SESSION X

DYNAMIC MODELING OF TRADE LIBERALIZATION

Modeling Trade Policies and U.S. Growth: Some methodological issues.

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ABSTRACT

Most analyses of trade policies are now done using dynamic numerical models. These intertemporal equilibrium models have proven very useful in discussing the link between policy and growth. There are, however, many difficult methodological issues that must be confronted in implementing such models, problems that are absent in traditional static models. We discuss these implementation issues and present our approach in dealing with some of them. We report the result of simulating the elimination of tariff and nontariff barriers in the U.S. to illustrate the effects of considering dynamic effects. We also report how different parameter values may affect the estimates of output and welfare.

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Our work has many collaborators but we must mention especially Peter Wilcoxen.

1. Introduction

The continual negotiations over trade liberalization among countries have prompted a large amount of applied research on the impact of changes in trade policies. Traditional approaches to this issue have been purely static.[1] These approaches ignore the effects of trade policy on capital formation and productivity growth.

Recent work has focused on dynamic modeling of the economy. These include Baldwin (1992), Goulder and Eichengreen (1992), Keuschnigg and Kohler (1994), the G-cubed model (McKibbin and Wilcoxen 1995), and Bohringer, Pahlke and Rutherford (1997). In Ho and Jorgenson (1994) we presented a model for analyzing the effect of trade liberalization on U.S. economic growth. All these models combine intertemporal modeling with detailed disaggregation by commodities (and often by regions) and thus capture the impact of trade policy on imports and exports, the sectoral composition of output, and capital formation. (The main feature that distinguishes our approach is that we utilize all the data available during the sample period rather than a single data point in calibrating our model.)

In Ho and Jorgenson (1994), for example, we reported that if tariffs in the U.S. and rest of the world had been eliminated in 1980, U.S. consumption of goods and services would have risen by only 0.16 percent in the first year. This is similar to the results of static analysis in Deardorff and Stern (1986) and Whalley (1985). However, consumption would have been 0.82 percent higher in the long run. The mechanism underlying this substantial growth in consumption is that trade liberalization reduces the price of capital goods relative to other prices. This leads to an increase in investment and more rapid growth of capital, thereby expanding both output and consumption. If the most significant quantitative restrictions had been eliminated along with tariffs in 1980, the consumption of goods and services would have been 1.08 percent higher in the long run, compared to a first year increase of only 0.36 percent. The difference over time is due to the impact of trade liberalization on U.S. capital formation and productivity growth.

Our results are fairly typical of those generated by intertemporal equilibrium models. Like static models the results here depends on the functional forms used. However, they confront a further difficulty that the results are also affected by the dynamic specification and projections of the exogenous variables. As we show, numerous assumptions have to be made, many of which appear wrong to the most casual observer.

In this paper we examine the methodological issues of dynamic modeling of trade impacts, whether with a one-country model or with a multi-region one. We then discuss our model's approach to some of these problems and briefly summarize our previous results. Rather than focusing on specific estimates of the effects of policy shocks we discuss how sensitive the results are to alternative specifications and assumptions, and to the use of different parameter values.

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[1] The first of these is based on detailed partial equilibrium models, such as that of Hufbauer, Berliner, and Elliot (1986). The second approach uses multi-country general equilibrium models, such as the "Michigan Model" of Deardorff and Stern (1986) and the world trade model of Whalley (1985).

2 Issues in numerical dynamic models.

The importance of considering dynamic aspects in general equilibrium modeling is now well known. It allows a more flexible specification of expectations, it provides a transition path, and it makes clear the link between adjustment specification and the speed of adjustment. Current investment, and hence the structure of the economy, can react to expectations of future policies.

When modelers turn these ideas into numerical models many assumptions regarding the dynamic specification have to be made. Second, the immense data requirements for a detailed specification of a dynamic model are very daunting. We shall discuss here the specification issues that all builders of dynamic models face.[2] We divide our comments into three parts -- production, consumer behavior, and trade modeling.

2.1 Modeling production over time

We write the output of sector j in period t as:

$$Q_{jt} = f(KD_{jt},\ LD_{jt},\ M_{jt},\ t) \qquad (1)$$

where $KD_{jt},\ LD_{jt}$ are the capital and labor input demands, and M_{jt} is intermediate input. First, let us consider constant returns to scale models. Many such models employ a Harrod-neutral specification where productivity growth comes from labor augmenting technical change. That is, the production function is written as $f(KD_{jt}, \lambda_t N_{jt},\ M_{jt})$ where N is the number of hours worked and λ_t is the index of labor effectiveness. Such a specification is employed, for example, in the G-cubed model.

Harrod-neutrality implies that factor shares change only when prices change. However, many of the movements in input shares over time cannot be explained by price movements alone. Figure 1 illustrates this problem for a typical industry in the U.S., Primary Metals.[3] The top graph gives the value ratio of energy to labor input, while the bottom graph gives the (log) ratio of the price of energy to the price of labor. The rapid rise in real wages in the postwar period is not accompanied by any significant change in the energy:labor value ratio, while the oil shocks did lead to a change. (For a more detailed discussion see Jorgenson, Gollop and Fraumeni (1987) Chap. 7). Simulations over the historical period using a Harrod-neutral form will therefore miss these changes. For simulations of the future, non-neutral production functions are required. Only if there will be no change or the change is completely random can a neutral form be used.

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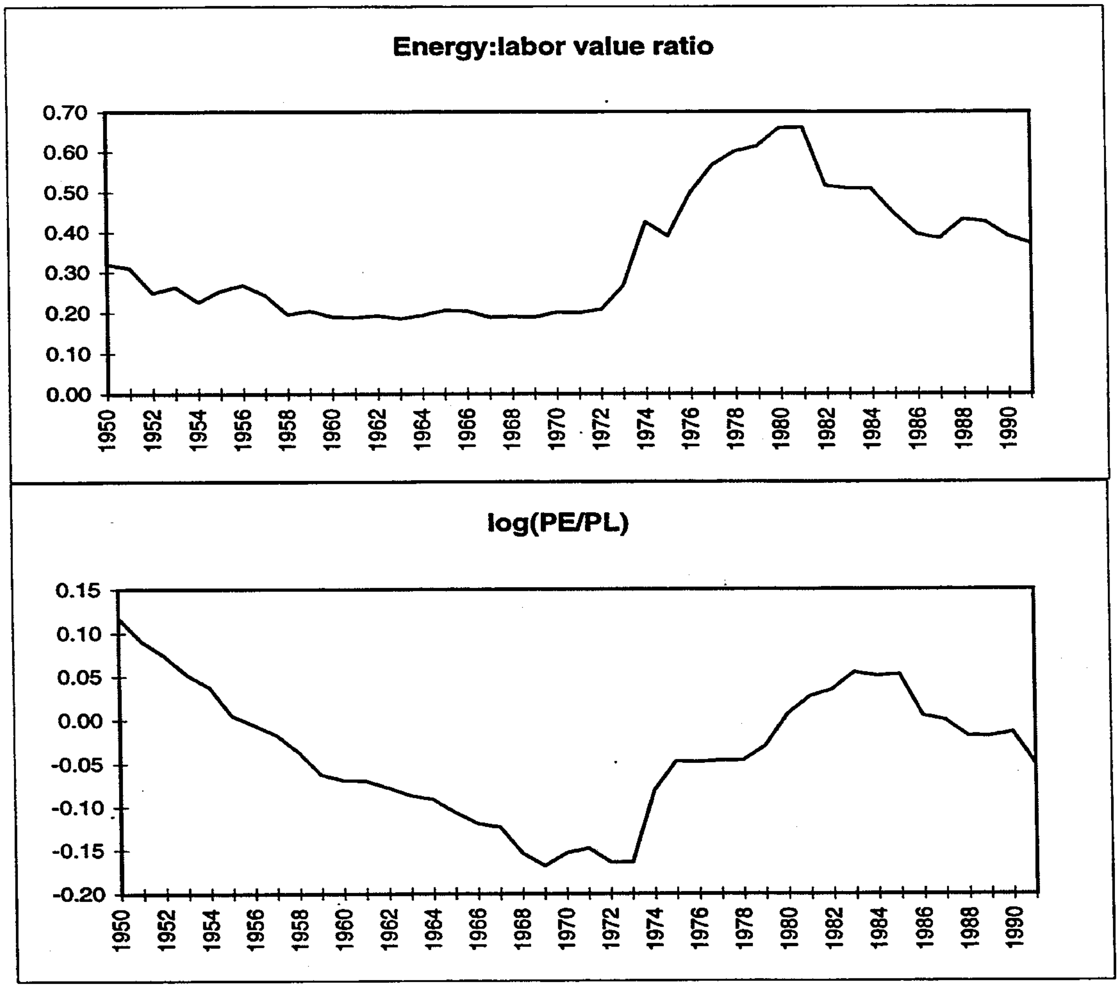
[2] The complete model is presented in a technical appendix available on request from the authors.
[3] The construction of our data is described in the Appendix.

Fig. 1 Factor inputs and their prices for a typical industry



If it is decided to use nonneutral production functions then one must choose the exact formulation. The typical form used in empirical work contain linear and quadratic time terms. (See Diewert and Wales 1987 for a discussion of flexible functional forms.) A typical cost function, like the translog or Generalized McFadden, have the form:

$$cost(t) = \alpha_0 + f_1(p) + f_2(p'p) + f_3(p)t + \alpha_1 t + \alpha_2 t^2 \qquad (2)$$

where p is the input price vector and t denotes time as the index of the level of technology. $p'p$ denotes the second order price terms. In the case of the translog, for example, the value shares in input factors (v_t) derived from the above cost function is:

$$v(t) = f_1^{/} + f_2^{/}(p) + f_3^{/} t \qquad (3)$$

The problem of using such a formulation in an infinite horizon model is obvious. The value shares would diverge to plus or minus infinity unless $f_3^{/}$ is zero (which implies neutral technical change). What is reasonable for estimation over a given sample period is unusable for dynamic models. The implementation of nonneutral technical change must therefore be done with nonstandard functional forms.

In our model we deal with this problem by modifying the standard translog and using a logistic time trend instead of a quadratic. That is, the *t* term above is replaced by a logistic $g(t)$. The coefficient on the price times time term gives the magnitude and direction of the bias. This bias gradually disappears over time. That is, a well defined steady state requires neutral technical change in the long run. Our functional form thus allows biased change in the near term and also satisfies this steady state requirement.

Other forms that allow for such flexibility may of course be used. Such flexibility, however, comes with a cost. The difficulty of estimating such highly parameterized forms are discussed in the econometric literature. (Diewert and Wales 1987). The first difficulty is that time series of output and inputs are required as opposed to a single input-output table. Secondly, numerical models require that production or cost functions have the appropriate curvature. Such curvature may not be produced in unconstrained estimation of the data.

A distinct but related problem is estimating the rate of technical progress. In eq. 2 this corresponds to the terms involving α_1 and α_2. The formulation in (2) produces continual technical progress (or regress). If these functions are estimated separately for the different industries then the different estimates of the α's will cause relative prices to diverge. This is not consistent with a steady state. The long run rate of technical progress must be equal across sectors. In our formulation we express the time term as a logistic function, $\alpha_1 g(t) + \alpha_2 g^2(t)$. This gives us a common long run growth rate of zero while allowing the current rates of technical progress be different across sectors.

In models where there is costly adjustment of capital the econometric difficulties are compounded by the lack of data on the value of "q" (value of installed versus uninstalled capital). Such models have therefore resorted to using a priori plausible values of the adjustment parameter instead of estimating it.

These problems are magnified manifold if one wishes to incorporate economies of scale or learning-by-doing. Modeling scale economies and investment over time in a oligopolistic environment is so complex that strong assumptions have to be employed. Keuschnigg and Kohler (1994) is one of the few efforts at this, and they assume that firms engage in monopolistic competition and capital is mobile across all the firms in each industry. Their degree of returns to scale is taken, not from cost functions, but from engineering estimates.

2.2 Consumption, Engel curves and the steady state.

We next discuss the demand for goods and then turn to the demand for leisure and savings. Flexible modeling of household demand for commodities is akin to modeling production under scale economies and biased technical change. It is well known that Engel curves are not linear, that is, expenditure on some goods rise less than proportionally with income while other goods are income elastic.[4]

Most multisector models use simple Cobb-Douglas or LES formulations calibrated to some base year. This includes both Goulder-Eichengreen and some versions of G-cubed. These have unit income elasticity and would be unsuitable for "backcasting" or simulations over the historical period given this observed non-homotheticity.

Empirical work on commodity consumption functions have mostly ignored secular trends and attribute all nonprice changes to income effects. (In the language of production functions this means allowing for scale economies or diseconomies but no technical change.) An example of such estimates is Jorgenson and Slesnick (1987) which is incorporated into our model. In that paper the income elasticity for Food is estimated at 0.8, for Capital 1.0, and for Services 1.3.

Ignoring this feature of consumer behavior would bias the sectoral projections of the economy. The effects of policy shocks that change not just prices but incomes also, will not be captured by usual homothetic models. To illustrate the magnitude of this effect consider a policy shock that changes prices by 5% and incomes by 1%. Say that in a homothetic model this leads to a 5% quantity change due to price effects and a 1% change due to income effects. Using our estimates of the income elasticities the gap between Food and Services would then be off by 0.5%, that is, an error of about 0.5 out of 6.

Allowing for nonhomothetic demands, however, produces a long run problem similar to the biased technical change issue described above. If incomes rises to infinity due to exogenous productivity growth or endogenous growth, as in many models, then the demand for some commodity will vanish to a zero share and the demand for the most elastic commodity will rise to a 100% share. This is clearly unacceptable and there are two ways of dealing with it. One is to have a consumption function that approaches homotheticity. Another is to have zero long run productivity, and hence income, growth. In

[4] This problem may be quite difficult. There is some evidence that the demand curves are of rank three, i.e. the curves need more than a quadratic term to fit well. (See Lewbel 1991 for estimates using U.S. data.)

our model we have chosen the second option, that is, we preserve the functional form in Jorgenson and Slesnick (1987) and the long run productivity growth is set to zero.

Labor and savings

Many of the numerical dynamic models in use, including ours, feature endogenous labor supplies and endogenous savings. To make this tractable the following specification, or something very similar, is used for aggregate household utility in all the dynamic models cited above :

$$U = \sum_{t=0}^{\infty} \frac{F_t^{\sigma}}{(1+\rho)^t} \tag{4}$$

$$F_t = F(CC_t, LEIS_t)$$

$$CC_t = CC(C_{1_t}, C_{2_t}, \cdots C_{nt})$$

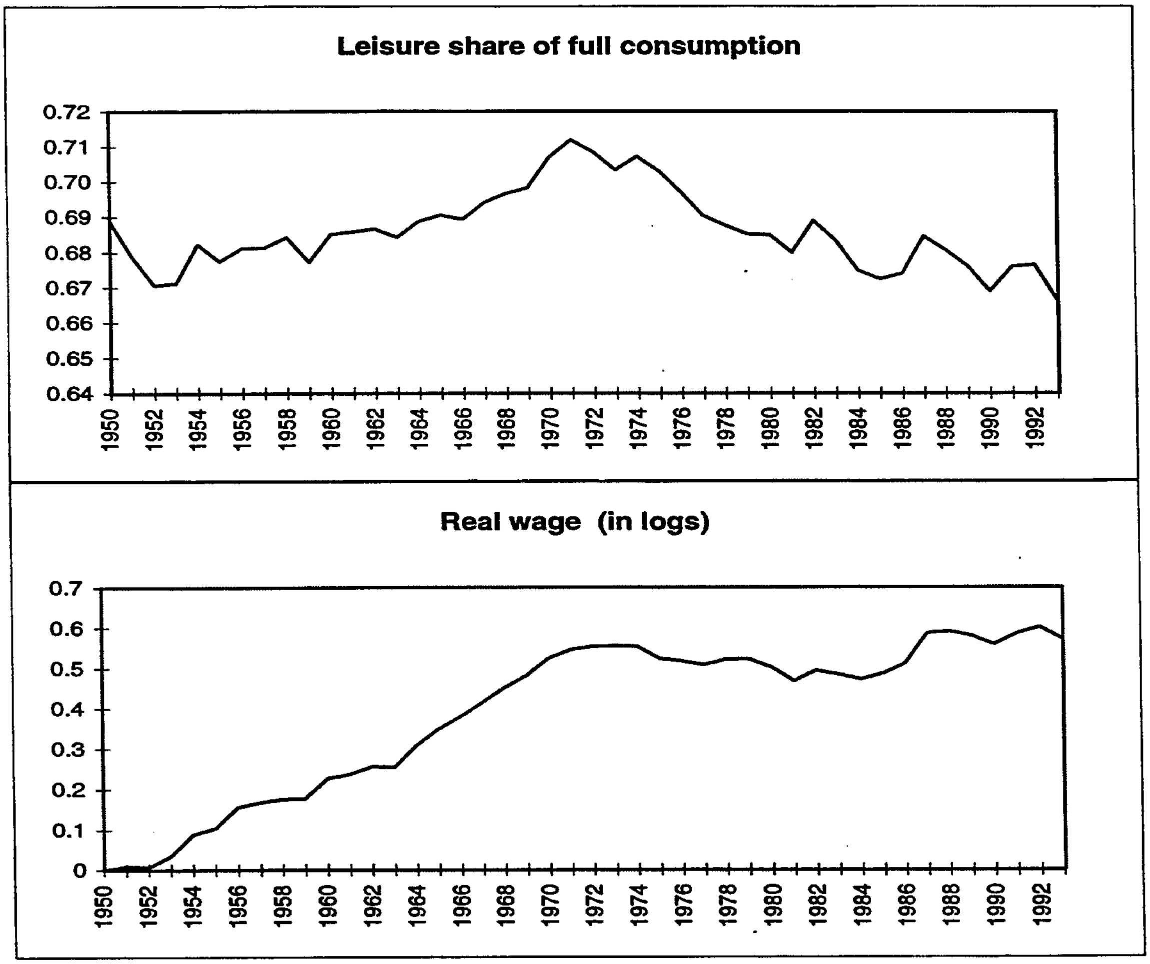
where F_t is full consumption and ρ is the rate of time preference. Full consumption is a function of leisure and a commodity aggregate *(CC)*. The commodity aggregate is a function of the separate commodities (C_{it}) .

Unlike some static models which have disaggregated income classes or labor groups, all the infinite-lived models assume an aggregate household as in the theoretical literature. The above formulation means that consumption is assumed to be separable over time despite evidence to the contrary. (See Browning and Lusardi 1996 for a survey). An exception is the G-cubed model which incorporates liquidity constraints. It also assumes that commodities and leisure are separable. This is rejected by some empirical work, e.g. Browning and Meghir (1991).

Even if we are willing to ignore these rejections of the standard model at both the household and aggregate levels, implementing the above simple system in a numerical model still presents some difficulties. Writing leisure demand (or labor supply) in the above manner implies the existence of an aggregate labor supply curve. However, much of the empirical labor literature estimates labor supplies by demographic groups, e.g. prime age males, married women, and so on. Most do not test that the elasticities of the different groups are different.

What then should one put as the elasticity of labor supply in the aggregate function? Furthermore, how should one treat the secular trends in hours worked? To illustrate this problem Figure 2 plots the value share of leisure in full consumption and the price of leisure over time in the U.S. The value of leisure is defined as the after tax wage multiplied by the nonwork hours of all working age residents.

Fig. 2 Aggregate Leisure and wages in the U.S.



There are two trends in the U.S. labor supply. First we have the reduction in work hours in the immediate postwar period. Secondly, there is the rise in female participation rates after 1971. The first trend was accompanied by a rapid rise in real wages, the second had a relatively flat wage. Such data could obviously not be explained by a simple aggregate labor supply function. One could disaggregate the data into demographic groups but even this would not be able to capture the secular trend in female labor supply.

The approach that we chose to retain an aggregate labor supply equation and yet be able to track the historical data is to add a time term in the full consumption function. Again we choose a logistic form for the time function so that there is no long run change. In conclusion, existing empirical work on labor supply which concentrate on cross sectional data is not suitable for direct use in dynamic models. The changing behavior of different cohorts have to be taken explicitly into account. Modelers have to take care in interpreting the labor supply elasticities from the empirical literature.

2.3 Modeling trade over time.

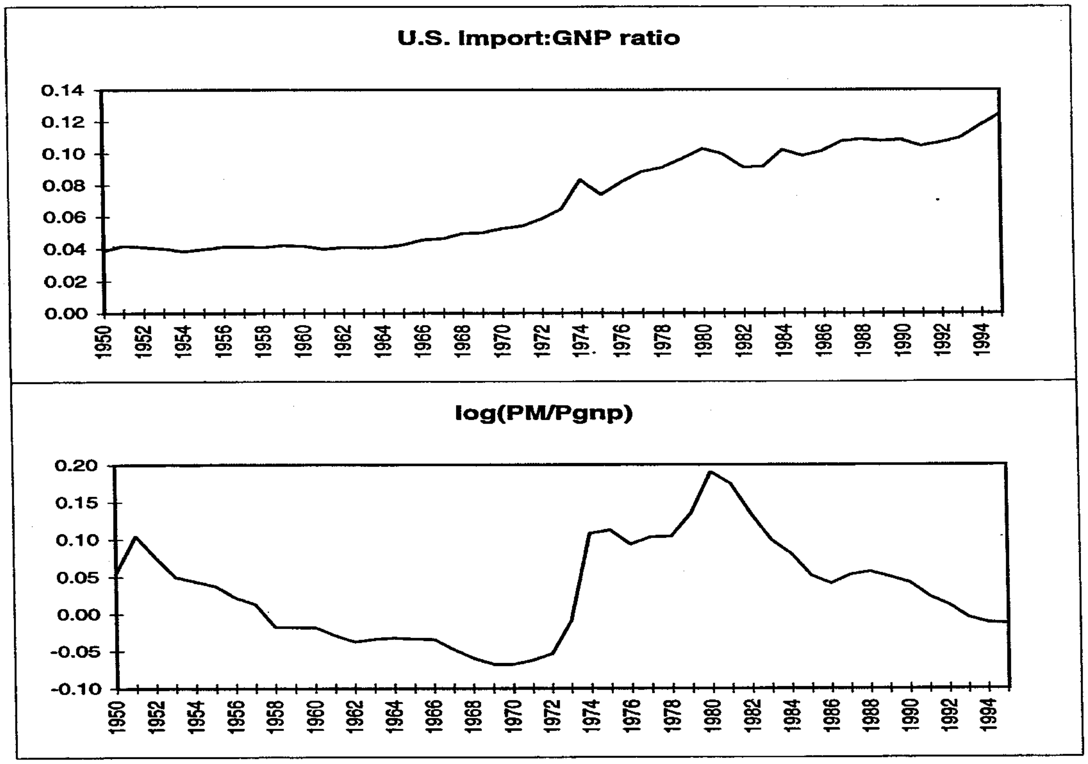
The empirical literature on trade functions -- import demands and export supplies -- is vast. See, for example, Goldstein and Khan (1984). These, however, concentrate on finding the price and income elasticities of imports or exports. Estimating functional forms suitable for use in numerical models like those discussed here are not the focus of such research. Like the production and consumption cases above there are special problems in specifying and estimating such trade functions.

The behavior of import and export shares in the U.S. parallels that of the labor supply, that is, there is a secular trend in quantites that is not accompanied by price movements. Figure 3 plots the aggregate commodity imports as a share of GNP and the ratio of import prices to the GNP deflator. (While one should, strictly speaking, use the price of domestic tradables, the difference between that and the GDP deflator is small in this context.) Very similar trends exist for data at the 2-digit level that we use in our model.

The import share rose throughout this period with a sharp acceleration in the 1970s. The price of imports relative to domestic goods prices however, showed no particular trend. Any import demand function that has only prices will fail to track these data by a large margin. Much of the empirical work with time series data use an income term, like aggregate activity, in addition to prices to explain these trends. However, we concur with Petri's conclusion (1984, p. 51) that the high income elasticities estimated are probably spurious. We therefore explain the share of imports using a time trend as in Petri (1984).

Here again we confront the problem that specifications that are reasonable for estimating over a given sample is unsuitable for use in dynamic models. Simple time trends would push imports to infinity. We have opted for a imple solution by using a logistic trend. From Fig. 3 it is clear that such a trend would be poorly estimated since U.S. imports seem to be rising with no end in sight. Another way of saying this is that there are fundamental changes in the world's supply of tradable goods over time, and import demand functions are shifting. These shifts do not appear to be converging and we must therefore make some assumption about the maximum possible shift. The assumption we have chosen is to have the logistic curve converging to a point close to the share at the end of the sample period.

Fig. 3. Import share and the price of imports



3. The Structure of the Model

We divide the U.S. economy among four sectors: businesses, households, governments, and the rest of the world. Since trade policy differs substantially among industries, we subdivide the business sector into the thirty-five industries listed in Table 1 below. These industries correspond approximately to two-digit industries in the Standard Industrial Classification. Our model distinguishes the same number of commodities as industries. Each industry produces a primary product; this is the commodity group in which the industry is predominant. Industries also produce secondary products, the primary products of other industries. The interindustry flows are illustrated in Figure 4.

We shall give an overview of the important features of the model here. The detailed equations are in Appendix A.

3.1 Consumer behavior

Our model of consumer behavior is based on full consumption, comprised of commodities and leisure time, following the structure in eqn. 4. Full consumption is allocated over time to maximize an intertemporally additive utility function, subject to an intertemporal budget constraint. The necessary conditions are expressed as an Euler equation, giving the growth rate of full consumption as a function of the discount rate and the growth rate of the price of full consumption. Current full consumption incorporates expectations about all future prices that are fulfilled by the solution of the model. This is the first component of our dynamic model of adjustment to changes in trade policy.

There is a single, exogenously given, time endowment. The U.S. population grew substantially during our sample period, 1947-1985. For later periods we project the population and transform it into a projection of the time endowment. In each period this endowment is divided between leisure time and the labor market. Our model allocates full consumption between commodities and leisure. Time in the labor market is allocated among the thirty-five industries; labor services are also included in final demands for personal consumption expenditures and public consumption. We assume that labor is perfectly mobile among sectors so that the wage rate in each sector is proportional to a single wage rate for the U.S. economy as a whole.

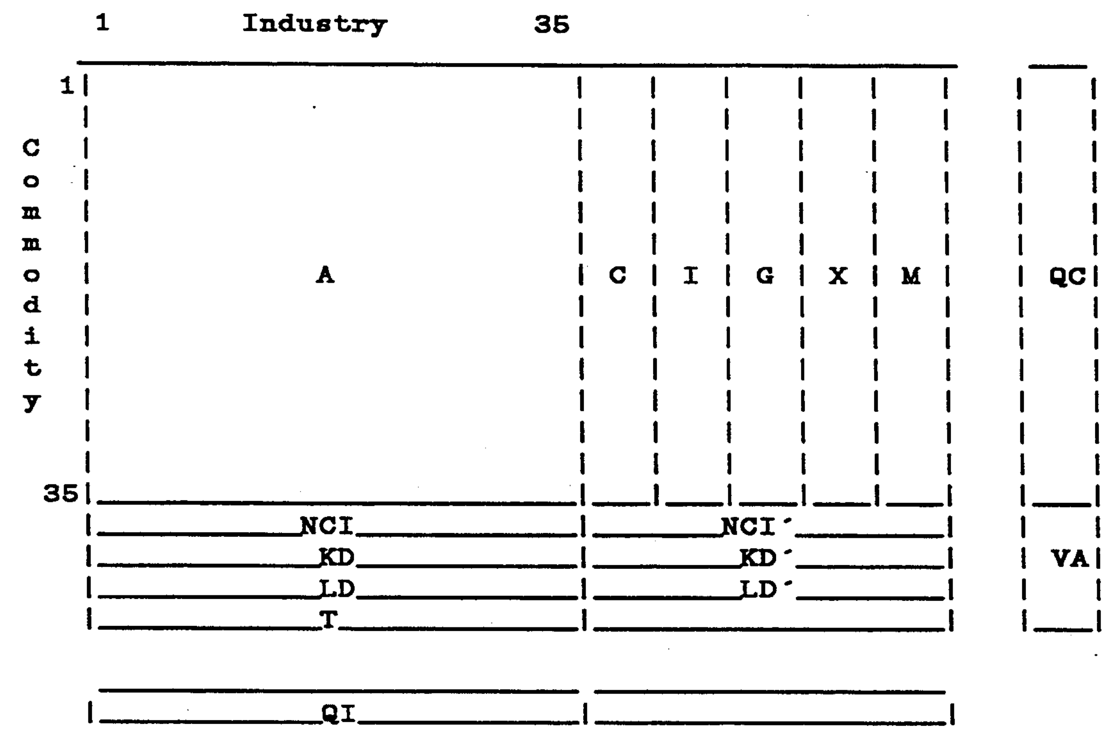
Finally, total expenditure on commodities by the household sector is allocated to the thirty-five commodities represented in the model, capital services, and labor services. We estimate price and total expenditure elasticities econometrically for each of 672 types of households.

3.2 Producer behavior

We represent producer behavior by means of econometric models for each of our thirty-five industries. We first express the output of each industry as a function of inputs of intermediate goods, capital services, and labor services. These production functions are characterized by constant returns to scale. The rate of productivity growth in each industry is endogenous and can be expressed as a function of the input prices. The intermediate inputs include the thirty-five commodities produced within the U.S. business sector. Each commodity group is allocated among intermediate demands by the thirty-five industries and final demands for private and public consumption, investment by households and businesses, and exports to the rest of the world.

Figure 4 Intersectoral flows.

Use Table



Make Table.

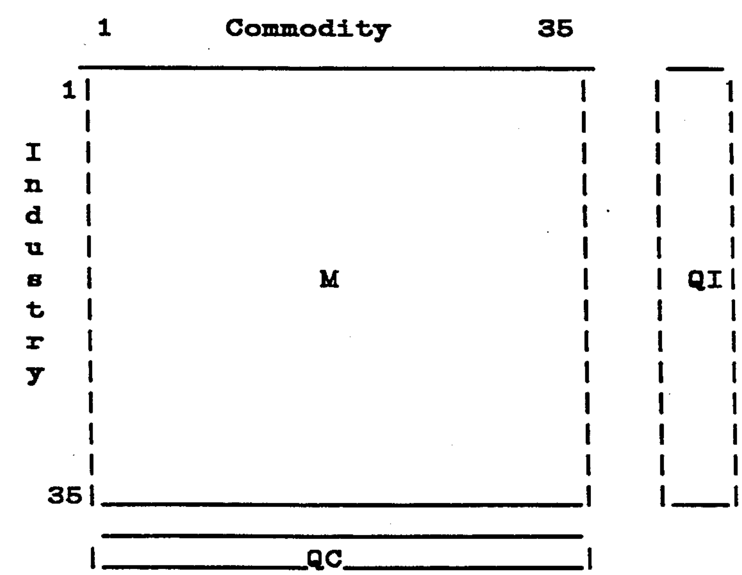


Figure 4 Continued.

A	Use matrix; commodities used by industries
M	Make matrix; Industries contribution to commoditiy supply.
C	Household consumption of nondurables and services only. Service flow from durables enter in the capital row of that column.
I	Investment in the domestic capital stock.
G	Government purchases of goods and services.
X	Exports of commodities (interest receipts are accounted separately)
M	Competitive imports (entered as a negative column)
NCI	Non-competitive imports
KD	Capital demanded by producers
LD	Labor demanded by producers
T	Sales tax on industry output
	NCI',KD',LD' are factor inputs allocated directly to final demand
QI	Industry output
QC	Commodity output of domestic producers
QS	= QC+M = Total commodity supply
VA	Total value added = GDP

Table 1. Import Demand Elasticities.

Industry	Substitution Elasticities			Import Price Elasticities				
	Stern	Sheills	Ours	Stern	Sheills	Petri	Cline	Ours
Agriculture			0.70				-0.90	-0.68
Metal mining			0.11				-0.22	-0.09
Coal mining							-0.22	
Oil & gas mining							-0.22	
Non-metal mining			0.34				-0.22	-0.34
Construction								
Food & kindred	1.13	0.31	0.65	-1.13	-0.21		-1.13	-0.62
Tobacco	1.13	-16.2	2.60	-1.13	-7.57		-1.13	-2.59
Textile mill	1.15	2.58	1.62	-1.14	-1.41	-1.2	-2.43	-1.54
Apparel	4.27	1.62	1.27	-3.92	-0.52	-1.2	-2.43	-1.01
Lumber & wood	1.76	0.26	1.76	-0.69	-1.32	-1.4	-0.96	-1.60
Furniture	3.10	12.13	1.49	-3.00	-9.56	-1.4	-0.96	-1.36
Paper	1.58	1.80	1.16	-0.55	-1.80	-1.4	-1.44	-1.07
Printing & publish	3.01	2.72	1.22	-3.00	-1.46	-1.4	-1.44	-1.20
Chemicals	2.61	9.85	1.20	-2.53	-6.82	-0.8	-0.97	-1.10
Petroleum refining	2.36	-0.34	1.09	-1.96	-0.79	-0.8	-0.97	-1.00
Rubber & plastic	5.71	2.67	1.76	-5.26	-1.32	-0.8	-3.57	-1.65
Leather	1.81	4.11	1.86	-1.58	-2.01		-2.46	-1.11
Stone Clay & Glass	1.63	4.29	1.86	-1.60	-2.86	-0.8	-1.37	-1.72
Primary metal	1.45	3.05	1.48	-1.42	-2.28	-1.6	-1.99	-1.29
Fabricated metal	3.67	1.54	1.13	-3.59	-0.94	-1.1		-1.08
Machinery	1.02	3.34	1.72	-1.02	-0.88	-0.9	-0.87	-1.53
Electrical machine	2.11	7.46	1.45	-1.00	-3.08	-0.6	-0.87	-1.23
Motor vehicles	3.59	2.01	1.52	-3.28	-1.24	-2.5	-2.53	-1.16
Transport. equipme	3.59	2.01	1.35	-3.28	-1.24	-2.5	-1.70	-1.28
Instruments	1.98	0.45	0.86	-1.08	-0.44	-0.9		-0.77
Misc. manufactures	1.98	3.55	1.52	-2.06	-2.37	-0.8	-4.44	-1.14
Transportation								
Communications								
Electric Utilities								
Gas Utilities								
Trade								
Finance, Insurance								
Services								
Govt Enterprises								

The industrial classification system is different for each study. All entries correspond to the categories used in this study.

Stern: Central tendencies in Stern, Francis and Schumacher (1976).
Sheills: Sheills, Stern and Deardorff (1986), sample period 1962-78.
Petri: Petri (1985), U.S. imports from rest of the world, excluding Japan, 1960-80.
Cline: Cline, et al. (1978), page 58.
Ours: Elasticities evaluated at 1983 shares, sample period 1964-85.

To implement our econometric approach to modeling producer behavior we have constructed a consistent time series of interindustry transactions tables for the U.S. economy, covering the period 1947-1985 on an annual basis. Empirical evidence on substitutability among inputs is essential in analyzing the impact of trade restrictions. A high degree of substitutability implies that the cost of these restrictions is relatively low, while a low degree of substitutability implies high costs of trade restrictions.

3.3 Investor behavior

In our model a single stock of capital is allocated among the thirty-five industries and the household sector. We assume that capital is perfectly malleable and mobile among sectors, so that the price of capital services in each sector is proportional to a single capital service price for the economy as a whole. The supply of capital available in every year is the result of past investment. This relationship is represented by an accumulation equation, giving capital at the end of each year as a function of investment during the year and capital at the beginning of the year. This backward-looking equation incorporates the whole past history of investment and constitutes the second component of our dynamic model of adjustment to changes in trade policy.

Our model of investor behavior also includes an equation giving the price of capital services in terms of the price of investment goods at the beginning and end of each period. The current price of investment goods incorporates expectations about future prices of capital services and discount rates through the assumption of perfect foresight or rational expectations. Under this assumption the price of investment goods is based on expectations that are fulfilled by the solution of the model. This forward-looking equation incorporates expectations about all future prices and is the third component of our dynamic model of adjustment to trade policy changes.

3.4 The Government

The government in this model imposes taxes, buys commodities, make transfers and borrows to finance its deficits. The government deficit is set exogenously since we do not have an equation (e.g. a portfolio choice model) to determine it in the steady state. That leaves us with two possible closures for the model, either endogenizing government purchases given fixed tax rates, or, fixing public spending and adjusting tax rates/lump sum taxes. Both methods are used depending on the simulation.

On the revenue side the government imposes taxes -- sales tax, import tariffs, capital income tax, labor income tax, property tax and wealth (estate) tax; and collects fees -- "non-tax revenues" and surpluses of government enterprises.

Government spending falls into 4 major categories -- purchases of goods, transfers (to household sector and foreign aid), interest payments on debt (to domestic and foreign bondholders), and subsidies to producers. Transfers and interest payments are included to maintain a realistic set of accounts, they are set exogenously and play no endogenous role.

3.5 Total Supply, Imports and the Rest-of-the-world.

The total supply of commodities in the U.S. economy comes from the output of domestic industries and "competitive" imports. Competitive imports are defined in the U.S. national income and product accounts as commodities similar to those produced in the U.S. In our model purchasers of these commodities regard them as imperfect substitutes for the domestically produced counterparts. Noncompetitive imports enter directly into the production functions for each industry in the same way as other inputs. They also enter final demands for consumption by households and governments and investment by businesses and households. Some examples of noncompetitive imports are tropical agricultural products and tourism.

The demand for competitive imports is derived from a translog cost function with a logistic time trend to deal with the rising imports as described in section 2.3 above. The share of total supply due to imports is derived as:

$$\frac{PM_i M_i}{PS_i QS_i} = \alpha_0^i + \frac{\beta_0^i}{1 + e^{-\mu_i(t-\tau_i)}} + B^i \ln \frac{PM^i}{PC_i} \qquad (5)$$

where *PM* and *PC* are the prices of the imported and domestic commodities, and *PS* is the price of the total supply. The corresponding quantities are denoted *M*, *QC* and *QS*. The value of total supply is :

$$PS_i QS_i = PC_i QC_i + PM_i M_i \qquad (6)$$

The above import demand equation is estimated by applying two-stage least squares to annual data for the period 1960-85. We present the implied price elasticities of demand for imports in Table 1. For comparison we also present elasticities employed in previous studies. Imports of most manufactured commodities are price elastic, while imports of most primary commodities are price inelastic. For eighteen of our twenty-five highly tradable groups the values of R^2 are greater than 0.8.

Our model is limited to the U.S. economy, so that we do not model production by the rest of the world. Accordingly, we take the prices of competitive and noncompetitive imports into the U.S. as exogenously given; during our sample period, 1947-85, we set these prices equal to the actual data. Since our model determines prices, both domestic and foreign, relative to a numeraire given by the U.S. wage rate, we allow prices of imports from the rest of the world to change through the terms of trade, say e_t, and through tariffs levied on imports by the U.S. government, say θ_{it} and θ_{it}^n:

$$PM_{it} = (1+\theta_{it}) e PM_{it}^*, \qquad (7)$$

$$PNCI_{it} = (1+\theta_{it}^n) e_t \; PNCI_{it}^*,$$

where PM_{it} and $PNCI_{it}$ are prices for competitive and noncompetitive imports paid by the U.S. and PM_{it}^* and $PNCI_{it}^*$ are prices received by the rest of the world. The terms of trade e_t is the price of goods in the U.S. relative to the price of goods in the rest of the world.

Exports.

Since we do not model production in the rest of the world, we express the demand for U.S. exports, say X_{it}, as a function of rest of the world output Y_t^* and the price of exports PC_{it}:

$$X_{it} = EX_{i0}(Y_t^*) \; [(1+\theta_{it}^*) \; \frac{PC_{it}}{e_t}]\eta i, \qquad (8)$$

where $EX_{i0}(Y_t^*)$ represents actual U.S. exports during the sample period, 1947-85, and projected exports outside this period, θ_{it}^* is the rest of the world tariff rate on U.S. exports, and the term in square brackets is the price for U.S. exports faced by the rest of the world. We do not have the data on rest of the world imports from the U.S. required for estimation of the export price elasticities η_i. We take these elasticities as averages of import price elasticities of major trading partners of the U.S. These are given in Table 2.

The U.S. current account balance is the above commodity exports less commodity imports plus net factor income less transfers. Since the commodity flows are functions of the terms of trade e_t, the current account also depends of e_t. The current account is set exogenously like the government deficit and this constraint is met by the endogenous terms of trade.

3.6 The Markets, Equilibrium and Solution of model.

The intraperiod equilibrium obtains when the markets for goods and factors clear. The first set of markets is for the 35 commodities, the supply comes from the producers (via the make matrix) and imports, and the demands are from intermediate users, household consumption, investment, government demand and exports. These markets are cleared by the commodity prices.

Next we have the factor markets. The supply of the malleable capital is equated to the sum of the industry and household demands by an aggregate rental price. The demand for leisure translate into a supply of labor. The demand for labor comes from the producers and households and the market is cleared by the wage rate.

We have exogenous government deficits and tax rates. The "revenue, expenditure, deficit" constraint is met by an endogenous level of public spending on goods. Similarly the exogenous current account balance is met by the endogenous terms of trade, e_t.

Finally we have the savings and investment equation. This is determined from the Euler equation linking consumption between adjacent periods.

Our model may be described as a multi-sector Cass-Koopmans model. Intertemporal equilibrium obtains when the two dynamic equations of the model are satisfied – the Euler equation for full consumption, and the capital accumulation equation. The transversality condition must of course also hold.

The economy moves along the saddle path from a given initial capital stock to a steady state defined by two conditions. The first condition is that full consumption is constant (recall that there is no

Table 2. Export Price Elasticities.

Industry	Petri	Stone	Cline
Agriculture		-0.72	-0.61
Metal mining		-0.92	
Coal mining		-0.92	
Oil & gas mining		-0.92	
Non-metal mining		-0.92	
Construction	*		
Food & kindred		-1.975	-0.63
Tobacco		-1.975	-0.63
Textile mill	-1.6	-1.18	-1.57
Apparel	-1.6	-1.18	-1.57
Lumber & wood	-1.0	-1.5	-1.43
Furniture	-1.0	-1.5	-1.43
Paper	-1.0	-1.41	-1.53
Printing & publishing	-1.0	-1.41	-1.53
Chemicals	-0.5	-0.98	-1.47
Petroleum refining	-0.5	-1.72	-1.47
Rubber & plastic	-0.5	-2.10	-2.14
Leather	-1.6	-0.62	-1.49
Stone Clay & Glass	-0.7	-1.26	-1.56
Primary metal	-1.1	-1.65	-1.97
Fabricated metal	-1.1	-1.06	-1.59
Machinery	-0.9	-1.04	-1.59
Electrical machinery	-1.2	-1.05	-1.59
Motor vehicles	-0.9	-2.49	-1.55
Transport. equipment	-0.9	-2.49	-1.55
Instruments	-0.9	-1.18	-1.85
Misc. manufactures	-1.0	-1.55	-1.62
Transportation	*		
Communications	*		
Electric Utilities	*		
Gas Utilities	*		
Trade	*		
Finance, Insurance	*		
Services	*		
Govt Enterprises	*		

*Sectors assumed to have zero price elasticities. Trade and transportation exports are margins on exported goods; other service sectors have only negligible exports.

Petri: Petri (1984).
Stone: Stone (1979), average of import elasticities for EEC and Japan.
Cline: Cline, et al. (1978), average of Canada, EEC, Japan.

long run technical progress). The second is that investment exactly matches depreciation. The first condition implies that at the steady state the net marginal product of capital is equal to the rate of time preference.

The saddle path is calculated by iterating on a guess of the path of the costate variable until both intraperiod and intertemporal equilibrium conditions are satisfied. The procedure is described in more detail in the Appendix.

4. Effects of Trade Barriers.

In this section we summarize the results reported in Ho and Jorgenson (1994) where we estimated the impact of trade policy on U.S. economic growth. We constructed a base case for growth of the U.S. economy under actual trade policies, incorporating historical data for all exogenous variables. We then simulated the U.S. economy with a change in trade policy. The economic impact of the policy change is estimated by comparing the results of the two simulations. We initiate both simulations in 1980, immediately after the conclusion of the Tokyo Round negotiations in 1979.

4.1 Tariff reductions.

We first describe the effects of multilateral reductions in tariffs with no change in quantitative restrictions on trade. In Table 3 we present tariff rates on U.S. imports in 1980, following several rounds of tariff reductions under GATT that culminated in the Tokyo Round. The most highly taxed commodity imports were textiles, apparel, leather (mainly footwear), glass, and primary metals (mainly iron and steel). Total customs duties collected on U.S. imports amounted to $7.2 billions or about 2.9 percent of total commodity imports of $251 billions. For comparison the U.S. gross national product in 1980 was $2,732 billions in prices of that year.[5]

To evaluate the economic impact of tariffs, we eliminate all domestic and foreign tariffs, beginning in 1980. In both the base case and alternative case simulations, we set the U.S. capital stock and all other state variables at the beginning of 1980 equal to their historical values. We then simulate the growth of the U.S. economy from 1980 to the year 2100. In the base case the government deficit and tax rates are exogenous, but government spending is endogenous. With all tariffs removed we set government expenditures equal to values from the base case. The exogenous government transfers and interest payments are kept the same in both simulations.

The economic impact of eliminating tariffs is summarized diagrammatically in Figures 5a and 5b. The vertical axis in these figures gives the percentage change in each variable from the elimination of tariffs. The impact of the tariff cut is to raise consumption of goods and services by 0.16 percent in the first year. From the first panel of Figure 5b we see that the price of capital goods is lower than in the base case and keeps falling. A falling price of capital goods leads to an increase in investment and boosts the growth of capital stock, as shown in Figure 5b. By the year 2000 the capital stock is 0.49 percent higher than in the base case.

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[5] Tariff rates given in Table 3 were calculated from data provided by Andrew Parks of the U.S. International Trade Commission, described in detail by Ho (1989), Appendix H. Tariff rates for the rest of the world are taken from Deardorff and Stern (1986).

Table 3. Tariff Rates in 1980.

NO.	Sector	Tariff rates ROW	Tariff rates U.S.	Tariff equiv.
1	Agriculture		0.035	
2	Metal mining		0.000	
3	Coal mining		0.000	
4	Oil & gas mining		0.000	
5	Non-metal mining		0.003	
6	Construction		0.000	
7	Food & kindred		0.027	
8	Tobacco		0.111	
9	Textile mill	0.107	0.108	0.030
10	Apparel	0.207	0.218	0.063
11	Lumber & wood	0.027	0.020	
12	Furniture	0.103	0.035	
13	Paper	0.058	0.005	
14	Printing & publishing	0.029	0.008	
15	Chemicals	0.094	0.041	
16	Petroleum refining		0.000	
17	Rubber & plastic	0.058	0.067	
18	Leather	0.045	0.097	0.056
19	Stone Clay & Glass	0.105	0.091	
20	Primary metal	0.058	0.030	0.048
21	Fabricated metal	0.090	0.057	
22	Machinery	0.067	0.041	
23	Electrical machinery	0.096	0.055	
24	Motor vehicles	0.077	0.023	*0.047
25	Transport. equipment	0.077	0.026	
26	Instruments	0.078	0.065	
27	Misc. manufactures	0.078	0.058	
28	Transportation			
29	Communications			
30	Electric Utilities			
31	Gas Utilities			
32	Trade			
33	Finance, Insurance			
34	Services			
35	Govt Enterprises			

U.S. tariff rates are calculated from International Trade Commission data. Rest of the world (ROW) tariff rates are from Deardorff and Stern (1986). See Table 3.1b below for tariff equivalents of quotas. *1981 data.

Table 4. Tariff Equivalents of Selected Quotas.

	Textiles	Apparel	Leather	Metals	Autos
1973	0	0	0	0.032	0
1974	0.030	0.063	0	0.032	0
1975	0.030	0.063	0	0	0
1976	0.030	0.063	0	0	0
1977	0.030	0.063	0.056	0	0
1978	0.030	0.063	0.056	0.048	0
1979	0.030	0.063	0.056	0.048	0
1980	0.030	0.063	0.056	0.048	0
1981	0.030	0.063	0.056	0.048	0.047
1982	0.071	0.095	0	0.048	0.047
1983	0.071	0.095	0	0.048	0.047
1984	0.071	0.095	0	0.048	0.047
1985	0.071	0.095	0	0.048	0

Tariff equivalents of "voluntary" export restrictions are calculated from Hufbauer, Berliner, Elliot (1986) by aggregation to our model's industry classification.

Table 4b. Tariff Equivalents of Quotas on U.S Imports from Japan.

Sector	1970	1980
Textiles, Apparel	3.5	1.3
Primary Metal	6.0	7.0
Electrical Macinery	-	0.8

Petri (1984), page 138.

Figure 5a. Dynamic Effects of Tariff Elimination

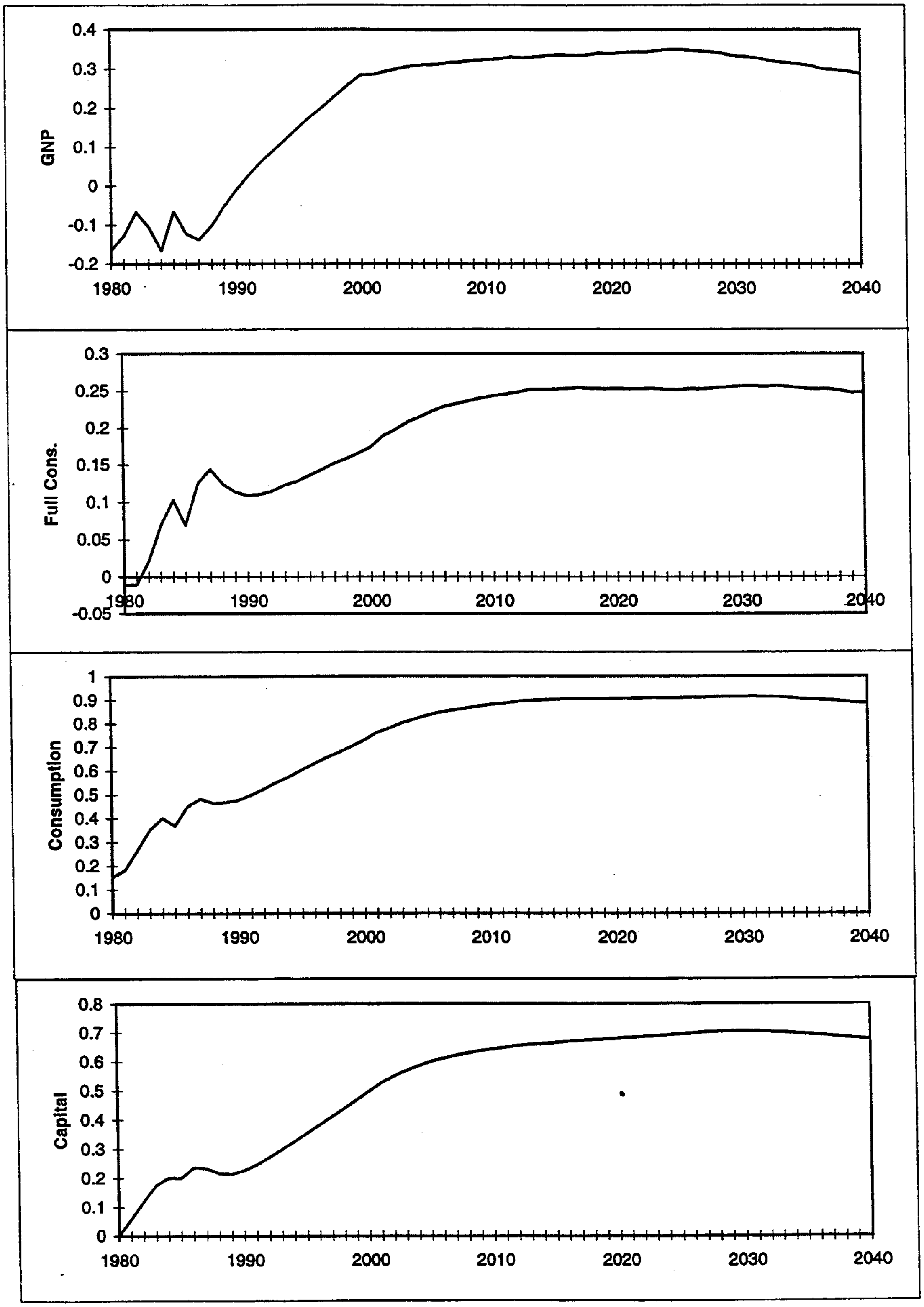
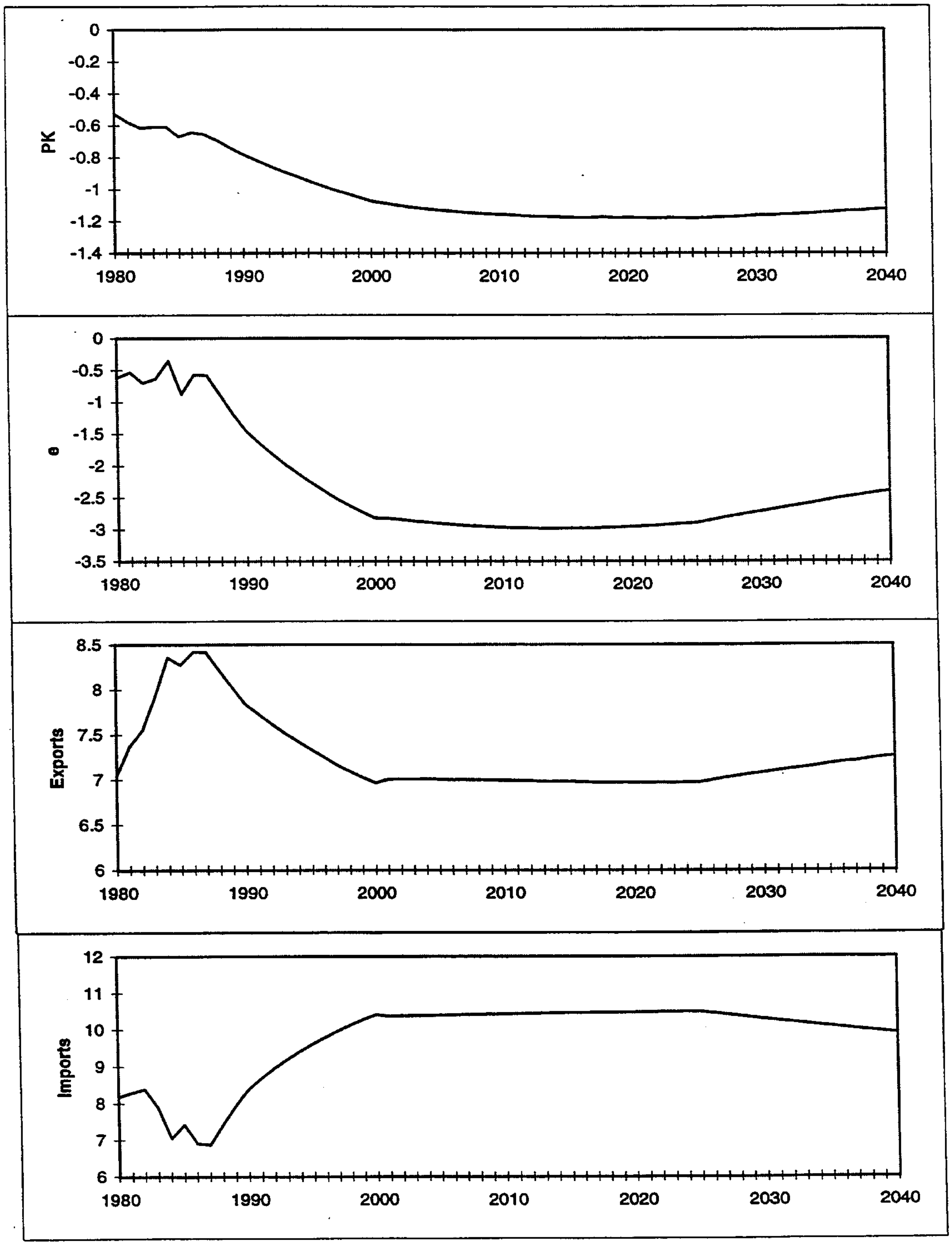


Figure 5b. Dynamic Effects of Tariff Elimination



Lower commodity prices and an investment boom induce higher import demands. U.S. exports also increase with reduced tariffs in the rest of the world. From Table 3 we see that these tariffs are generally higher than those in the U.S. Given the elasticities we have employed, the initial impact is greater for exports than for imports. Since the current account balance is exogenous, the terms of trade e_t must fall to stimulate higher imports. The required decrease of 0.6 percent in the terms of trade is very substantial. The quantity of exports increases by 6.7 percent while the quantity of imports rises by 7.5 percent.

Over time the difference between the two simulations increases, due to the growth in capital stock resulting from the elimination of tariffs. By the year 2000 full consumption is 0.17 percent higher; this is comprised of an increase of 0.74 in consumption of goods and services and a decrease of 0.6 percent in leisure. The terms of trade decline over time, since U.S. prices fall but rest of the world prices remain constant, implying an increase in U.S. international competitiveness. As a consequence, the quantity of exports is only 6.5 percent higher in the year 2000, while the quantity of imports is 9.7 percent higher.

Table 5 gives the sectoral effects of tariff elimination in the initial year, while Table 6 shows the effects after twenty years. Raw material industries such as mining have small trade flows; the small decreases in exports are due to the fall in the terms of trade. Agricultural trade is largely governed by quantitative restrictions, including trade embargoes, that we do not explicitly model. The small changes in trade should be interpreted with this in mind. Similarly, the industries producing nontradables -- trade, finance, and services -- have small declines in exports, due mainly to the terms of trade. Commodities with the highest tariff levels -- textiles, apparel, rubber, leather, and glass -- show the largest gains in imports. Chemicals, electrical machinery (which includes computers), and instruments have the highest rest of the world tariffs and the most substantial increases in exports.

The output and employment effects of tariff reductions largely parallel the shifts in imports and exports. Chemicals, primary metals, machinery, electrical machinery, and instruments show the largest gains in output and employment. Since the capital stock is initially fixed in supply, capital must be drawn from other sectors to these export oriented industries. Import penetration is so high in the food, furniture, and leather industries that domestic output actually falls. Capital and labor shift from these sectors to sectors that are more competitive internationally.

4.2 Quantitative restrictions.

With successive reductions in tariff rates, trade policy has shifted away from tariffs to quantitative restrictions like quotas and "voluntary" export restraints on suppliers of U.S. imports. As a concrete example, world trade in apparel is governed by Multi-Fiber Agreements that allocate quotas to each exporting country. The quotas are highly detailed, covering many categories of apparel. Some countries attain these limits while others are constrained in only a few or even none of the categories. Another example is motor vehicles, where Japanese exports to the U.S. in the 1980s are under "voluntary" export restrictions, while European exports are not.

Table 5 Sectoral Effects of Eliminating All Tariffs in 1980 (% change).

Sector	Output	Capital	Labor	Exports	Imports
Agriculture	-0.32	-0.44	-0.47	-0.34	2.09
Metal mining	2.17	2.08	2.04	-0.43	2.31
Coal mining	0.36	0.26	0.17	-0.44	0.84
Oil & gas mining	0.08	0.00	0.16	-0.56	0.69
Non-metal mining	0.75	0.59	0.35	-0.42	0.97
Construction	0.23	0.05	0.22	-0.14	
Food & kindred	-0.34	-0.45	-0.44	-0.31	1.62
Tobacco	-0.42	-0.47	-0.52	-0.30	20.56
Textile mill	1.42	0.88	0.17	18.94	20.23
Apparel	1.71	-0.26	0.09	29.07	31.06
Lumber & wood	0.25	-0.06	-0.35	3.39	4.59
Furniture	-0.51	-0.66	-0.72	16.25	6.03
Paper	0.85	0.71	0.69	8.64	1.98
Printing & publishing	0.70	0.70	0.57	3.57	2.27
Chemicals	2.47	2.39	2.36	14.58	8.01
Petroleum refining	0.17	0.10	0.12	-0.62	0.75
Rubber & plastic	1.71	1.58	1.45	12.74	15.07
Leather	-1.40	-2.17	-1.75	5.93	16.93
Stone Clay & Glass	0.37	0.23	0.00	18.04	20.38
Primary metal	2.34	1.74	1.74	11.80	7.48
Fabricated metal	1.63	1.17	1.24	15.56	8.67
Machinery	2.51	1.94	1.87	11.11	10.52
Electrical machinery	2.29	1.84	2.06	16.77	11.17
Motor vehicles	1.84	1.44	0.85	13.08	5.76
Transport. equipment	2.93	2.30	2.38	12.65	7.09
Instruments	3.78	3.62	3.50	15.35	9.81
Misc. manufactures	1.44	1.23	1.07	12.94	11.23
Transportation	0.26	0.15	0.15	-0.01	0.78
Communications	0.28	0.26	0.24	-0.05	
Electric Utilities	0.22	0.21	0.13	-0.06	0.09
Gas Utilities	0.40	0.32	0.34	-0.03	
Trade	0.26	0.22	0.22	-0.02	
Finance, Insurance	0.08	0.08	0.07	-0.07	0.65
Services	0.02	-0.01	-0.09	-0.11	0.61
Govt Enterprises	0.30	0.31	0.27	-0.10	
Household		-0.54	-0.27		
Govenrment		0.00	-0.82		

Entries are percentage change in the first period from the base case. Output is industry output, not commodity supply. Imports are competitive imports only.

Table 6. Eliminating all trade barriers vs. tariffs only after 20 years (percentage change from base case).

	No tariffs	No barriers
Capital	0.50	0.54
Full consumption	0.17	0.26
Consumption	0.74	0.96
C.P.I.	1.00	1.25
Exports	6.54	7.19
Imports	9.72	10.68
Price of capital	-.72	-1.30

Table 7. Elimination of all Trade Barriers vs. Tariffs: effects on GNP growth.

	Annual GNP growth rate %		
	Base case	No tariffs	No barriers
1980:1990	3.47	3.48	3.50
1980:2000	2.34	2.37	2.38

We have modeled all quantitative restrictions by assuming that the realized import prices reflect the full effects. The primary justification for this approach is simplicity. More specifically, we assume that quotas result in a higher world price of imports PM_{it}^{*}. Hufbauer, Berliner and Elliott (1986) have provided estimates of the tariff equivalents of quantitative restrictions on U.S. imports. While bearing in mind the many limitations of the concept of a tariff equivalent, these tariff rates are consistent with the assumptions of constant returns to scale and perfect competition employed in our model for all industries.

We next consider the economic impact of eliminating all domestic and foreign tariffs and the tariff equivalents of quantitative restrictions for textiles, apparel, shoes, steel and automobiles given in Table 4. These are the most significant restrictions, but do not exhaust U.S. quotas. We have ignored restrictions on agricultural products and motor vehicles other than autos. We simulate the elimination of quantitative restrictions by reducing the rest of the world price of U.S. imports PM_{it}^{*}. Under this change in trade policy foreigners lose rents that accrue to them under quotas.

As before, we begin our simulation in 1980 and continue through the year 2100. We have combined tariffs with quantitative restrictions to provide an estimate of the impact of eliminating both types of trade barriers. The results given in Figure 6a and 6b are similar but more substantial in magnitude than those for tariff reductions alone. The only exception is the terms of trade e_t. In our simulations the elimination of quantitative restrictions is unilateral. Given the exogenous trade balance, the terms of trade must rise in some years to cover the increased U.S. imports of textiles, steel, autos, and shoes. In the initial year the fall in the terms of trade is only 0.53 percent compared with 0.61 percent for tariffs alone.

By the year 2000 the economic impacts of eliminating all trade barriers are considerably greater than the effects of tariff cuts alone. The percentage changes at the aggregate level are shown in Table 6. These impacts arise from reductions in import prices for all the five quota items and the implied reduction in the price of investment goods. Investment goods industries are large consumers of steel; automobiles are included among these industries.

The sharp drop in the price of investment goods due to the elimination of auto quotas raises the U.S. investment level and economic growth rate. These quotas were eliminated in 1985, so that the impact on the growth rate fell. The effects of the elimination of all tariff barriers on growth of the U.S. gross national product is summarized in the Table 7.

The sectoral effects of eliminating all trade barriers are given in Table 8. This can be compared with Table 5 for tariff cuts alone. The sectoral effects are quite similar, except for the commodities subject to quotas. Apparel imports, for example, rise by forty-two percent, compared to a gain of only thirty-one percent for tariff cuts alone. For iron and steel the gain is fifteen percent versus only seven percent; for leather the gain is twenty-eight percent versus seventeen percent. These shifts translate into parallel output changes. The leather industry's output falls by 2.5 percent by comparison with 1.4 percent with tariff cuts alone, while textile output rises by only 1.2 percent compared to 1.4 percent. Resources move out of apparel; since textiles, its main intermediate input, also falls in price, the output of apparel actually rises.

Figure 6a. Dynamic Effects of Eliminating Tariffs and Quotas

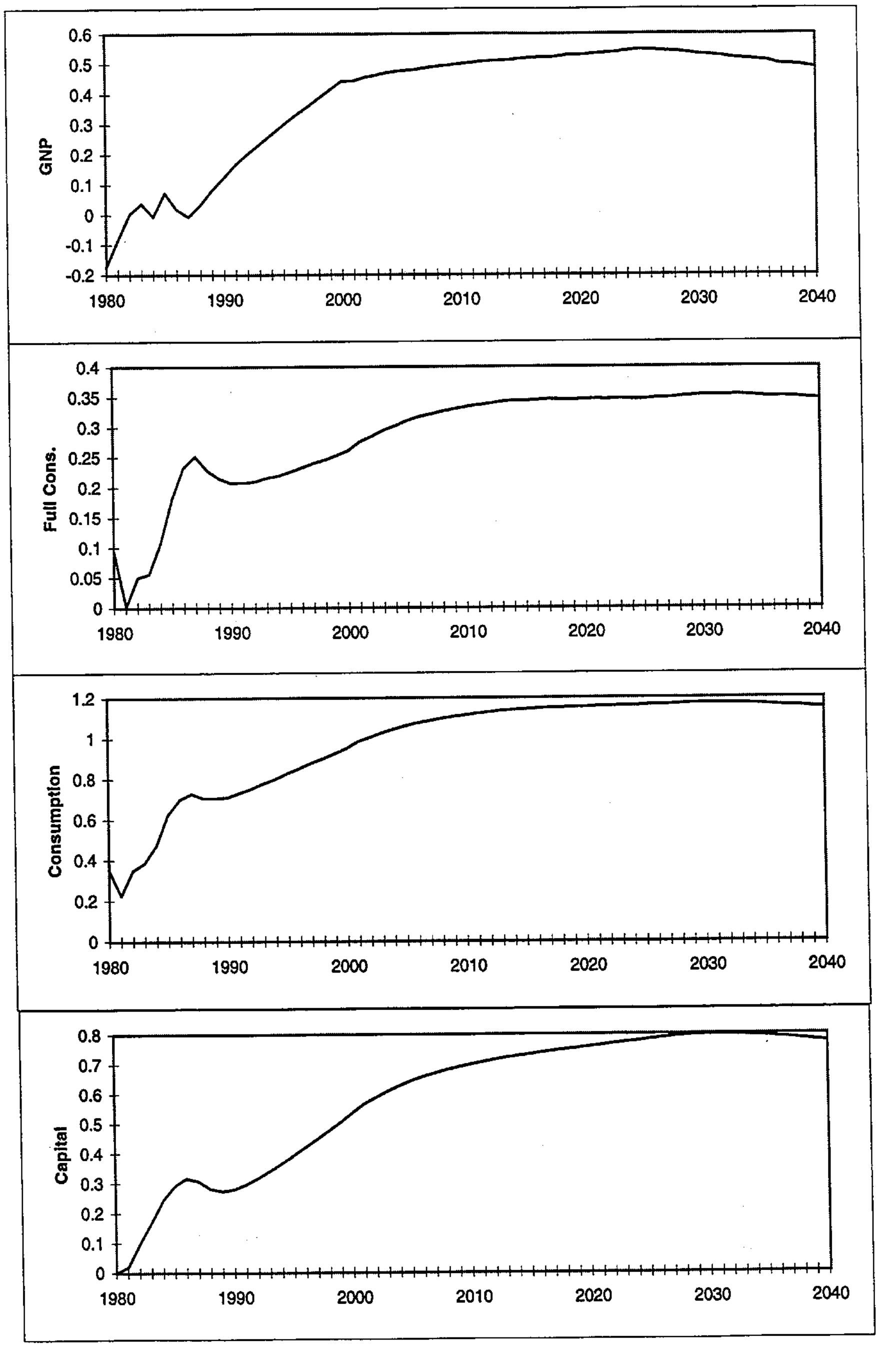


Figure 6b. Dynamic Effects of Eliminating Tariffs and Quotas

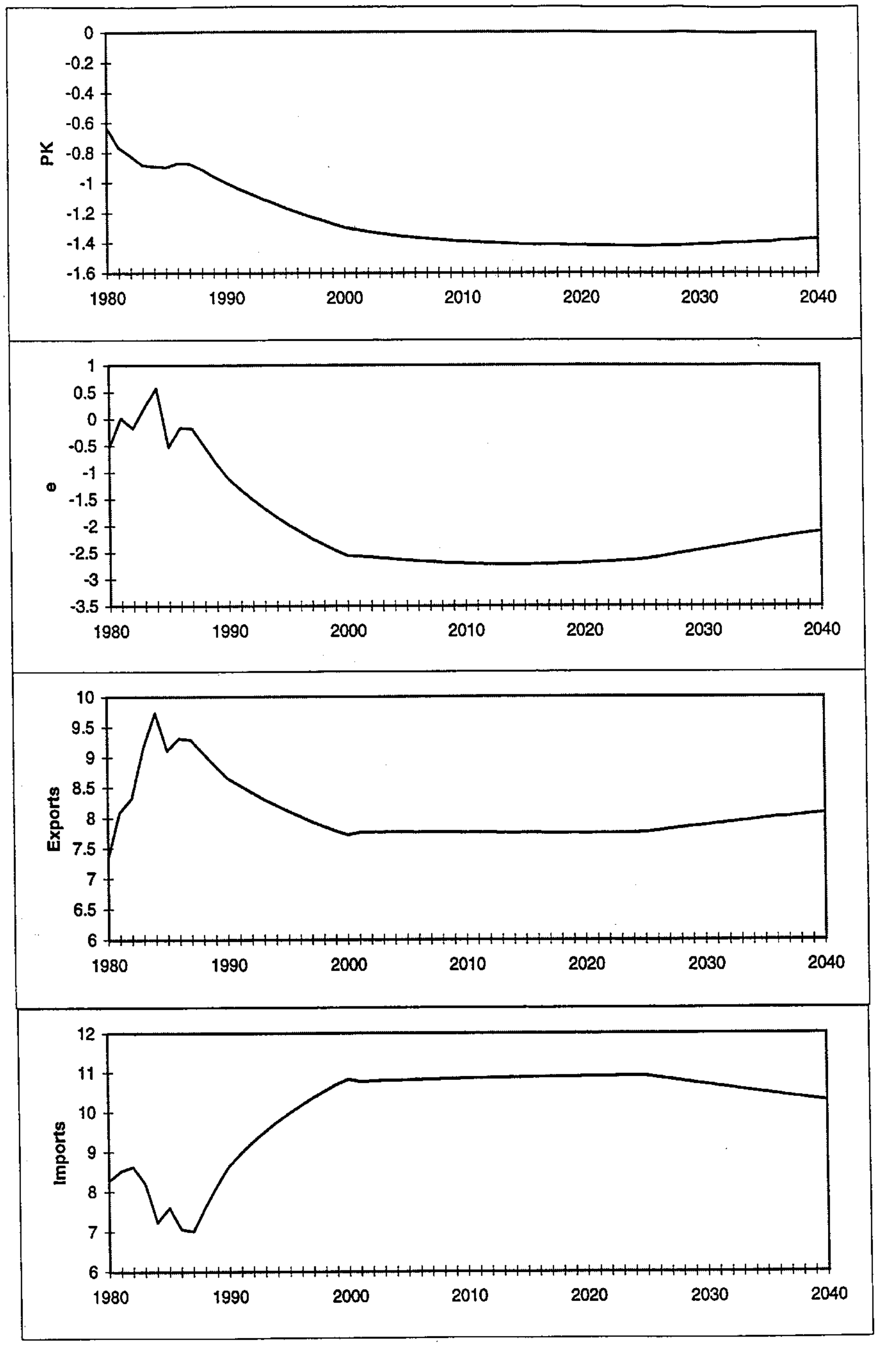


Table 8. Sectoral Effects of Eliminating Tariffs and Selected Quotas.

Sector	Output	Capital	Labor	Exports	Imports
Agriculture	-0.34	-0.43	-0.51	-0.14	1.97
Metal mining	2.10	2.09	1.86	-0.18	2.20
Coal mining	0.30	0.24	0.02	-0.27	0.60
Oil & gas mining	0.07	0.00	0.15	-0.32	0.56
Non-metal mining	0.50	0.32	0.03	-0.23	0.68
Construction	-0.15	-0.30	-0.17	-0.21	
Food & kindred	-0.50	-0.56	-0.62	-0.13	1.37
Tobacco	-0.54	-0.54	-0.73	-0.09	20.06
Textile mill	1.19	0.61	-0.24	19.91	25.64
Apparel	2.01	-0.46	-0.09	33.60	42.31
Lumber & wood	-0.12	-0.45	-0.83	3.81	3.91
Furniture	-1.20	-1.35	-1.49	16.81	4.93
Paper	0.81	0.67	0.62	8.94	1.75
Printing & publishing	0.90	0.93	0.72	3.89	2.29
Chemicals	2.45	2.38	2.31	15.13	7.74
Petroleum refining	0.18	0.19	0.09	-0.44	0.62
Rubber & plastic	1.30	1.21	1.01	13.44	14.38
Leather	-2.52	-3.59	-3.04	11.27	27.56
Stone Clay & Glass	-0.04	-0.16	-0.47	18.83	19.56
Primary metal	2.40	1.33	1.32	13.57	15.09
Fabricated metal	1.66	0.86	0.95	16.42	8.23
Machinery	2.36	1.59	1.45	11.96	9.87
Electrical machinery	2.02	1.46	1.72	17.94	10.52
Motor vehicles	1.58	1.13	0.29	13.95	5.02
Transport. equipment	2.87	2.15	2.10	13.15	6.70
Instruments	3.56	3.40	3.21	16.41	9.42
Misc. manufactures	1.50	1.28	1.02	14.58	10.89
Transportation	0.10	-0.01	-0.03	0.00	0.49
Communications	0.21	0.20	0.14	-0.07	
Electric Utilities	0.23	0.25	0.05	-0.02	0.12
Gas Utilities	0.35	0.31	0.25	-0.03	
Trade	0.10	0.06	0.05	-0.04	
Finance, Insurance	0.04	0.09	-0.01	-0.09	0.46
Services	-0.01	-0.04	-0.15	-0.15	0.45
Govt Enterprises	0.23	0.28	0.18	-0.14	
Household		-0.40	-0.50		
Government			-0.99		

Entries are percentage change from base case in 1980. Imports are competitive imports only.

In summary, the economic impact of quantitative restrictions is substantial, even though only a few commodities are affected by them. Elimination of these restrictions on the five items we have considered would produce a gain in U.S. consumption that exceeds the gain from abolishing all remaining tariffs. A multilateral reduction of nontariff barriers would probably have had an even greater impact, given the likelihood that quantitative restrictions in the rest of the world are even higher than those in the U.S.

4.3 Sensitivity Analysis

There are two major issues with the parameters used in this and any other model. The first is the usual variance of estimated parameters due to the error term. The second is the assumption of the functional forms, e.g. our logistic trends. Using quadratic instead of logistic trends would produce different parameter estimates of the price elasticities and other coefficients. This would not be the place to discuss the econometric issues in detail, we would merely follow the sensible practice of using different parameter values and report the sensivity of the results to the various parameters. (A more ambitious project would be to use the estimated variances to give confidence intervals for our estimates, as suggested by a discussant. This is a very involved exercise, as can be seen in the small model used in Pizer 1996.)

Trade Elasticities

For our exercise the most important parameter imprecision is the set of price elasticities in the import demand equations and the export elasticities taken from the literature. The strong feeling in the literature is that these substitution elasticities are biased downwards (Goldstein and Khan 1985). One problem is that aggregates are dominated by the low elasticity-high price volatility components, which would bias the estimates downwards. Following Deardoff and Stern (1986) we therefore, simply doubled all elasticities in our sensitivity analysis.[6] We used the 1985 shares to calculate the more elastic parameters. The export elasticities η_i are simply doubled.

In the steady state the capital stock gain due to a multilateral tariff elimination is 0.75%, in contrast to the 0.59% gain for base elasticities. Aggregate commodity consumption is 1.07% higher compared to 0.82% previously. Leisure falls 0.07% with the higher real wage. The real price of capital is 1.36% lower vs. 0.68%.

The steady state sectoral results of eliminating tariffs beginning in 1980 for the two sets of parameters are given in Table 9. The first three columns of numbers are the % changes in the section 4.1 experiment, the last three columns are the changes with the doubled elasticities. The differences are unfortunately large (or fortunately depending on one's emphasis). The elasticities obviously have a significant effect on the estimates of output response, it may even change the sign.

Overall, the magnitudes of export and import changes are increased and with no changes in sign. Output responses are different. Despite the increased aggregate labor supply some sectors show a reduction in output in response to the increased import competition. That is, in the more elastic case the

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[6] The elasticity of substitution is : $E = \frac{B}{share} + share - 1$ where *B* is the price coefficient of eqn. 5.

Table 9. Sensitivity test using more elastic trade parameters.

Sector	Base elasticities			Doubled elasticities		
	Output	Exports	Imports	Output	Export	Import
Agriculture	-0.56	-0.88	1.85	-1.59	-2.94	5.71
Metal mining	2.74	-1.13	2.39	2.91	-3.72	2.68
Coal mining	0.29	-1.37	1.83	-0.32	-4.20	3.92
Oil & gas mining	0.08	-1.12	2.19	-0.47	-2.56	3.63
Non-metal mining	1.32	-1.15	2.01	1.23	-3.76	3.12
Construction	-0.05	-0.53	0.00	-0.02	-0.63	0.00
Food & kindred	-0.98	-0.66	2.48	-1.68	-2.27	5.30
Tobacco	-0.83	-0.78	15.08	-1.48	-2.54	32.51
Textile mill	1.04	17.44	22.83	-2.55	34.31	39.56
Apparel	2.54	31.52	24.59	-2.28	66.07	39.73
Lumber & wood	0.22	2.17	4.89	-0.55	2.12	9.60
Furniture	-0.22	15.03	5.55	-0.04	28.84	11.36
Paper	1.00	7.09	3.45	0.87	12.30	7.33
Printing & publishing	0.96	2.18	3.45	1.01	1.83	6.55
Chemicals	3.31	13.56	8.97	4.74	25.76	16.41
Petroleum refining	0.54	-1.70	2.63	0.56	-4.02	5.65
Rubber & plastic	1.99	10.78	13.85	1.23	18.51	23.16
Leather	-1.56	9.09	14.76	-12.87	13.47	22.39
Stone Clay & Glass	0.51	17.05	12.38	-0.39	32.60	21.65
Primary metal	2.76	10.23	9.13	2.91	17.73	15.83
Fabricated metal	1.83	13.91	7.00	2.49	26.43	12.40
Machinery	3.54	9.63	11.79	6.43	16.58	40.20
Electrical machinery	3.55	15.84	11.53	4.24	29.95	20.00
Motor vehicles	2.89	12.52	8.93	2.78	23.14	17.94
Transport. equipment	3.77	10.79	7.87	6.10	19.62	17.07
Instruments	4.70	13.82	10.38	8.42	24.65	21.46
Misc. manufactures	1.90	13.21	8.93	-1.11	23.24	13.91
Transportation	0.32	0.01	1.99	0.33	0.02	2.86
Communications	0.55	-0.14	0.00	0.71	-0.17	0.00
Electric Utilities	0.76	0.22	0.65	0.86	0.41	0.56
Gas Utilities	0.84	0.13	0.00	1.22	0.37	0.00
Trade	0.11	-0.07	0.00	0.11	-0.09	0.00
Finance, Insurance	0.24	-0.12	1.91	0.26	-0.15	2.85
Services	0.02	-0.27	1.82	0.03	-0.34	2.75
Govt Enterprises	0.45	-0.16	0.00	0.55	-0.20	0.00

Entries are % changes between "no-tariffs" and "base" case.
Base trade elasticities are those estimated in Ho (1989).

Textile, Apparel, Lumber, and Miscellaneous Manufacturing industries have negative output responses to tariff reduction, while in the base elasticities case they are positive due to stronger export effects.

Time preference and labor supply

We now turn to other parameters in the model. The value of ρ, the rate of time preference, estimated over 1948-85 is 0.0288. In the alternative case we use a value of 0.04. The effect of this is very modest. Trade liberalization in this case produces a slightly smaller long run increase in the capital stock. For a given set of tariff rates, the rate of investment is of course higher in a $\rho = 0.03$ economy than in a $\rho = 0.04$ } economy. The *percentage* change in investment due to a reduction in tariffs is, however, roughly the same. (The steady state capital stock is 29,100 billion dollars in the base parameter case and 26,200 in the $\rho = 0.04$ case.)

Using a different value of the time preference parameter means using a different utility function and therefore utility comparisons must be made carefully. The equivalent variation of the welfare gain in the $\rho = 0.0288$ case is 0.14% (i.e. the change in utility value of the discounted stream of consumption as a percentage of initial wealth). The equivalent variation of the welfare gain in the $\rho = 0.04$ case is a similar 0.13% as reported in Table 10. In other words the percentage change is very similar but the levels are different.

As noted in section 2.2 above we have tried to track the secular increase in labor supply (i.e. the decrease in leisure per capita) using an exogenous time trend. In appendix equation A.8 the estimated values of the time trend parameters are $\beta_0 = 0.04$, $\mu = 0.585$. To simulate the effect of not tracking this shift we set the value of this β_0 to 0 and repeated the above calculations. That is, the base case with this new value of β_0 is simulated and then the tariffs are set to zero and a new path calculated. The effects of trade liberalization under this "no labor supply shift" scenario is reported in Table 10.

With no increase in the labor supply the paths of GDP and capital are lower than the base parameter case. The percentage increase in output and work hours due to the elimination of tariffs is, however, slightly bigger. This means a bigger percentage reduction in leisure and thus a smaller increase in full consumption and utility. The equivalent variation of trade liberalization is thus smaller, 0.10% versus 0.14%.

The other problem parameter discussed in section 2 is the labor supply price elasticity. We estimate the value of the share elasticity in the goods-leisure tier of the utility function to be 0.0375 (this is the first element of the 2x2 B matrix in appendix equation A.6.) A value of $B_{11} = 0$ corresponds to the Cobb-Douglas case of unit elasticity, our value estimated from time series aggregate data is a little less elastic than that. To see the effects of a more inelastic labor supply we set the value of B_{11} to twice the base case. The results (also reported in Table 10) are not surprising, a more inelastic function leads to a smaller increase in labor supply due to a rise in the real wage when the prices of goods fall due to the tariff cuts. This leads to a smaller increase in long run output and capital. The effect on capital accumulation is plotted in Fig. 7. (The bold line gives the effect of trade liberalization on the path of capital stock using original parameters, the dotted line gives the effect using more inelastic parameters.) The welfare effect of trade liberalization, measured in terms of this different utility function, is thus lower than the base parameter case, 0.12% versus 0.14%.

Table 10. Sensitivity analyses of different values of time preference and leisure trends.

	dK	dY	E.V.
Base case ($\rho = 0.0288$, $\beta_0 = 0.04$, $\beta^{CL} = 0.0375$)	0.65%	0.71%	0.14%
High time preference case ($\rho = 0.04$)	0.64%	0.80%	0.13%
No labor supply shift case ($\beta_0 = 0$)	0.68%	0.46%	0.10%
More inelastic labor supply ($\beta^{CL} = 0.0750$)	0.53%	0.57%	0.12%

dK = Change in steady state capital stock due to trade liberalization
dY = Change in steady state GDP due to trade liberalization
E.V. = Equivalent variation as share of Wealth due to liberalization

It is clear from comparing the various rows of Table 10 that there is no systematic relation between the effect on steady state capital, output and welfare. These must be calculated separately for a complete sensitivity analysis. There are some parameters that affect the level of the projections but has little effect on the percentage change, and hence are less of a worry. These include the rate of time preference, the population growth rate, and the exogenous rate of long-run neutral technical progress.

5 Conclusion

In this paper we have described some of the issues that must be addressed in implementing dynamic multi-sector general equilibrium models of trade policy and economic growth. Such models are useful in that they can capture dynamic adjustments by businesses and households to changes in policy. These effects predominate in the long run, so that economic impacts estimated from static models may be substantially understated.

Our specific estimate is that a multilateral elimination of tariffs alone beginning in 1980 raised long run consumption by 0.82% compared to an initial gain of only 0.16%. Eliminating both tariffs and nontariff barriers lead to a long-run gain in consumption of 1.08% versus 0.36% in the first year. The ratio of welfare cost to the tariffs is about 2. With more comprehensive estimates of tax equivalents of the quotas that we have ignored here the welfare and growth effects would of course be higher.

These estimates are sensitive to the assumptions of the model and the parameter values used. We have illustrated the magnitude of the effect using different key parameters on welfare, output and capital accumulation. As is well known, using more elastic substitution elasticities will lead to gains that are bigger than the base case ones. We have also performed sensitivity analysis on parameters that are not subsitution elasticities. It is hoped that this is useful for users of numerical models to get a sense of the range of uncertainty.

The degree of sensitivity found here highlights again the need to carefully relate the results of numerical models to the underlying assumptions, of which many must be made in this kind of analysis. Complete Monte Carlo investigations of the sort econometricians do may not be feasible for complicated models like these but even limited sensitivity tests would be very useful.

TECHNICAL APPENDIX IS AVAILABLE ON REQUEST.

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DATA APPENDIX

The data for this model covers the period 1974 to 1985 and follows the methodology of Christensen and Jorgenson (1973) and Jorgenson, Gollop, and Fraumeni (1987) (JGF). The goal of the exercise is to construct a time series of input-output tables (Both "use" and "make" matrices) over which one can estimate the production and demand function. In addition we also need financial accounts that are not in the i-o tables.

The constructions of the i-o matrices are described in Wilcoxen (1988), basically, the official tables published every 5 years are interpolated using annual industry data.[7] The capital and labor inputs (the value-added rows in the i-o table) are updated with some improvements following the approach in JGF. The detailed investment data from the BEA is cumulated into stocks of capital by Divisia aggregation, the rental price of capital is calculated from National Income Accounts (NIA). Labor input is aggregated over the labor force cross-classified by sex, age, educational attainment and industry. With the Divisia aggregation we take into account the different productivities of the various groups, instead of a simple sum of hours.

The final demand columns are estimated from the NIA and "bridge tables" from the official i-o tables. Imports are aggregated from trade data classified according to the SITC,[8] and price indices from the BLS are used where available (unit values are used otherwise). The financial accounts (stocks of debt, government accounts, tax rates, etc.) are from the *US Worksheets* which are revised of Christensen and Jorgenson.

The top tier of the production functions are estimated using the "use matrix," while the bottom tiers are from Hudson and Jorgenson. The first two stages of the household model are estimated from aggregate data in the *US Worksheets*. The top tier of the Consumption function is from Jorgenson and Slesnick, while the bottom tiers are estimated from the i-o table, as are the investment functions. The import share equations are estimated from the "import" and "total output" columns of the i-o table. Al estimates are reported in Chapters 4 and 5 of Ho (1989).

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[7] I-O data are from the Bureau of Economic Analysis, the latest version is described in the *Survey of Current Business* May 1984. Annual industry output and prices are from the Bureau of Labor Statistics database *Time Series on Output, Prices, and Employment*.

[8] At the 4-digit level and supplemented by more detailed dtat where necessary to get a better price index. The former are from the OECD data base and the 7-digit data from the Census Bureau's *US Improts by SITC*.

Unilateral versus Multilateral Trade Liberalization: The Importance of International Financial Flows

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ABSTRACT

This paper explores the impact on economies of trade liberalization under alternative regional and multilateral arrangements: unilateral liberalization; liberalization as part of the ASEAN regional grouping; liberalization as part of the APEC regional grouping; or liberalization as part of a multilateral trade liberalization regime. A primary focus is on the role of international financial flows during the liberalization process. The paper is based on a Dynamic Intertemporal General Equilibrium model (DIGEM) called the Asia-Pacific G-Cubed Model. It is shown that the long run gains from a country's own liberalization tend to be large relative to the gains from other countries liberalizing although this varies across countries. It is also shown that there is a significant difference between the effects on GDP (production location) and the effects on consumption per capita of the alternative liberalization approaches across countries. This difference reflects the adjustment of international financial flows. The timing of liberalization is also shown to matter. With open capital markets the gains from credibly announced trade liberalization are realized before the reforms are put in place because there is a rise in global investment which raises the global capital stock. In addition there is a reallocation of capital via financial market adjustment. This paper also demonstrates that for some economies, there can be short run adjustment costs to trade liberalization because resources cannot be instantly reallocated across sectors in an economy. These adjustment costs from own liberalization can be reduced if more countries also liberalize. The nature of the dynamic adjustment suggests that other macroeconomic policies may play an important role during the early period of phased-in trade liberalization.

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1. Introduction

When a country reduces barriers to international trade, there are a number of factors that determine the nature of the gains and losses that result in both the short run and the longer run. Some of the key mechanisms through which gains are realized are direct, but many others are indirect and require the use of an economy wide model to capture these effects. In addition, the time profile of liberalization as well as the fact that it is not costless to restructure any economy complicate the analysis in the short run. Many studies and the professional debate in general, tend to ignore the short run adjustment issues of trade liberalization. This complicates the political barriers to trade liberalization once the liberalization begins because the gains take a while to materialize and are widely dispersed yet the costs are usually highly visible and incurred in the short term. This of course differs across economies and depends on whether liberalization is being undertaken during a period of rapid or stagnant economic growth. With highly visible short run job losses, the resolve of liberalizers are sorely tested. The nature of these adjustment problems are important to explore empirically because it needs to be recognized in advance that some costs may be incurred while achieving more substantial medium term and long term gains. However, understanding the likely adjustment path is also important for formulating appropriate macroeconomic policy responses in order to ease the transition. It is reassuring to know from many CGE studies that gains will be achieved in the long run from trade liberalization, but it is possibly more important for policy makers to know what the road will look like during the adjustment process.

Computable General Equilibrium (CGE) models have become a popular tool for calculating the various direct and indirect effects of trade liberalization and have given a range of useful insights. The sorts of mechanisms that these models capture are clear. In the case of unilateral liberalization, a reduction in trade barriers tends to reduce import prices which increases the purchasing power of consumers, thus making consumers directly better off . The change in relative prices induces firms to reallocate resources away from protected sectors towards other more efficient activities which tends to raise economic efficiency in the economy. CGE models are particularly useful for calculating how much the efficiency gains will be and how much consumption will rise a result of these processes in the longer run.

However, there are a number of other gains that many standard CGE models ignore. One aspect is if there is imperfect competition or increasing returns to scale (see Francois et al (1995)). Another occurs if the removal of distortions increases the return to capital and stimulates investment in the economy. These dynamic effects can be much larger than the efficiency triangles many CGE modelers calculate (See McKibbin and Salvatore (1995) and Kouparitsas (1997)). Once allowance is made for the reality that financial capital is mobile internationally and these financial flows are related to the real returns to physical capital then further complications arise. If domestic saving does not rise as the return to capital rises from trade liberalization and these additional investments are made by foreign owners of capital, then additional GDP will be generated in the economy but this won't show up directly as a domestic consumption gain because the returns will be repatriated to foreign owners of capital (see Manchester and McKibbin (1995)). Thus is it important in evaluating trade liberalization in terms of income or consumption gains rather than changes in production or GDP (see McKibbin (1996)). In all evaluations of trade liberalization, understanding the dynamic path of adjustment is crucial.

The gains to an economy from the liberalization of another economy are also transmitted through a number of channels. The reduction in trade barriers in foreign economies (ceteris paribus) will stimulate the demand for exports which will raise income in the home economy although not by the full value of increased exports because these exports need to be produced with resources that otherwise would be domestically consumed. Secondly owners of capital in the home economy may be able to invest in the liberalizing economy leading to additional income gains if those investments realize a higher rate of return than in the home economy.

The process becomes more complicated in the case where trade reform is phased in or where an economy exhibits short term Keynesian features either due to wage stickiness or adjustment costs in allocating physical capital or where asset prices adjust quickly in response to international financial capital flows yet other prices are more sticky. In this case overshooting of the exchange rate (e.g. Dornbush (1976)) during the adjustment process can complicate the standard insights.

This paper has a number of goals all of which are aimed at improving our understanding of the magnitude of the above factors. The first goal is to determine the extent to which longer run gains from trade liberalization for particular economies are due to domestic liberalization versus gains from other countries liberalizing. This provides direct evidence for the arguments by economists such as Garnaut (1996) that trade liberalization is a prisoners delight (all participants gain) rather than a prisoners dilemma (where a gain by one country is a loss for another). Trade liberalization under four alternative trade groupings are considered in this paper: **unilateral** liberalization; **ASEAN** liberalization; **APEC** liberalization; and **multilateral** liberalization involving APEC and European economics. In each case the trade liberalization is phased in according to the timetable underlying the APEC Bogor declaration in which industrial economies reduced barriers to trade to zero by 2010 and developing economies by 2020 (the exception is that Taiwan, Korea and Singapore follow the 2010 timetable)[2]. This type of liberalization assumes the concept of "open regionalism" defined by Garnaut (1996) in which liberalization is non discriminatory. Thus the paper does not focus on regional trading blocs per se. Discriminating and non-discriminating trade reform in ASEAN versus APEC regional groups using an earlier version of the same multi-country model are explored further in McKibbin (1996).

The second goal of the paper is to show the difference between the allocation of production across economies as a result of trade liberalization versus the gain in welfare which we measure by gains in real consumption per capita. It is quite possible for GDP to fall in a country but for consumption to rise because the additional income is generated by shifting production overseas. In the model underlying this study, labor is assumed to be immobile across economies but there is a high degree of financial capital mobility (which over time implies mobility of physical capital in response to arbitrage between financial returns and the real rate of return to physical capital adjusted by the cost of moving physical capital). Therefore to the extent that trade liberalization leads to a reallocation of capital to take advantage of high rates of return from other countries liberalization, there can be a fall in GDP but higher income to domestically owned factors of production and therefore higher consumption generated.

The third goal is to explore the short run adjustment process when there is allowance for Keynesian style rigidities in labor markets; costly to adjust physical capital stocks and exchange rate overshooting from a combination of sticky wages and flexible asset prices.

This study can be distinguished from other studies of trade liberalization such as in Dee and Walsh (1994), Francois et al (1995), Goldin and van der Mensbrugghe (1995), Harrison et al (1995), Hertel et al

[2] Trade in services is assumed not to be liberalized even though we can explore this in the modelling framework. This will be explored in future research.

(1995), Huff et al (1995) Martin et al (1995) or Murtough et al (1994) because the model used in this paper is not from the class of static or period linked CGE models that have been used in these earlier studies. This study follows the alternative Dynamic Intertemporal General Equilibrium (DIGEM) approach focusing on the dynamic adjustment to trade reform as in Manchester and McKibbin (1995), McKibbin (1994) using the MSG2 model; McKibbin and Salvatore (1995) using the GCUBED model; and McKibbin Pearce and Wong (1995) and McKibbin (1996) using the Asia Pacific G-Cubed Model[3].

The model used in this paper is derived from the G-Cubed model developed by McKibbin and Wilcoxen (1995). Because of this link, this model is named the Asia-Pacific GCUBED model (AP-GCUBED). As with the GCUBED model, this new model captures simultaneously the macroeconomic and sectoral linkages in a global model with partially forward looking asset market and spending decisions (assuming rational expectations). The AP-GCUBED model has country/regional dis-aggregation of: Korea, Japan, Thailand, Indonesia, China, Malaysia, Singapore, Taiwan, Hong Kong, Philippines, Australia, United States, India, Rest of the OECD, Oil exporting developing countries, Eastern Europe and Former Soviet Union and all other developing countries. Each country/region has an explicit internal macroeconomic and sectoral structure with sectoral dis-aggregation in production and trade into 6 sectors based on data from standardized input/output tables.

Section 2 gives a brief overview of the theoretical basis of the AP-GCUBED model. The alternative scenarios for trade liberalization are analyzed in section 3. The results are examined in two parts. The longer term outcomes are examined first in order to determine for each economy whether the gains arise from own liberalization or various forms of coordinated liberalization. The dynamic adjustment path is then explored for a subgroup of countries focusing on how economic activity and trade and capital flows adjust to trade liberalization that is gradually phased in.

A conclusion is presented in section 4.

2. The AP- GCUBED model

The AP-GCUBED multi-country model is based on the GCUBED model developed in McKibbin and Wilcoxen (1995). It combines the approach taken in the MSG2 model of McKibbin and Sachs (1991) with the dis-aggregated, econometrically-estimated, intertemporal general equilibrium model of the U.S. economy by Jorgenson and Wilcoxen (1989). The MSG2 model had one sector per country. The Jorgenson-Wilcoxen model has 35 separate industries, each of which is represented by an econometrically estimated cost function. The AP-GCUBED model has 6 sectors in each of 17 economies.

The GCUBED model was constructed to contribute to the current policy debate on global warming, trade policy and international capital flows, but it has many features that make it useful for answering a range of issues in environmental regulation, microeconomic and macroeconomic policy questions. It is a world model with substantial regional dis-aggregation and sectoral detail. In addition, countries and regions are linked both temporally and intertemporally through trade and financial markets.

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[3] See also Kouparitsas (1997) for a dynamic model of NAFTA trade reform in a 3 country model. This alternative but very similar approach has evolved from the real business cycle literature and has many similarities to the supply side approach taken in the G-Cubed model.

Like MSG2, GCUBED contains a strong foundation for analysis of both short run macroeconomic policy analysis as well as long run growth consideration of alternative macroeconomic policies. Intertemporal budget constraints on households, governments and nations (the latter through accumulations of foreign debt) are imposed. To accommodate these constraints, forward looking behavior is incorporated in consumption and investment decisions. Unlike MSG2, the GCUBED model also contains substantial sectoral detail. This permits analysis of environmental and trade policies which tend to have their largest effects on small segments of the economy. By integrating sectoral detail with the macroeconomic features of MSG2, GCUBED can be used to consider the long run costs of alternative environmental regulations and trade policy changes yet at the same time consider the macroeconomic implications of these policies over time. The response of monetary and fiscal authorities in different countries can have important effects in the short to medium run which, given the long lags in physical capital and other asset accumulation, can be a substantial period of time. Overall, the model is designed to provide a bridge between computable general equilibrium models and macroeconomic models by integrating the more desirable features of both approaches. The AP-GCUBED model differs from the GCUBED model because of the focus on the Asia-Pacific region as well as having 6 sectors compared to 12 for GCUBED. The theoretical structure is essentially the same.

The key features of AP-GCUBED are summarized in Table 1. The country and sectoral breakdown of the model are summarized in Table 2. It consists of seventeen economic regions with six sectors in each region (there are also two additional sectors in each region that produce the capital good for firms and the household capital good). The seventeen regions in AP-GCUBED can be divided into two groups: 14 core countries/regions and three others. For the core regions, the internal macroeconomic structure as well as the external trade and financial linkages are completely specified in the model. Our approach for each country is to first model them assuming the theoretical structure we use for the "generic" country but calibrating each country to actual country data. We then proceed country by country to impose institutional features, market structures, market failures or government regulations that cause certain aspects of these economies to differ from our generic country model. In this paper we have only just begun this process, therefore the countries we represent in the region are endowed with resources, trading patterns, saving and investment patterns etc that are based on actual data for these countries but in many important ways may not be truly representative of these countries because of institutional factors that we are still implementing into the model.

Each core economy or region in the model consists of several economic agents: households, the government, the financial sector and the 6 production sectors listed in table 2. Each of these economic actors interact in a variety of markets, both domestic and internationally.

Each of the six sectors within each country is represented by a single firm in each sector which chooses its flexible inputs (labor, energy, materials) and its level of investment in order to maximize its stock market value subject to a multiple-input production function (KLEM), knowledge that physical capital is costly to adjust once it is in place, and subject to a vector of prices it takes to be exogenous. Energy and materials are an aggregate of inputs of intermediate goods. These intermediate goods are, in turn, aggregates of imported and domestic commodities which are taken to be imperfect substitutes. Due to data limitations we assume that all agents in the economy have identical preferences over foreign and

Table 1: Summary of Main Features of AP-GCUBED

☻ Specification of the demand and supply sides of economies;

☻ Integration of real and financial markets of these economies with explicit arbitrage linkage real and financial rates of return;

☻ Intertemporal accounting of stocks and flows of real resources and financial assets;

☻ Imposition of intertemporal budget constraints so that agents and countries cannot forever borrow or lend without undertaking the required resource transfers necessary to service outstanding liabilities;

☻ Short run behavior is a weighted average of neoclassical optimizing behavior based on expected future income streams and Keynesian current income;

☻ The real side of the model is dis-aggregated to allow for production of multiple goods and services within economies;

☻ International trade in goods, services and financial assets;

☻ Full short run and long run macroeconomic closure with macro dynamics at an annual frequency around a long run Solow/Swan/Ramsey neoclassical growth model.

☻ The model is solved for a full rational expectations equilibrium at an annual frequency from 1995 to 2070.

Table 2: Overview of the AP-GCUBED Model

Regions:

- United States
- Japan
- Australia
- Rest of the OECD
- India
- Korea
- Thailand
- Indonesia
- China
- Malaysia
- Singapore
- Taiwan
- Hong Kong
- Philippines
- Oil Exporting Developing Countries
- Eastern Europe and the former Soviet Union
- Other Developing Countries

Sectors:

- Energy
- Mining
- Agriculture
- Non Durable Manufacturing
- Durable Manufacturing
- Services

Agents

- Households
- Firms
- Governments

Markets:

- Final Goods
- Services
- Factors of production
- Money
- Bonds
- Equities
- Foreign Exchange

domestic varieties of each particular commodity. We represent these preferences by defining six composite commodities that are produced from imported and domestic goods.

Following the approach in the MSG2 model, we assume that the capital stock in each sector changes according to the rate of fixed capital formation and the rate of geometric depreciation. The investment process is assumed to be subject to rising marginal costs of installation, with total real investment expenditures in sector equal to the value of direct purchases of investment plus the per unit costs of installation. These per unit costs, in turn, are assumed to be a linear function of the rate of investment. One advantage of using an adjustment cost approach is that the adjustment cost parameter can be varied for different sectors to capture the degree to which capital is sector specific.

The price of labor is determined by assuming that labor is mobile between sectors in each region, but is immobile between regions. Thus, wages will be equal across sectors. The wage is assumed to adjust to varying degrees based on labor market institutions in the different economies. In the long run, labor supply is given by the exogenous rate of population growth, but in the short run, the hours worked can fluctuate depending on the demand for labor. For a given nominal wage, the demand for labor will determine short run unemployment in each industry. This will vary across industries depending on the composition of demand for each sectors good.

The solution of the optimization problem also gives that the rate of gross investment in sector h is a function of "Tobin's q" for that sector. Following the MSG2 model, it is assumed that investment in each sector is a weighted average of forward looking investment and investment out of current profits.

Households consume a basket of composite goods and services in every period and also demand labor and capital services. Household capital services consist of the service flows of consumer durables plus residential housing. Households receive income by providing labor services to firms and the government, and from holding financial assets. In addition, they also receive transfers from the government.

Aggregate consumption is chosen to maximize an intertemporal utility function subject to the constraint that the present value of consumption be equal to human wealth plus initial financial assets. Human wealth in real terms is defined as the expected present value of future stream of after tax labor income of households. Financial wealth is the sum of real money balance, real government bonds in the hand of the public, net holding of claims against foreign residents and the value of capital in each sector. The solution to this maximization problem is the familiar result that aggregate consumption is equal to a constant proportion of private wealth, where private wealth is defined as financial wealth plus human wealth. However, based on the evidence cited by Campbell and Mankiw (1987) and Hayashi (1982)) we follow the approach in the MSG2 model and assume that only a portion of consumption is determined by these intertemporally-optimizing consumers and that the remainder is determined by after tax current income. This can be interpreted as liquidity constrained behavior or a permanent income model in which household expectations regarding income are backward-looking. Either way we assume that total consumption is a weighted average of the forward looking consumption and backward-looking consumption.

Once the level of overall consumption has been determined, spending is allocated among goods and services based on relative prices.

We take each region's real government spending on goods and services to be a fixed share of GDP and assume that it is allocated among final goods (consisting of both domestically produced and imported goods), services and labor in fixed proportions, which we set to 1992 values. Total government outlays include purchases of goods and services plus interest payments on government debt, investment tax credits and transfers to households. Government revenue is generated from sales tax, corporate income tax and personal income taxes, and by issuing government debt. We assume that agents will not hold government bonds unless they expect the bonds to be paid off eventually. This transversality condition implies that the current level of debt will be equal to the present value of future budget surpluses.[4]

The implication of these constraints is that a government running a budget deficit today must run an appropriate budget surplus as some point in the future. Otherwise, the government would be unable to pay interest on the debt and agents will not be willing to hold it. To ensure that the constraint holds at all points in time we assume that the government levies a lump sum tax in each period equal to the value of interest payments on the outstanding debt.[5] In effect, therefore, any increase in government debt is financed by consols, and future taxes are raised enough to accommodate the increased interest costs. Thus, any increase in the debt will be matched by an equal present value increase in future budget surpluses. Other fiscal closure rules are possible, such as requiring the ratio of government debt to GDP to be unchanged in the long run. These closures have interesting implications but are beyond the scope of this paper.

The seventeen regions in the model are linked by flows of goods and assets. Flows of goods are determined by the import demands described above (based on demand for goods for consumption, investment and government uses).

Trade imbalances are financed by flows of financial assets between countries (except where capital controls are in place). We assume that existing wedges between rates of return in different economies are generated by various restrictions that generate a risk premium on country denominated assets. These wedges are assumed to be exogenous during simulation. Thus when the model is simulated the induced changes in expected rates of return in different countries generate flows of financial capital reacting to return differentials at the margin.

Determining initial net asset positions and hence base-case international capital flows is non-trivial. We assume that capital flows are composed of portfolio investment, direct investment and other capital flows. These alternative forms of capital flows are perfectly substitutable ex ante, adjusting to the expected rates of return across economies and across sectors. Within an economy, the expected return to each type of asset (i.e. bonds of all maturities, equity for each sector etc) are arbitraged, taking into account the costs of adjusting physical capital stock and allowing for exogenous risk premia. Because physical capital is costly to adjust, any inflow of financial capital that is invested in physical capital (i.e. direct investment) will also be costly to shift once it is in place. The decision to invest in

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[4] Strictly speaking, public debt must be less than or equal to the present value of future budget surpluses. For tractability we assume that the government is initially fully leveraged so that this constraint holds with equality.

[5] In the model the tax is actually levied on the difference between interest payments on the debt and what interest payments would have been if the debt had remained at its base case level. The remainder, interest payments on the base case debt, is financed by ordinary taxes.

physical assets is based on expected rates of return. However, if there is an unanticipated shock then ex-post returns could vary significantly. Total net capital flows for each economy in which there are open capital markets are equal to the current account position of that country. The global net flows of private capital are constrained to zero.

The data used in the AP-GCUBED model comes from a number of sources. Unlike the GCUBED model we have not yet estimated the CES production elasticities of substitution. We currently assume the production function are Cobb-Douglas.

The input-output tables for the Asia-Pacific economies are from the Institute of Developing Economies. The Australian table is from the Australian Bureau of Statistics. In lieu of obtaining input-output tables for the aggregate ROECD region, we currently create the tables for this region based on the U.S. table and adjusted for actual final demand components from aggregate ROECD macroeconomic data. In effect, we are assuming that all countries modeled share the same production technology but differ in their endowments of primary factors and patterns of final demands. This assumption is a temporary necessity while we complete construction of the AP-GCUBED database.

Trade shares are based on the United Nations SITC (Standard Industry Trade Classification) data for 1992 with sectors aggregated from 4 digit levels to map as closely as possible to the SIC (Standard Industry Classification) used in the U.S. input/output data. This data is from the International Economic Databank at the ANU.

The parameters on shares of optimizing versus backward looking behavior are taken from the MSG2 model. These are based on a range of empirical estimates (see Campbell and Mankiw (1987) and Hayashi (1982)) as well as a tracking exercise used to calibrate the MSG2 model to the experience of the 1980s (see McKibbin and Sachs (1991)). It is important to stress that the results in this paper are very sensitive to the range of parameters used in the model. In particular the substitution possibilities in production are important. It is worth stressing that the adjustment cost model of capital accumulation implies that short run changes in inputs for a given relative price change will be lower than the long run substitution possibilities (despite having the same partial substitution elasticities in the short and long runs) precisely because physical capital is fixed in the very short run and therefore substitution possibilities are reduced.

AP-GCUBED is solved using the same software as the MSG2 model The model has approximately 7,400 equations in its current form with 140 jumping or forward looking variables, and 263 state variables. For further details on the model the reader should refer to McKibbin and Wilcoxen (1995), McKibbin and Bok (1993) and McKibbin and Wong (1998).

3. Results for Trade Liberalization

The results for trade liberalization in each country under each regional grouping are presented in this section. Results are first presented for the longer run outcomes focusing on the year 2020. Next the dynamics of adjustment for various countries are examined in some detail. There are a vast number of results and in this section a subset are presented to illustrate various key points.

To generate the results we first solve the model from 1996 to 2070 to generate a model baseline based on a range of assumptions. Table 3 contains the aggregated tariff rates for each sector and each region in the model based on a WTO tariff database supplied by the Centre for International Economics. These tariff rates are assumed to be unchanged for the horizon of the baseline simulation. Other crucial assumption needed for generating the baseline include assumptions about population growth and sectoral productivity growth by country as well as fiscal and monetary policy settings. The issue of projection using a model such as the AP-GCUBED model is discussed in detail in Bagnoli et al (1996).

Once the baseline is generated each simulation is run and results are reported as a percentage deviation from this baseline. For each tariff reduction simulation countries are assumed to reduce tariff rates from the levels shown in table 3 to zero over the period specified. In each case industrial economies are assumed to reduce tariffs in equal increments from 1996 through 2010. Developing countries are assumed to reduce tariffs by 2020. Taiwan, Singapore and Korea are assumed to follow the timetable for non developing economies.

It is important to stress that macroeconomic policy is assumed not to respond to undesirable fluctuations in short run economic activity. Monetary policy is assumed to be targeting a stock of nominal money balances in each economy. Fiscal policy is defined as a set of fixed tax rates (apart from a lump sum tax on households that varies to satisfy the intertemporal budget constraint facing the government) and government spending constant relative to simulated GDP. With higher output, tax revenues rise implying a move towards fiscal surplus in each economy. In McKibbin (1996), higher growth meant lower fiscal deficits. In this paper the higher growth leads to higher government spending and therefore fiscal deficits are relatively constant.

Table 3: Initial Tariff Rates

	Agriculture	Energy	Mining	Durable Manufacturing	Non Durable Manufacturing
United States	6.7	0.5	0.0	8.5	26.2
Japan	148.8	1.1	0.6	4.9	59.4
Australia	1.9	0.7	0.7	13.9	15.2
Indonesia	11.0	1.5	2.4	16.4	11.4
Malaysia	104.0	2.5	3.5	13.7	57.4
Philippines	104.0	5.8	10.2	24.1	63.3
Singapore	9.9	2.1	0.0	0.2	9.6
Thailand	107.6	6.9	10.9	33.4	70.5
China	16.7	14.0	18.7	45.1	43.5
Taiwan	12.6	14.3	23.5	39.3	42.1
Korea	105.0	2.8	4.4	16.0	41.0
Hong Kong	0.0	0.0	0.0	0.0	0.0
India	24.0	0.9	3.2	15.7	20.7
ROECD	6.9	0.4	0.2	8.2	16.5

Source: Centre for International Economics aggregations based on WTO/World Bank data.

a. Longer Run Results

Tables 4 through 7 show results for GDP, consumption, investment and exports under the four assumptions about the group of countries undertaking the trade liberalization. The results in each table are the percentage deviation from what otherwise would have occurred by 2020 relative to the baseline projection of the model without any trade liberalization.

First refer to the results for real GDP in Table 4. The first column contains the country names. The second column shows that the percentage deviation in US GDP from own liberalization is -0.04% relative to baseline by 2020. This compares to a gain in GDP of 0.23% under both APEC (column 4) and multilateral (column 6) liberalization. For each country, GDP is higher when liberalization is

Table 4: Percentage Change in real GDP in 2020 from Trade Liberalization

	Own	ASEAN	APEC	Multilateral
United States	-0.04	0.03	0.23	0.23
Japan	-0.95	-0.01	-0.87	-0.86
Australia	0.62	0.01	0.77	0.82
Indonesia	1.58	1.99	6.19	6.93
Malaysia	1.09	1.44	1.77	1.84
Philippines	-0.28	-0.18	1.99	2.26
Singapore	0.64	0.79	0.91	1.09
Thailand	-1.42	-1.14	1.00	1.40
China	0.46	-0.01	0.91	1.01
India	0.24	0.00	0.12	0.49
Taiwan	0.96	0.05	1.80	1.92
Korea	-0.66	-0.04	0.08	0.17
Hong Kong	0.00	0.04	0.16	0.18
ROECD	0.05	0.00	0.07	0.12

Table 5: Percentage Change in Real Consumption in 2020 from Trade Liberalization[6]

	Own	ASEAN	APEC	Multilateral
United States	0.23	0.20	1.89	1.73
Japan	0.35	0.02	0.84	0.89
Australia	1.74	0.06	1.93	2.03
Indonesia	2.86	3.45	9.45	10.34
Malaysia	9.05	10.73	14.61	15.00
Philippines	3.96	4.28	7.09	7.42
Singapore	1.71	3.66	5.86	6.09
Thailand	3.73	4.31	7.10	7.53
China	2.34	0.06	3.88	4.12
India	1.03	0.04	-0.06	1.11
Taiwan	5.06	0.26	10.05	10.74
Korea	1.43	0.02	4.28	4.63
Hong Kong	0.00	0.43	0.09	0.00
ROECD	0.66	0.03	0.30	0.97

[6] Note that results for consumption and exports are now expressed as percentage deviation from baseline. In earlier versions of this paper they were expressed as percent of GDP deviation from baseline.

Table 6: Percentage Change in Real Investment in 2020 from Trade Liberalization

	Own	**ASEAN**	**APEC**	**Multilateral**
United States	-0.14	0.33	2.84	2.66
Japan	-1.92	-0.12	-1.78	-1.85
Australia	3.55	-0.05	4.39	4.51
Indonesia	3.16	3.37	7.01	7.63
Malaysia	0.47	1.26	2.79	3
Philippines	2.37	2.53	3.5	3.58
Singapore	-0.49	-0.22	0.73	0.88
Thailand	0.4	0.49	1.8	2.01
China	0.62	-0.08	0.75	0.8
India	0.8	-0.03	-0.21	0.73
Taiwan	2.94	-0.11	4.37	4.51
Korea	-0.55	-0.16	0.31	0.36
Hong Kong	0	0	0.52	0.48
ROECD	0.99	-0.01	1.06	2.06

Table 7: Percentage Change in Real Exports in 2020 from Trade Liberalization[7]

	Own	**ASEAN**	**APEC**	**Multilateral**
United States	14.49	0.16	14.63	21.90
Japan	10.08	0.66	13.28	15.24
Australia	8.51	1.36	18.76	21.77
Indonesia	3.00	4.76	13.20	15.78
Malaysia	12.57	15.33	19.92	22.13
Philippines	12.67	14.93	30.95	34.46
Singapore	1.88	3.66	10.97	13.25
Thailand	22.30	24.00	34.93	38.31
China	12.17	0.76	19.77	21.93
India	8.65	2.72	14.76	32.40
Taiwan	11.77	0.95	17.24	18.71
Korea	7.57	0.72	14.17	16.00
Hong Kong	0.00	0.90	8.91	10.85
ROECD	5.35	0.49	6.68	12.08

[7] Note that results for consumption and exports are now expressed as percentage deviation from baseline. In earlier versions of this paper they were expressed as percent of GDP deviation from baseline

undertaken with other countries in a group than undertaken alone. The highest gains for GDP occur under multilateral liberalization. For some countries (U.S., Japan, Philippines, Thailand and Korea) , own liberalization leads to a reduction in GDP. This implies that capital flows out of the liberalizing economy into other economies as a result of the trade reforms. This is not necessarily a negative outcome as can be seen from the results in table 5 for consumption in each economy. All countries have higher consumption by 2020 under unilateral liberalization despite the fact that GDP fell for some countries. This is because the return to capital that is freed up as a result of the liberalization is higher than under baseline but some of this higher return is being earned outside the domestic economy.

The consumption results follow the same pattern as the GDP results as you move across the table from left to right, in the sense that consumption is higher when liberalizing with a group of countries relative to liberalizing alone. This suggests that trade liberalization, at least in the longer run, should be "prisoners delight" in the Garnaut(1996) sense. A country's own liberalization raises consumption and the liberalization by other countries raises your consumption even more. One point to note from the consumption and GDP comparison is that for some countries the gains from own liberalization more than outweigh the gains to the same country from other countries liberalizing. For example the gains to Australia from APEC liberalization increase Australia's gain from own liberalization by 11% and multilateral liberalization increases these gains by 17%. In contrast for the United States, own liberalization gains are small and most of the gains come from other countries liberalizing. These relative differences reflect a number of factors including the amount of liberalization being undertaken domestically relative to the amount being undertaken overseas (i.e. the US does not need to do much). It also reflects the degree to which other liberalizing economies are markets for home country products, the composition of home country production relative to the extent of distortions being removed in similar sectors in foreign economies as well as each country's initial reliance on international trade for income generation. The asymmetries across economies in many of these factors underlay the dispersion of results in tables 4 and 5.

Table 5 illustrates another important point. For members of APEC, liberalization within this regional grouping captures most of the gains from multilateral liberalization because APEC is so large. It should be stressed that many developing countries are not counted in the multilateral liberalization exercise.

Tables 6 shows the percentage change in real private investment by 2020 relative to what it otherwise would have been in 2020. As indicated in the results for GDP, physical investment in some economies fall as a result of trade liberalization. This fall in domestic investment is more than offset by a rise on home investment in foreign economies. Overall world investment rises.

Table 7 shows the effect of own versus alternative group liberalizations on real exports of each economy by 2020. In each case for each country, international trade expands. When an individual economy reduces tariffs, the nominal exchange rate depreciates which causes a real depreciation and stimulates demand for exports. This also reflects the falling input costs in export sectors from the reduction in tariffs. In the group liberalizations these exchange rate effects are diminished because as more countries liberalize there are less countries to depreciate against. Nonetheless the stimulus to world trade is reinforced by the demand spillover effects of foreign countries reducing their tariffs and raising their demand for home country exports. In each case more countries liberalizing leads a larger expansion of exports for each country.

The results for 2020 accord with results from many studies using CGE models apart from the impact of endogenous capital accumulation and savings behavior incorporated in the AP- GCUBED model.

b. Dynamic Adjustment

Now turn to the dynamic adjustment from the time the tariff reductions are announced until 2020. There are a vast amount of results for each country. Rather than presenting pages of numbers a few select results will be presented in order to draw out some key insights.

Figure 1 presents the time path of real GDP for 4 countries: Australia, Taiwan, China and Indonesia. These countries are selected to represent a range of experiences. Australia is an industrialized economy liberalizing by 2010, Taiwan is a developing economy liberalizing by 2010, China is a developing economy liberalizing by 2020 and Indonesia is also a developing country but also part of the ASEAN regional bloc.

The first point to note in that GDP rises in each of these countries in the medium term with the increase rising with the more countries participating. The ASEAN liberalization has a tiny impact on non-ASEAN economies and even for Indonesia leads to small gains relative to own liberalization.

Now focus on the results for Australia in figure 1. In the short run, the credible announcement of future tariff reductions leads to a reduction in GDP as firms begin to restructure in the early periods. The gains to tariff reduction only accumulate over time as tariffs are cut although some of these gains are bought forward through access to forward looking asset markets. In the short run from 1996 through 1997 GDP grows less quickly than base but after 1997 grows more quickly than baseline. By the year 2000 GDP is equal to the baseline GDP and after 2000 is permanently above the baseline. For Australia and a range of countries not shown here, own liberalization is costly in terms of GDP loss in the short term but substantially more beneficial in the medium and long term. Secondly, this figure and other results indicate that the more that other countries liberalize, the smaller the loss in short run GDP and the larger the gain in long run GDP. This is true for all countries in the model. Depending on the discount rate of political leaders this may explain why countries are reluctant to undertake trade liberalization without having foreigners also liberalizing. The problem with this strategy is that although all the short term costs are the result of own liberalization, most of the medium and long term gains are also due to own liberalization. Thus free riding on the liberalization of other countries may be an inferior policy strategy in the medium term. Unfortunately short sighted policymakers would usually choose the no liberalization strategy because of the short term costs of own liberalization.

The results for Australia also apply for each other economy although in some cases such as Taiwan, China and Indonesia, the short run losses disappear quickly. In the case of Indonesia, where there is a lot of growth already in the baseline, the absorption of dislocated resources occurs more quickly.

The results for consumption are shown in figure 2 for the same group of countries. This is similar in many ways to the path of GDP (note the different scales) except that for some countries the large future gains in income, cause consumption to rise more quickly than GDP. These countries are also the countries that experience a trade balance deficit in the early periods of liberalization as consumers borrow from the rest of the world to take advantage of the future income gains. In Australia the pickup in consumption relative to GDP occurs from 2002. Before that year, the Keynesian style business cycle induced by sticky nominal wages leads to a low consumption path for a number of years. Most household consumption is constrained by the short term slowdown in economic activity and the short term rise in unemployment caused when prices fall but nominal wages are sticky. This effect is dampened in other economies by more rapid labor market adjustment.

Figure 1: Effects on GDP of trade Liberalization Under Alternative Regional Groupings 1996 - 2020

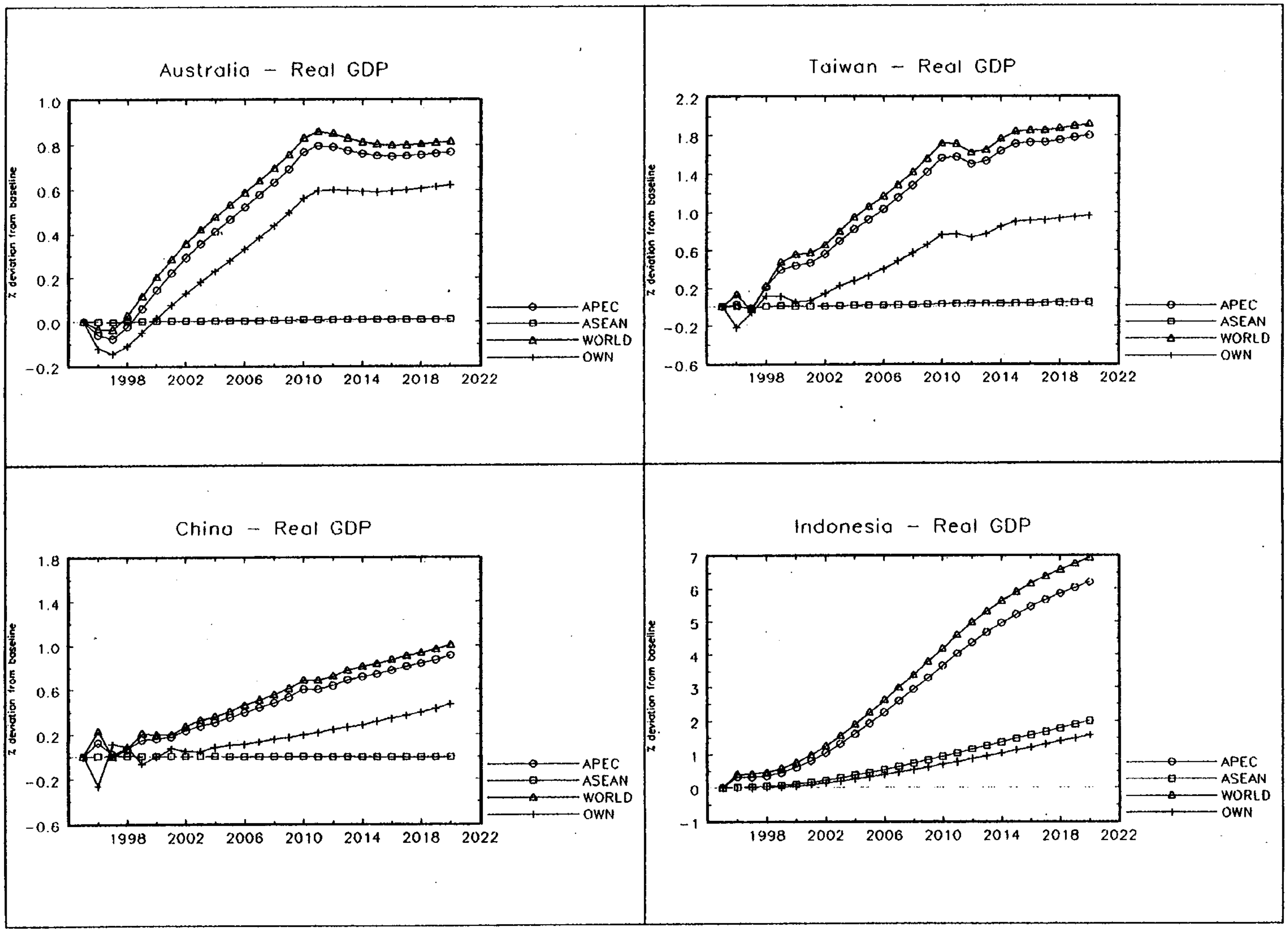
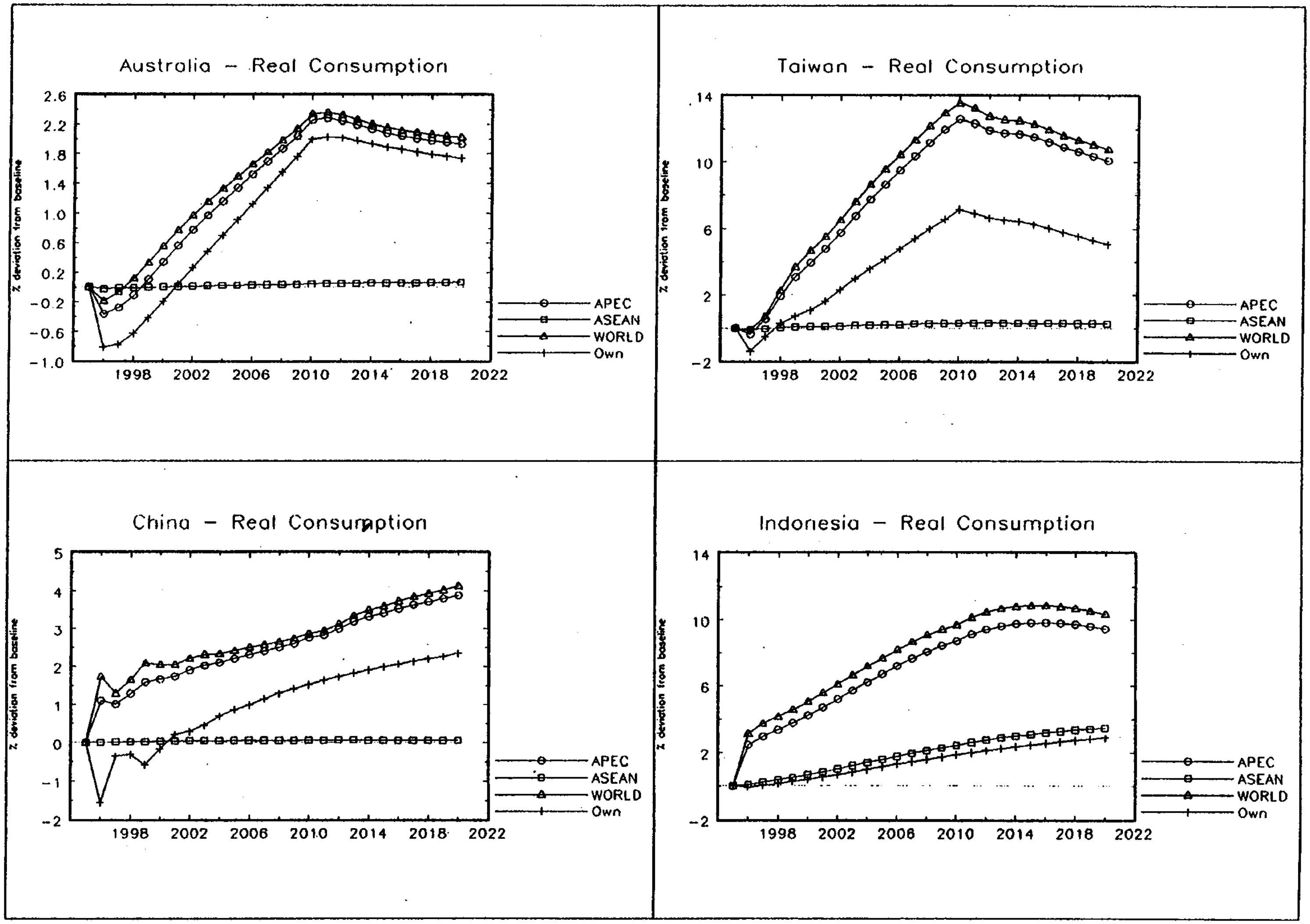


Figure 2: Effects on Private Consumption of Trade Liberalization Under Alternative Regional Groupings 1996-2020



Next it is interesting to look at what adjustment occurs in the trade accounts of a representative economy under own liberalization. Results for changes in exports, imports and the trade balance (as a percent of GDP) for own liberalization in Taiwan are contained in figure 3. When the policy of future tariff reductions is announced in 1996, there is a realization that in the future, the real exchange rate will depreciate. Financial markets are rational in this model and therefore the current nominal exchange rate depreciates in anticipation. With sticky nominal wages, the real exchange rate also depreciates in 1996. This reduces imports initially and increase exports. The trade balance improves slightly. Over time as the tariff cuts are implemented, exports continue to rise through reduced input costs and imports also rise due to the fall in home prices for these imports. The trade balance begins to deteriorate as households raise consumption relative to income in anticipation of future wealth gains and as the fiscal deficit marginally worsens due to the loss in tariff revenue. This borrowing against future income is not concentrated in the first few periods because households in this model are relatively myopic and future income only raises perceived wealth over relatively short time horizons. Once liberalization is complete in 2010, note that the trade balance begins to improve again reflecting the fact that debt accumulated pre 2010 to raise consumption and investment levels must be serviced over time. The trade balance improvement reflects this repatriation of borrowing as well as repatriation of returns to equities from direct foreign investment in Taiwan. While the trade balance improves this is reflected in both higher exports and imports.

Similar qualitative results for own liberalization can be found for the other economies although there are quantitative differences across economies.

Results for the trade balance adjustment in Taiwan under the alternative regional groupings is shown next in Figure 4. The case of own liberalization is the same as that shown in figure 3. In the case of both APEC and multilateral liberalization the deterioration in the trade balance is much greater. In this case the expected gains are also much greater and thus households borrow more to raise consumption and domestic firms borrow more to raise investment. Foreign capital also flows into Taiwan to take advantage of the higher expected returns in Taiwan. The real exchange rate depreciation is smaller in the short run because the inflow of capital tends to bid up the price of the Taiwanese dollar in real effective terms. Similar patterns occur for other economies although those economies undertaking the larger liberalization tend to attract greater capital inflows and countries such as the United States and ROECD regions tend to supply the capital to these liberalizing regions.

5. Conclusion

This paper has offered empirical estimates of the long run gains to trade liberalization for a range of countries primarily in the Asia Pacific region under alternative assumptions about the grouping of countries. It is found that in the medium to long term substantial gains are realized from own liberalization AND additional gains emerge for all countries from other countries' liberalization. Multilateral liberalization leads to larger overall economic gains for each country.

It is also found that the adjustment path to a phased liberalization can exhibit short run costs as resources begin to be reallocated before the trade reforms are implemented. To the extent that this is a problem, liberalization by other countries at the same time as own liberalization helps to reduce the short run adjustment costs. There is an irony for some countries, such as Australia, in that a substantial part of the long run gains are the result of own liberalization however this liberalization is also the source of short run costs. These costs are related directly to the extent of labor market rigidities.

Figure 3: Trade Adjustment in Taiwan During Unilateral Liberalization 1996 to 2010

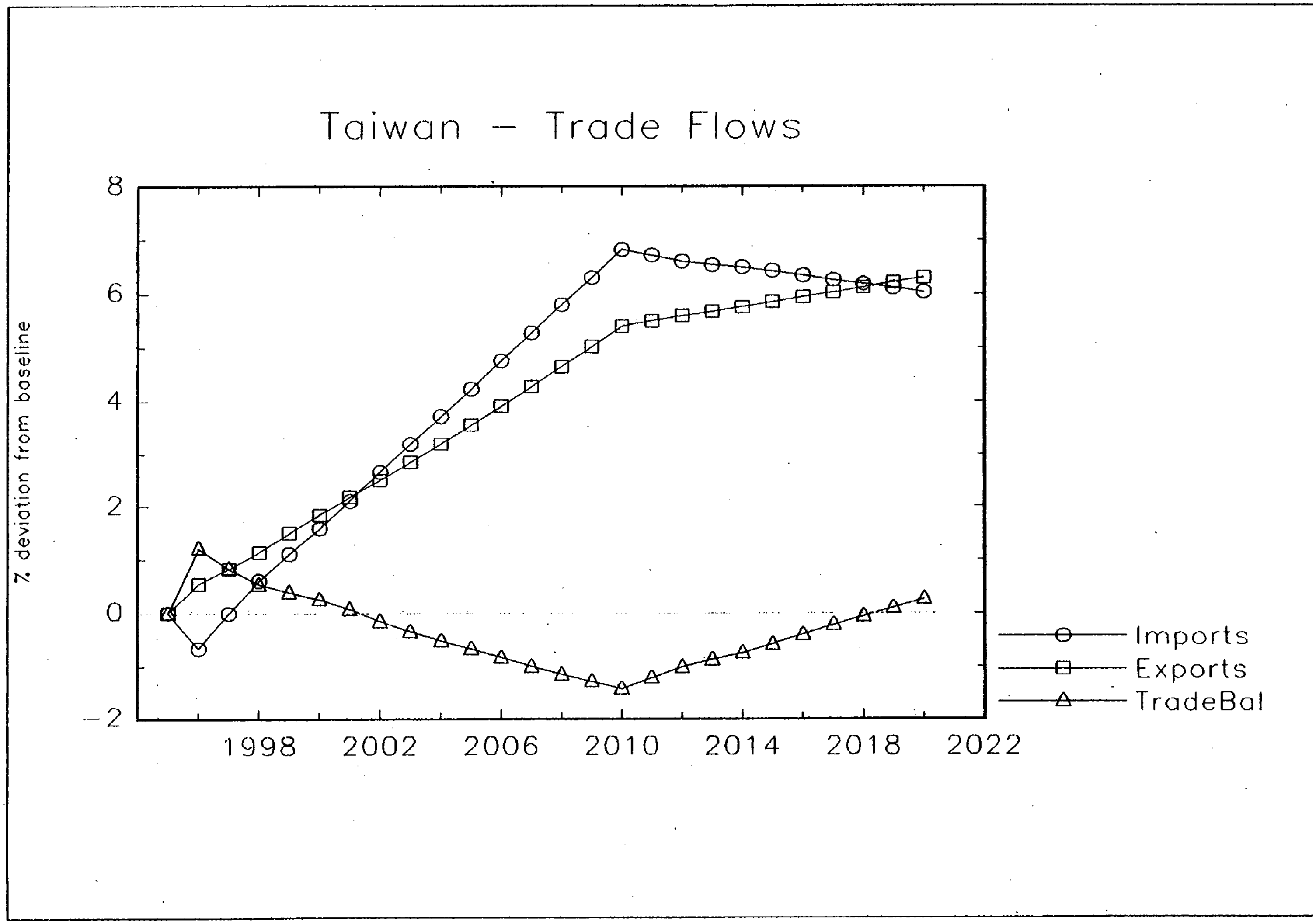
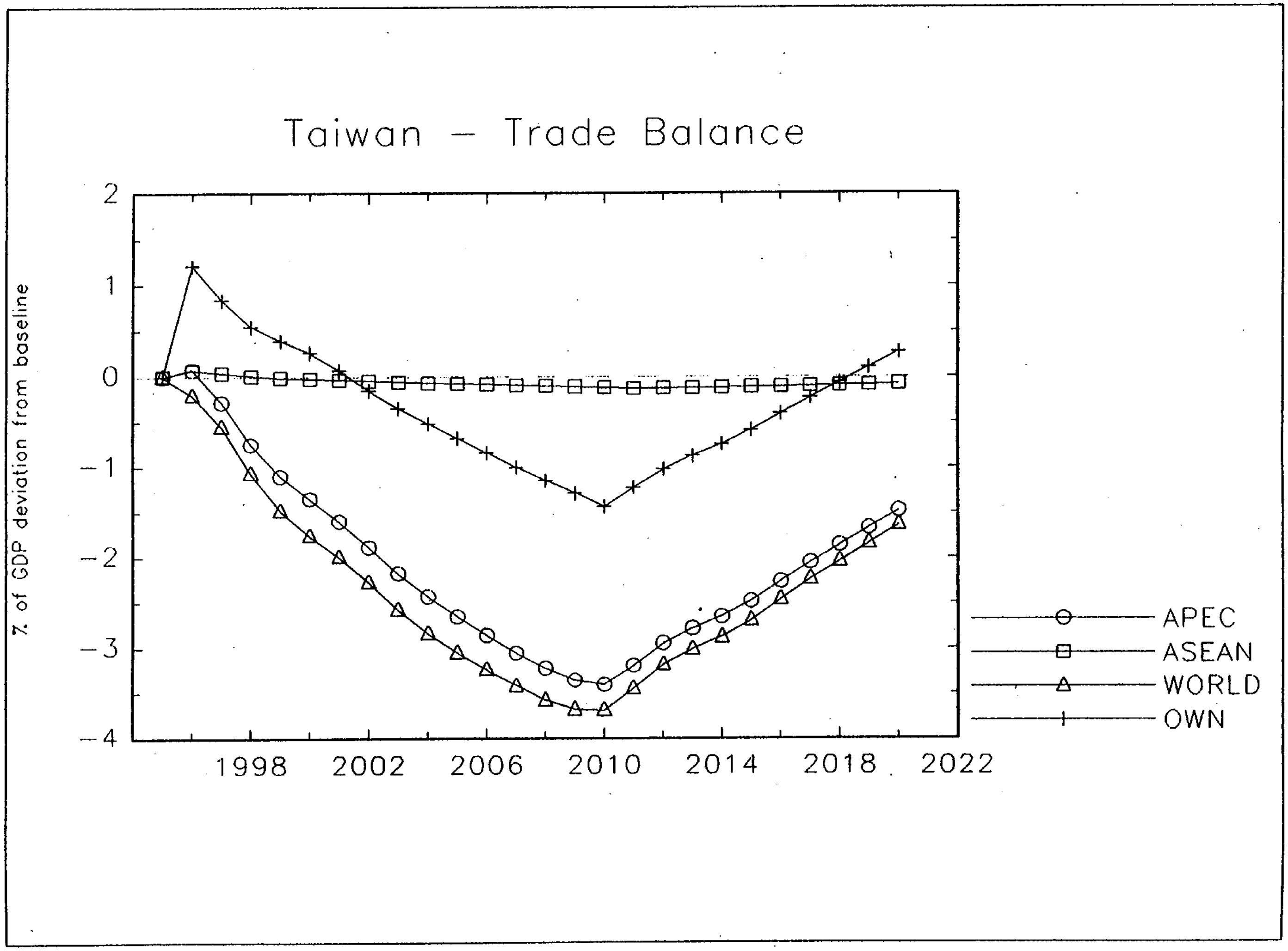


Figure 4: **Trade Balance Adjustment in Taiwan Under Alternative Regional Trade Liberalizations**



A significant amount of further research is required. The nature of the adjustment path is likely to be importantly affected by the timing of tariff cuts. In this paper a simple linear implementation is assumed but the issue of optimal timing of tariff reductions is not addressed (see Wong (1997)). Also the role for macroeconomic policy adjustment in the short run is suggested by the results for this paper but not directly evaluated. Finally and perhaps most importantly a great deal of sensitivity analysis as well as more precise econometric estimates of key parameters would improve our understanding of the robustness of the results in this paper. Despite these obvious caveats, the results here are raise some new insights for policy makers who must deal with the realities of policy changes in a world of highly integrated global capital markets. Incorporating factors these as well as adjustment dynamics enriches our understanding of a number of key policy issues that standard CGE models have not been able to address.

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Comments by Ralph Bryant on

Modeling Trade Policies and U.S. Growth: Some Methodological Issues by Mun S. Ho and Dale Jorgenson
and
Regional and Multilateral trae Liberalization: The Effects on Trade, Investment and Welfare by Warwick McKibbin

MR. BRYANT: I think both these modeling efforts here are important. They carefully examine a disaggregated sectoral intertemporal story. This painstaking empirical work does not get the attention or professional gold stars that it deserves. So I am really pleased that these papers are in the conference.

The Ho/Jorgenson paper looks only at the effects on the United States, but the McKibbin paper compares the results of liberalization for other countries. The Warwick paper is interesting, progressing from our own liberalization all the way through to multilateral liberalization. His qualitative conclusions seem the same that Jeffrey Lewis stressed earlier in the afternoon. So let me come to the question of limitations, and turn first to the Ho/Jorgenson model. And indeed, we saw almost nothing about the results from that model of trade liberalization, because Mun talked about the difficult issues in numerical models, of adequately modeling the short run, and then getting long-run convergence to a steady state that makes sense. The discussion is thoughtful, but I am a little uncomfortable with the choices made in their model. Forcing the long-run growth rate to be zero means that income growth is zero, and long-run productivity change, and long-run growth in population and change in labor supply are also zero. As he admitted, these are not acceptable assumptions about the very long run. I am not confident (as he seems to be) that this zero will not have any effect on the results for the first few decades, which we are concerned about. I prefer model convergence to the long run, where you get a positive growth rate in technical change, maybe in demographics. We could be not too comfortable with the thought that population growth rate might go to zero.

When worrying about participation rates, it gets even harder to see that we get exactly to zero in labor supply growth rates. Could we find some way (for example, when we worry about the nonhomotheticity in consumption) to have a positive income growth in the long run. And in the production function, I like to see us converge toward a neutral technical progress with a positive growth rate, rather than converging to zero. Our goal should be to get the models to work this way. Mun spent so much time talking about that. But the Ho/Jorgenson model is unsatisfying, as a one-country model is, for making these assumptions. Prices and output in the rest of the world are exogenous, and the budget deficit and the U.S. current account balance is exogenous.

The model has a lot of intertemporal action in saving and investment, but we should think of the savings and investment identity as having four pieces to it. It says,"Private saving plus a government budget balance is equal to domestic investment and the balance on current account." Of those four pieces, they are freezing two to be exogenous, which means that key channels of interaction between the United States and the rest of the world are just being shut off. And we know from the models G-cubed and others, when you allow for that kind of endogenous determination of the current account, exchange rates, and interest rates, then the cross-border changes are really important.

The Warwick presentation emphasized how much capital could flow, and hence, how big a difference you could have between GDP and GNP, or between GDP and consumption. Let me call New

Zealand a true-blue small open economy from which you would specify the rest of the world as exogenous in all respects. Prices, output employment, the world interest rate would be given, and the home interest rate would be very closely tied to the world interest rate, especially if home-currency-denominated assets were good substitutes for foreign currency denominated assets.

If you think about that model for the United States as a small open economy, the U.S. interest rate is closely tied to the world interest rate. And in those circumstances, for shocks or policy actions originating within the United States, virtually the entire variation in national savings would have to be matched by improvements or deteriorations in the current account. The current account and exchange rate would be the endogenous places where you would see a lot of the adjustment action. So the analyst who is interested in international interdependence, would see the Ho/Jorgenson model as unsatisfactory when it freezes the current account in the budget deficit. The model is a strange mixture of a small open economy model, and something else which does not clearly fall into any of the theoretical categories.

Of course, the United States is not a small open economy. When things like output and employment change in the United States, they have a nontrivial effect on the rest of the world. Changes in U.S. interest rates put significant pressure on world interest rates, and vice versa. Any division of the net change in U.S. national saving between higher domestic investment and a change in current account in the balance of payments is important.

It is difficult to say what that split is. We look at the United States reducing tariffs, and we look at foreign countries reducing tariffs. And the Ho/Jorgenson paper describes results in output and employment within the United States, especially across sectors. Analogous things are going to happen in the rest of the world. If the sequencing differs, enormous changes in current accounts and exchange rates occur. Now that they have the terms of trade changing endogenously, it is hard to model with a single country that freezes everything in the rest of the world. If I could see the results from the Ho/Jorgenson model, where (1) first you tried own liberalization of tariffs, the U.S. acts alone, then you (2) add in the effects of the U.S. reducing nontariff barriers, and then (3) you get to the simulations that you actually have done, which has the rest of the world reducing tariffs, too, with the United States, I think we would probably get more insight into how the model works and does not work if you looked at liberalization by the United States.

Another set of simulations would have been at least as interesting. And then I found myself asking about the possibility of your constructing a “world model,” where a world is in quotation marks here. You have the United States as you have modeled it, and you have another country that is a mirror image of the United States, but you work out carefully all the international interactions, so that things like the current account, the whole savings and investment equilibrium, and exchange rate and the interests rates in the countries are endogenously determined. My conjecture is that you would learn something interesting from that, but different from your model, run the way it is. Now, to be fair, I do not know enough about the Ho/Jorgenson model.

But for sure, in the Wilcoxen/McKibbin model, you are not really dealing with the problem that Mun is so worried about, of nonhomothetic demands. So if you have the demand for services within the income elasticity of 1.3, and foods 0.8, I think that that problem is not in yet in the G-cubed model. Another big thing has to do with demographics and aging inasmuch as they may change consumption and saving behavior and have enormous consequences for current accounts and exchange rates.

Now, let us take a couple of more minutes to talk about figure 2, where you can see the chart for consumption. It shows that you get a dip even more striking for consumption than it is for real GDP, say, in Australia. You see short-run costs, in terms of output and consumption, and big long-run gains, but it takes quite a while for the long-run gains to manifest themselves.

But a another deep normative question is not addressed. The people that are getting those consumption gains in 2020 are not the same people that are paying the costs in 1997 and 1998 and 1999. When we look at that path for consumption per capita, how do we think about those gains in 2020 compared with the costs in 1998? Should we not think about applying a discount rate? If we look at the present value of the integral of the costs, and we look at the present value of the integral of the gain, then we must ask which discount rate to use? Such a hard normative question with intergenerational equity issues at stake has no simple correct answer. In some work about the consequences of budget actions, the United States may reduce the budget deficit today, and we get the same kind of short-run costs but very big long-run gains. Because the capital stock is higher, production is higher, the net foreign asset position is stronger, so that consumption per capita can be much higher. But how do we weigh those against each other?

I have played with using different discount rates, and if I pick a discount rate that is something like the real interest rate we have today, those big long-run gains in consumption per capita start to look pretty small, because they are discounted back to the present. And those short-run costs that policymakers focus on, as Warwick said quite rightly, look pretty big.

That kind of a discount rate makes the trade-off for policy actions tough. On the other hand, if you use a discount rate of zero, which is implicitly what you do if you look at those graphs and you're not applying a present value of calculation, then of course the integral of the future gains is huge, relative to the short-run costs. And every sensible policymaker should be reducing U.S. tariffs or the U.S. budget deficit.

A last thought: Models like this are full of problems and deficiencies, and people who work on them the most, know about those deficiencies better than those who have not. And empirical models like this might look pretty untransparent or difficult to you, until you start trying to answer the questions by sucking the eraser on the end of your pencil. And then the models start to look very good.

Comments by Delfin S. Go on

Modeling Trade Policies and U.S. Growth: Some Methodological Issues by Mun S. Ho and Dale Jorgenson

The work of Ho and Jorgenson is a serious and significant piece of applied, dynamic general equilibrium modeling. Although dynamic models have become increasingly popular in analyzing the impact of trade policy, what distinguishes the work of Ho and Jorgenson, as part of the on-going, sophisticated program of research that Dale Jorgenson undertakes with several associates, is the unparalleled use of careful econometrics in estimating the equations of the model. While most researchers have been content to choose the parameters and calibrate their models from a single data point, Ho and Jorgenson estimate their parameters and utilize all available, historical observations in the sample period. The amount of data and effort that have gone into the work are clearly enormous. For example, to look at the empirical evidence on substitutability among production inputs, a consistent time series of interindustry transactions tables for the U.S. economy covering the entire period of 1947-85 on an annual basis is constructed. The specifications and estimations of the demand and production system are definitely representative of the best contemporary work in the field and should serve as a reference for others. All this background work, amply cited in the paper, have already been discussed elsewhere; the present paper focuses instead on methodological issues raised in the special context of an intertemporal framework.

A fundamental question often raised regarding applied general equilibrium models is whether the structure imposed by microeconomic theory is in fact reflective of the real world. This is true regardless of whether the model is estimated statistically or calibrated more traditionally with assumed parameters, and whether the model is static or dynamic. Of the several restrictions that are normally imposed to make economic sense or to ensure a stable equilibrium, the assumption of homotheticity is the most serious and most often violated by data. What Ho and Jorgenson showed is that the problem is best tackled by econometric method and that the actual shifts in the U.S. economy, particularly those that are not explained by relative price movements, are difficult to model or calibrate without time-series data. They also showed that many solutions create special problems in a dynamic context. The compromises they take while maintaining theoretical consistency, are quite ingenious. And it is here, I think, where the added discipline required to 'fit' the model to long-term patterns also shines, and the dividends are clear.

Take, for example, the observations that import and export shares in the U.S. economy are rising significantly over time and which appear independent of relative price movements or the general level of economic activity. Their solution is to make use of the logistic curve as an additional exogenous variable to model these biased shifts. This also prevents shares from going over one hundred or below zero percent in an infinite-horizon framework, particularly if a simple time trend is employed instead. Eventually, the biased shifts are removed and homotheticity is returned at the long term steady state, 50 or more years away from the last period of interest. For the same reasons, the logistic function is employed in several places with similar problems - whether it is to model nonlinear engel curves, rapid technical change observed in some industries, or empirical issues relating to the aggregate labor supply deriving from exogenous trends in work hours, female participation, or rise in real wage. Most other dynamic models would simply ignore these patterns and concentrate on the dynamic specifications and calibration. But as Ho and Jorgenson pointed out, ignoring them would not reflect historical observations and can lead to erroneous projections; moreover, incorporating them haphazardly can create problems in a dynamic setting.

The sophisticated blend of theory, flexible forms, awareness of historical shifts, and econometrics should by itself invite greater confidence in Ho and Jorgenson, at least when compared to other dynamic models. In many ways, it does. However, it is still difficult to translate the statistical tests of individual regressions and draw statistical confidence on the model as a whole. What is also gained in incorporating rational expectations makes it harder to simulate extra sample period. Checking if the model tracks history on an annual basis is not easy since every shock will be anticipated, unless of course every shock is unanticipated and the simulation is a string of one period runs. To be sure, these are longstanding issues affecting all dynamic modeling. Some progress is already being made in the statistical inference of simple models (see, for example, Abdelkalek and Dufour (1996).``Statistical inference for computable general equilibrium models, with application to a model of the Moroccan economy." University of Montreal.) But it needs to be extended for elaborate models such as Ho and Jorgenson.

Although employing logistic curves is innovative and reasonable, their presence signifies that there is still much we do not know about what drives the secular trends and how to model them. In the face of great refinement everywhere else in the model, their presence does seem arbitrary. There is also the problem of determining where we are in the curve, in the rapidly rising part or close to the maximum point? For example, Ho and Jorgenson assume that the export share near the end of the sample period is close to the maximum. I think it probably would be difficult to pin down exact positions without comparing distinct experiences or characteristics of several countries.

Does the result make good economic sense? The fear that the high degree of sophistication will make the model opaque and hard to decipher is unfounded. The impact of trade policy and its description is in fact easy to follow and understand. Moreover, the raison d'(tre for intertemporal models is to estimate the dynamic gains of trade policy, which is not possible with static models. Here, Ho and Jorgenson show that a multilateral elimination of both tariffs and non-tariff barriers would lead to a 1.08 % rise in long term consumption, compared to only 0.36 % in the first year. The latter is comparable to the result of a static model without the impact of trade liberalization on capital accumulation and productivity growth. The dynamic impact is most clearly seen in the several figures they provided.

The factor of about 3 between the long- and short-term impact on consumption is indeed a good way of highlighting the difference. The difference seems numerically high until one realizes that the full impact occurs only in the steady state, theoretically in the infinite time, which needs to be discounted properly. This points to the problem of how to compare the welfare gain of a dynamic model to the static case that is without capital accumulation and productivity growth. I wonder if the ratio will be as high if we compare a single welfare measure obtainable from the intertemporal utility with a comparable measure for the static case. For the latter, the first-year result can be assumed to continue in perpetuity and a comparable welfare measurement can be derived by discounting the constant consumption with the rate of time preference. In Devarajan and Go ("The simplest dynamic general equilibrium of an open economy" Journal of Policy Modeling, forthcoming), we show that the difference is insignificant for a simple, aggregate dynamic model of an open economy without productivity growth. In an elaborate and disaggregated model with possibilities for significant resource reallocation and for endogenous productivity growth in individual industries depending on relative input prices, the difference may still be numerically high but not by a factor of 3.

Nothwithstanding these criticisms, many of which are minor quibbles really, I would like to say that this piece of work gives me enormous pleasure to read and is a perfect antidote to routine and complacency in dynamic modeling. I look forward to the next improvement of an on-going work that is a standard in applied general equilibrium modeling.

Comments by Michael A. Kouparitsas on

Regional and Multilateral Trade Liberalization: The Effects on Trade, Investment and Welfare by Warwick J. McKibbin

Evaluating and/or predicting the impact of free trade agreements is a difficult task since it involves multisectoral and multilateral analysis. Given the complexity of the problem analysis is typically conducted within the confines a quantitative model of international trade. Currently, the dominant approach uses detailed simulation models with many households and firms to measure how different industries, household income groups, and countries are affected by changes in trade policy. This approach employs models that are designed to tell us something about the long-run impact of trade policy change. These models ignore any transitional effects associated with the change in trade policy are therefore appropriately referred to as static trade models.

Although widely used, static models have a number of shortcomings, which in the aggregate understate the benefits of trade liberalization and overstate the sectoral or individual costs of trade liberalization. This has encouraged the development of quantitative dynamic models that tell us something about the short- and long-run effects of changes in trade policy. Warwick McKibbin's analysis of Asian Pacific Economic Cooperation (APEC) trade liberalization adds to this small, but growing literature on dynamic trade policy analysis. The move to dynamic models has opened up a new set of methodological issues relating to: model specification; model evaluation; experiment design; and more directly the appropriate way to measure the welfare effects of trade liberalization. I will use this opportunity to add to this literature by critiquing the method adopted in McKibbin's APEC study.

The centerpiece of any trade liberalization analysis is a measure of the effect that the trade policy will have on the level of economic well-being (typically referred to as economic welfare) both nationally and internationally. In general, measures of economic welfare are theoretical constructs. A widely used measure of the change in liberalization-associated welfare that can easily be obtained from quantitative trade models is a "Hicksian compensating variation." In the context of APEC, the compensating variation is that level of consumption you would need to give households in each country in the pre-liberalized environment to make them indifferent to APEC liberalization. In other words, the compensating variation measures the amount of additional consumption goods households would need to have in the pre-liberalized environment to make them as well off as under APEC liberalization. In simple models where consumption goods are the only thing to enter the household's utility function the compensating variation is simply the change in the level of consumption that flows from the policy change. In more complicated models that allow for leisure or government spending to enter the household's utility function the compensating variation will differ significantly from the change in the level of consumption expenditure.
In a static setting a Hicksian compensating variation measures the change in welfare associated with a costless move from the pre-liberalized long-run equilibrium to the liberalized long-run equilibrium. In other words, the level of consumption would you need to give households in the initial long-run equilibrium to make them as well off as under the new long-run equilibrium. The main problem with static trade models is that they ignore the potential costs associated with the transition from one long-run equilibrium to another. A key advantage of dynamic models is that they trace out the time path of all variables in the economy over the short- and long-run. Households in a dynamic model solve an optimization problem that involves maximizing the sum of current and discounted future utility. In this setting King (1990) proposes the following dynamic analogue to Hick's static compensating variation. The dynamic compensating variation is the permanent change in pre-liberalization consumption that would make households indifferent to the consumption path associated with liberalization.

McKibbin does not measure welfare changes using a dynamic compensating variation measure. He instead measures changes in welfare associated with APEC liberalization as the change in the level of consumption from the pre-liberalized long-run equilibrium and liberalized long-run equilibrium. There are two weaknesses with this approach. First, government expenditure enters the households' utility function in McKibbin's model, so measuring welfare gains by changes in consumption expenditure ignores the welfare effects associated with changes in government spending. My rough calculations suggest that McKibbin's consumption measure overestimates the static welfare gains of trade liberalization. Second, by focusing on long-run comparisons (that is, static welfare analysis) he ignores the transition costs associated with the move to the liberalized equilibrium and in so doing overstates the welfare improvement from APEC liberalization.

In general it is not possible to generate an analytical solution for the class of dynamic multisector trade model used in the McKibbin paper, so they are solved using numerical techniques. A consequence of this is that the model's parameters must be defined before one can apply numerical solution methods. These models are typically parameterized using estimates from previous trade liberalization studies, estimates from the broader econometric's literature, and data on sectoral production and international trade flows. An obvious question that follows from this approach is how well do these models fit historic data.
Static models only tell us something about the long-run. Therefore statistics from static models can only be compared to first-moment aspects of the data, which include trade, production, and expenditure shares. This is undesirable because estimates of the output and welfare effects of trade liberalization policies are sensitive to the choice of elasticities of substitution in trade, production, and consumption and the appropriateness of these parameters can only be evaluated by studying the model's second moment characteristics. Second moment features of the data include the variance and covariance of time-series. Dynamic models produce this information, so the choice of elasticities in a dynamic model is easily evaluated by looking at the model's second moment characteristics.

McKibbin's parameterization is based on an ad hoc set of parameters. In many cases his parameter set differs significantly from its static counterparts. For example, static models, such as Whalley (1985), typically assume Leontief production functions, McKibbin adopts Cobb-Douglas production functions. This makes simple comparisons of his work with static models impossible. McKibbin's model evaluation is limited in that he follows the static literature in comparing the model's first moment characteristics with the data, but provides no evaluation of his model on the second moment dimension. In addition, there is no formal sensitivity analysis despite the fact that page 13 states that the paper's results are sensitive to the choice of elasticities of substitution. Clearly, more work needs to be done in this paper and the literature more generally to rectify these deficiencies. Until then the results of McKibbin's paper and all trade liberalization analysis involving quantitative static or dynamic trade models have more qualitative than quantitative content.

In the absence of analytical solutions one learns about the functioning of models by running controlled experiments and analyzing the model's impulse response function. Intuition is developed from these exercises. McKibbin's work is lacking in this regard. One of the more interesting results in his paper which is not fully explained is why unilateral liberalization in his model makes the liberalizing country better off. This result is interesting because we rarely observe unilateral liberalization, except in the case of very small open economies. My own dynamic trade liberalization analysis (see, Kouparitsas, 1997) suggests that the reason why we do not observe widespread unilateral liberalization is that the liberalizing country is made unambiguously worse off. In contrast, my work suggests that we observe a great deal of multilateral liberalization because in that setting all participants are made better off. The intuition for my work is well described by simple trade theory which argues that countries which have some monopoly power over their exports experience a significant decline in their real income, thorough worsening terms of trade, which makes them worse off. In a multilateral setting their terms of trade deterioration from own liberalization is offset by terms of trade improvements following liberalization in other countries. The only way to rationalize McKibbin's result is an appeal to small country models in which the liberalizing country faces a given world price for its exports and imports. This would require a higher degree of substitution in trade than is assumed in the McKibbin model.

Future dynamic research will no doubt address the methodological issues raised in this note, many of which seem to be an overhang from the static approach. McKibbin must be applauded for adding to the dynamic literature and the broader trade policy debate with a very rich and careful analysis of APEC liberalization. Although this type of work is in its early stages of development, it clearly dominates static trade analysis along many dimensions and should therefore replace it as the dominant paradigm for unilateral and multilateral trade liberalization analysis.

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