. the value of the rents it formerly paid to Brazil. This adds to the argument made above that all sugar imports must enter the U.S. at the same price, regardless of whether or not a particular foreign supplier is filling its quota allocation.

4.4.2 Simulating the Sugar Program in MONASH-USA

This section describes relatively briefly, how the TRQ theory discussed above is embedded in MONASH-USA, as mentioned earlier, a more comprehensive description is available in a Centre of Policy Studies working paper⁷. The equations are discussed in the order they appear in the MONASH-USA TABLO file. The commodity and industry set dimensions are suppressed in this paper, as to include them would only add clutter without providing any useful information. Keep in mind, as mentioned above, that the equations below are applied to variables that are defined across the set TRQCOM in MONASH-USA, which includes raw sugar, refined beet sugar and refined cane sugar. Using this approach (defining a subset of COM to apply these expressions to) allows easy future additions to the TRQCOM set, and plans are already in place to add the necessary data to allow dairy, beef and other U.S. commodities governed by TRQs to this subset.

The first tier rent is a simple function of the gap between the support price and the foreign cost of sugar production from region r in foreign currency, $MC^{dc,r}$ inflated by a freight and insurance margin for region r in foreign currency, $M_{FI}^{fc,r}$, and adjusted by the U.S. exchange rate with region r , e^r ,

$$MC^{dc,r} = \frac{MC^{fc,r} (1 + M_{FI}^{fc,r})}{e^r}. \quad (5)$$

$MC^{dc,r}$ and $M_{FI}^{fc,r}$ are read into the model from data. Depending on the region in question, this variable can vary with the level of supply in MONASH-USA. The margin, amongst other modelling benefits, implies the notion of “economic distance”, as opposed to geographical distance – for example, while Australia is about as far from the United States as one can get, the transport margins are quite competitive on Australian sugar due to the direct shipping route across the Pacific and the fact that the large cargo ships involved move sugar at a relatively low cost-per unit compared to (for example) rail transport.

⁷ See Winston (2005).

For a given r , the *power* (i.e. the rate plus 1) of the first-tier rent for region r is then given by

$$(1 + \phi^{1,r}) = \frac{P_s}{MC^{dc,r}}. \quad (6)$$

The support price is read into the model from data, and is a naturally exogenous policy variable.

The calculation of the second-tier rent involves making use of a true complementarity relationship between the quantity of imports and the value of the rent. The method used here owes much to Elbehri and Pearson (2000), with some added extensions. The complementarity relationship required for the second-tier rent sets the value of the power (1 plus the rate) at 1 when imports are in-quota, and at some number greater than 1 *but* less than $(1 + \hat{\phi}^{2,r})$ when imports are on quota. Furthermore, when imports go over-quota, the value of the *rate* of the rent is fixed at $\hat{\phi}^{2,r}$. You will notice that this defines a three-state complementarity like that described by expression (2) above with an upper bound of $(1 + \hat{\phi}^{2,r})$ and a lower bound of 1. As the “expression” component of the complementarity relies on its value being “less than”, “equal to” or “greater than” zero, *and* as GEMPACK prefers the absolute value of the components of the complementarity to be between 0 and 5, the expression is defined as

$$EXP = 1 - \left\{ \frac{M^r}{Q^r} \right\}. \quad (7)$$

The value of Q^r and the initial value of M^r are read into the model from data, and the ratio is calculated by formula.

Expression (7) needs to be applied with some caution. When imports are in-quota, the expression takes a value greater than zero, when on-quota is equal to zero, and when over-quota is less than zero, all at orders of magnitude very likely to be in the right range⁸. The danger is that it can potentially allow, via the complementarity expression, the values of rents and CIF prices for individual *regions* to move independently with regard to each other if the nesting at the regional level involves substitution elasticities between regions in the relevant CRESH nest that are too low. This then leads to the situation, discussed above, where one region could be in-quota and receiving no rents, while another is on-quota and is accruing rents, implying that imports from different regions would be entering the U.S. at different CIF prices. This makes no sense for a relatively homogeneous commodity like (a particular grade of) raw sugar.

The complementarity expression can be reformulated here as

$$1 \leq (1 + \phi^{2,r}) \leq (1 + \hat{\phi}^{2,r}) \perp \left\{ 1 - \frac{M^r}{Q^r} \right\} \quad (8)$$

⁸ In fact, only when imports are 6 or more times larger than the quota is this violated, which is unlikely to happen while a quota boundary and TRQ policy is in place.

such that

$$\text{Either} \quad (1 + \phi^{2,r}) = 1 \quad \text{and} \quad 1 > \frac{M^r}{Q^r} \quad [\text{state 1}]$$

$$\text{or} \quad 1 < (1 + \phi^{2,r}) < (1 + \hat{\phi}^{2,r}) \quad \text{and} \quad 1 = \frac{M^r}{Q^r} \quad [\text{state 2}]$$

$$\text{or} \quad (1 + \phi^{2,r}) = (1 + \hat{\phi}^{2,r}) \quad \text{and} \quad 1 < \frac{M^r}{Q^r}. \quad [\text{state 3}]$$

The technical details of this implementation in GEMPACK can be found in Winston (2005). The detail of the GEMPACK method and sub-routines are available in chapter 16 of the GEMPACK documentation and Harrison *et al* (2001).

The value of $(1 + \hat{\phi}^{2,r})$ is a function of the in-quota and over-quota powers of the tariff. The complementarity could, of course, have been specified using a lower bound of zero and an upper bound of $\hat{\phi}^{2,r}$ for variable $\phi^{2,r}$, but the implementation in MONASH-USA of these relationships uses the powers of the rents. This rules out values that pass through zero (which can create numerical problems), and allows the variables in the model to be related via multiplicative relationships, as, for example, in the definition of $(1 + \hat{\phi}^{2,r})$ (outlined below). The actual power of the second-tier rent, $(1 + \phi^{2,r})$, is calculated by the complementarity expression⁹. As demand expands while the level of imports is on the quota boundary, the value of $(1 + \phi^{2,r})$ increases until it reaches $(1 + \hat{\phi}^{2,r})$. An initial value for $(1 + \phi^{2,r})$ is read into the model from data.

The linkages between $(1 + \phi^{2,r})$ and the rest of the MONASH-USA equation system begins with defining a power of the total rent premium, denoted

$$(1 + \phi^{TOT,r}) = (1 + \phi^{1,r})(1 + \phi^{2,r}) \quad (9)$$

and a CIF import price,

$$P_{cif}^r = P_s (1 + \phi^{2,r}). \quad (10)$$

Next, the powers of *ad-valorem* equivalent rates of the excise tariffs are calculated: Firstly for the in-quota rate.

⁹ See Winston (2005).

$$(1 + t_i^{e,r}) = \left\{ 1 + \frac{t_i^r}{P_{cif}^r} \right\} \quad (11)$$

and then for the over-quota tariff,

$$(1 + t_o^{e,r}) = \left\{ 1 + \frac{t_o^r}{P_{cif}^r} \right\}. \quad (12)$$

The value of the upper bound on the complementarity expression for $(1 + \phi^{2,r})$ can now be defined as

$$(1 + \hat{\phi}^{2,r}) = \frac{(1 + t_o^{e,r})}{(1 + t_i^{e,r})}. \quad (13)$$

Next, a the power of the total price-wedge, denoted $(1 + w^r)$, is defined to explain the gap between $MC^{dc,r}$ and the basic price of import to the domestic user,

$$(1 + w^r) = (1 + t_i^{e,r})(1 + \phi^{TOT,r}). \quad (14)$$

When the level of imports is in-quota, expression (14) becomes

$$(1 + w^r) = (1 + t_i^{e,r})(1 + \phi^{1,r}), \quad (15)$$

while once imports have started entering the U.S. over-quota, this equals

$$(1 + w^r) = (1 + t_i^{e,r})(1 + \phi^{1,r})(1 + \hat{\phi}^{2,r}), \quad (16)$$

which, according to expression (13) is equal to

$$(1 + w^r) = (1 + t_o^{e,r})(1 + \phi^{1,r}). \quad (17)$$

This, when the model determines that the level of imports has gone over quota, the price wedge between $MC^{dc,r}$ and the landed duty paid price reaches a maximum.

The basic price of the imported good to the domestic user (the landed duty-paid price) denoted P_{ldp}^r , is

$$P_{ldp}^r = P_{cif}^r (1 + t_i^{e,r}). \quad (18)$$

Combining expressions (6), (10), (13), (14) and the complementarity relationship defining $(1 + \phi^{2,r})$, the value of P_{ldp}^r can be divided into three potential states: Firstly, when the level of imports is in-quota, we obtain

$$P_{ldp}^r = MC^{dc,r} (1 + \phi^{1,r}) (1 + t_i^{e,r}) = P_s (1 + t_i^{e,r}); \quad (19)$$

when the level of imports is on-quota, we have

$$P_{ldp}^r = MC^{dc,r} (1 + \phi^{1,r}) (1 + \phi^{2,r}) (1 + t_i^{e,r}) = P_s (1 + \phi^{2,r}) (1 + t_i^{e,r}), \quad (20)$$

with $(1 + \phi^{2,r})$ varying between 1 and $(1 + \hat{\phi}^{2,r})$; and, finally when the level of imports goes over-quota, the landed duty-paid price is

$$P_{ldp}^r = MC^{dc,r} (1 + \phi^{1,r}) (1 + \hat{\phi}^{2,r}) (1 + t_i^{e,r}) = P_s (1 + \hat{\phi}^{2,r}) (1 + t_i^{e,r}) \quad (21)$$

which, by introducing (13), can be rewritten as

$$P_{ldp}^r = P_s (1 + t_0^{e,r}). \quad (22)$$

The value of P_{ldp}^r is the price variable that enters the CRESH nest determining the choice of regional source, and the higher-level Armington nests that determine the choice of domestic and imported varieties of this good. In our case, with the focus on sugar, both the regional-substitution and Armington elasticities are set relatively high. This ensures that the theory we developed above is appropriately captured in the model's behaviour: At the regional-source level, a high substitution elasticity ensures (as mentioned briefly above) that when the level of a given region's supply hits the quota boundary, any tendency in its LDP price to increase via the complementarity expression and $(1 + \phi^{2,r})$ will cause a large degree of substitution away to other sources that are still in-quota, and thus stop the second-tier rent from increasing. In the Armington nest, a high Armington elasticity ensures that the domestic and imported varieties are seen as very close substitutes, implying that domestic and foreign suppliers are facing the same demand schedules and prices in the domestic market for sugar.

Next, the calculation of the total value of rents is dealt with. Firstly, some background.

When imports are in the range between zero and the quota boundary, the first-tier rent $\phi^{1,r}$ is accrued by the supplier at a constant rate per unit. The function that describes this component of total rents is a relatively simple linear function,

$$TVR_{IQ}^r = \bar{\phi}^{1,r} MC^{dc,r} M^r, \quad \forall M^r < \bar{Q}^r. \quad (23)$$

where TVR_{IQ}^r denotes the total value of rents for region r while in-quota. In this case, the value of the rent per-unit of imports is fixed and the value of imports itself is variable. When imports are on-quota, there is a second component of the total value of rents. Now the function becomes

$$TVR_{OQ}^r = (\bar{\phi}^{1,r} + \phi^{2,r}) MC^{dc,r} \bar{Q}^r. \quad (24)$$

There are now two fixed values – the level of imports (set at the quota level) and the first-tier rent, while the second tier rent varies along the quota boundary, taking a value between 0 and $\hat{\phi}^{2,r}$. When imports have exceeded the quota volume, TVR_{IQ}^r reaches a maximum as the value of the second-tier rent reaches a maximum. This defines a piece-wise linear function with variables that switch between being endogenous and exogenous.

To capture this set of relationships accurately in MONASH-USA, a complementarity based on the equivalence of a MIN function is used. Firstly, define an expression for calculating the value of total rents up to the point just before imports go over-quota, denoting the variable as TVR_1^r ,

$$TVR_1^r = \phi^{TOT,r} MC^{dc,r} M^r, \forall M^r. \quad (25)$$

Next, define an upper bound for the *rate* of the rents captured in the brackets of (24). As these are modelled as powers in MONASH-USA, the expression for this upper bound, denoted Φ_{UB}^r , is

$$\Phi_{UB}^r = \left[(1 + \phi^{1,r}) (1 + \phi^{2,r}) \right] - 1. \quad (26)$$

Thirdly, define an expression for upper bound on the total value of the rents, found by combining the idea of (24) with (26) to create

$$TVR_2^r = \Phi_{UB}^r MC^{dc,r} Q^r. \quad (27)$$

What is now required is a way to choose the expression – from equations (25) and (27) – that generates the *minimum* value for any given value of M^r in (25). Thus, we need an expression like

$$TVR^r = \text{MIN} \{ TVR_1^r, TVR_2^r \}. \quad (28)$$

where denotes the correct value of total rents. Recall that this relationship can be re-written as

$$TVR^r - TVR_1^r = \text{MIN} \{ 0, TVR_2^r - TVR_1^r \}. \quad (29)$$

Therefore, we can define an expression for a variable, denoted Z^r , for the left hand side of (29),

$$Z^r = TVR^r - TVR_1^r \quad (30)$$

and then define a complementarity relationship

$$Z^r \leq 0 \quad \perp \quad Z^r - (TVR_2^r - TVR_1^r). \quad (31)$$

This is a two-state complementarity with an upper bound of zero on Z^r . According to this relationship,

$$\text{Either} \quad Z^r < 0 \quad \text{and} \quad Z^r - (TVR_2^r - TVR_1^r) = 0 \quad [\text{state 2}]$$

$$\text{or} \quad Z^r = 0 \quad \text{and} \quad Z^r - (TVR_2^r - TVR_1^r) < 0. \quad [\text{state 3}]$$

This chooses the correct expression for total rents from (25) and (27) via equation (30) as follows: Begin by subtracting TVR_1^r from TVR_2^r to obtain the following expression -

$$TVR_2^r - TVR_1^r = MC^{dc,r} \left[\Phi_{UB}^r Q^r - \phi^{TOT,r} M^r \right]. \quad (32)$$

When the level of imports is either in-quota or on-quota, we know that $\phi^{TOT,r} < \Phi_{UB}^r$ and $M^r \leq Q^r$. Therefore, we know from (32) that $TVR_2^r > TVR_1^r$. When the level of imports is over-quota, $\phi^{TOT,r} = \Phi_{UB}^r$ and $M^r > Q^r$, implying via (32) that $TVR_2^r < TVR_1^r$. It is also true that TVR^r can only be equal to TVR_1^r or TVR_2^r . By a process of elimination, we can now see how the choice of expression with which calculate rents will work:

Assume that $TVR_2^r > TVR_1^r$, implying that imports are on- or in-quota. In this case, if TVR_2^r was incorrectly chosen to inform TVR^r , then both of $Z^r > 0$ and $Z^r - (TVR_2^r - TVR_1^r) = 0$ are true, which is ruled out. This forces Z^r to its upper bound, zero, meaning that, via expression (30), it must be true that $TVR^r = TVR_1^r$. This correctly enforces the choice of TVR_1^r as the relevant expression, which means that both of $Z^r = 0$ and $0 - (TVR_2^r - TVR_1^r) < 0$ are both true. The conditions for state 2 are satisfied.

Assume that $TVR_2^r < TVR_1^r$, implying that imports are over-quota. If TVR_1^r was incorrectly used to inform TVR^r , the complementarity expression would be positive - i.e. we would have $Z^r = 0$ and $0 - (TVR_2^r - TVR_1^r) > 0$, a situation ruled out by the complementarity relationships. Therefore, when $TVR_2^r < TVR_1^r$ is true, $TVR^r = TVR_1^r$ can *not* also be true. If, on the other hand, it is true that TVR^r is informed by TVR_2^r , equation (30) determines that $Z^r < 0$ and the complementarity expression becomes $TVR_2^r - TVR_1^r - (TVR_2^r - TVR_1^r) = 0$, which satisfies state 3 of the complementarity.

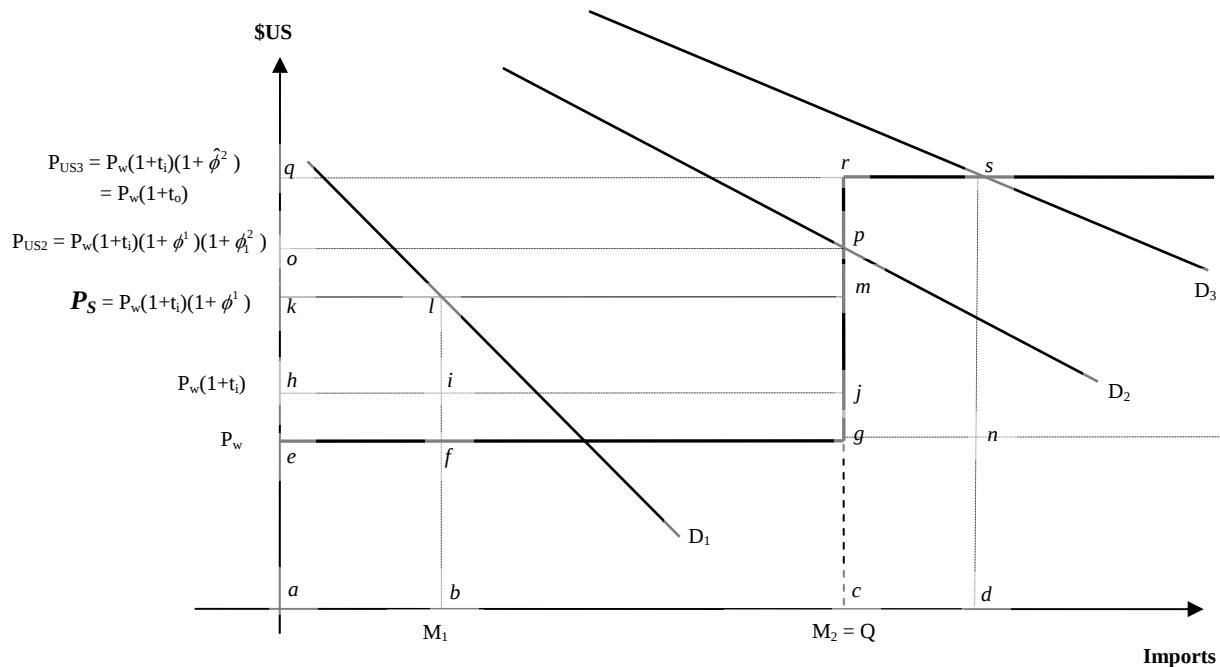
The total value of rents from a macro perspective can now be calculated as a sum across the regional dimension r of TVR^r ¹⁰. To take account of the transfer of rents to the foreign suppliers, this term is added to the current account as a transfer from the U.S. residents to foreigners. This approach allows an accurate calculation of rents at both the regional-source level and at the aggregate level, and thus enables a true welfare analysis to be conducted with MONASH-USA.

Finally, an equation is added to calculate tariff revenue. Two approaches were developed for this task:

The first used a similar method to that applied to calculating rents at the regional-source level above, where a two-state complementarity relationship is defined for a piece-wise linear function, and (in this case) a MAX function approach is used. This is explained in detail in Winston (2005).

The second approach takes advantage of some data generated by MONASH-USA that may not always be available in other applications. This method has the benefit of being relatively simple, and is due to an excellent suggestion by Ken Pearson and earlier work in Elbehri and Pearson (2000).

Figure 11



In figure 11, the total LDP value of imported sugar is calculated as $aklb$ in-quota (for D_1), $aopc$ on-quota (for D_2) and $aqsd$ over-quota (for D_3). This is made of a value calculated at the world price and a

¹⁰ In application, total rents are calculated by also summing across the set TRQCOM which, as mentioned, has been suppressed in this discussion.

“wedge” given by the sum of rents and tariff revenue. The total “wedges” are $eklf$ for D_1 , $eopg$ for D_2 and $eqsn$ for D_3 . Total rents in each case are $hkli$, $hopj$ and $hqrj$ respectively. These values are calculated by the equations discussed above and by other expressions already present in MONASH-USA. In each case for the respective demand curves, subtracting total rents from the “wedge” leaves an area of tariff revenue: $ehif$ in-quota, $ehjg$ on-quota, and $ehjg$ plus $grsn$ over-quota (again remember that these tariffs are excises or *ad-valorem* equivalents of excises with a denominator that varies with the CIF price, and so where they are placed on the graph is only important to the extent that they reflect the correct quantities). Thus, an equation is added to the model that simply subtracts the total value of rents from the “wedge”, generating the value of tariff revenue.

5 Two Illustrative Simulations

Refer to handout.

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