PWP IP-70

Eleventh Floor
Menzies Building
Monash University Wellington Road
CLAYTON Vic 3168 AUSTRALIA

Telephone:
(03) 9905 2398, (03) 9905 5112

from overseas:
61 3 9905 5112

Fax numbers:
(03) 9905 2426, (03)9905 5486

from overseas:
61 3 9905 2426 or
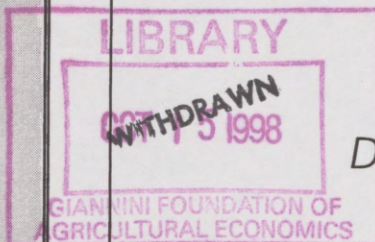61 3 9905 5486

e-mail
impact@vaxc.cc.monash.edu.au

LONG-RUN SIMULATIONS WITH GTAP:

Illustrative Results from APEC

Trade Liberalisation

by
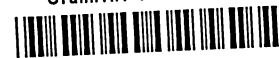
Terrie L. WALMSLEY

Department of Economics
Monash University

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ABSTRACT

In static applied general equilibrium models, the exogenous/endogenous split between variables (or closure) is used to infer the time frame over which the effects of a shock are simulated. This paper introduces a long-run closure for the GTAP model (Hertel and Tsigas, 1997) and uses this closure to simulate and compare the short-run and long-run effects of Asia-Pacific trade liberalisation. The approach explored here incorporates some relatively minor changes to existing GTAP theory in order to define a steady state in which growth rates of all real variables are uniform. Such uniformity must apply in the initial database (as well as in the post-shock solution). So to implement the new long run in GTAP a new initial database must first be created. Details concerning the creation of the new database are given, and results under the new approach are compared with those obtained under the old.

The emphasis of this paper is on the development of a long-run closure in which the percentage change form equations of the model and the relationships between the levels variables in the GTAP database are consistent. Further research is required into these types of long-run closures to incorporate changes in ownership of capital to ensure that changes in welfare are adequately modelled. In the results reported here, GDP is *not* a useful guide to national welfare.

The long-run closures introduced here are also compared with another comparative static long-run closure developed for GTAP by Francois, MacDonald and Nordström (1996).

JEL Classification: D58, F15.

Terrie L. Walmsley

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LONG-RUN SIMULATIONS WITH GTAP:

Illustrative Results from APEC Trade Liberalisation

by

Terrie L. WALMSLEY[*]

1. Introduction

The Global Trade Analysis Project (GTAP) model[1] is a global comparative static applied general equilibrium model. The GTAP system of equations is based on microeconomic foundations providing a detailed specification of household and firm behaviour within individual regions and trade linkages between regions. In addition to trade flows the GTAP model also recognises global transportation and the mobility of investible funds. It is these international saving and investment mechanisms which are the focus of this paper.

There are currently two methods available in the standard GTAP model for allocating global saving across regional investment. The first method allocates global saving across investment so that percentage changes[2] in the nominal rates of return expected for the period following the solution period ('expected rates of return') equate across regions. The second method allocates global saving across regional investment in such a way that the regional composition of global investment remains unchanged (Hertel and Tsigas, 1997). Both of these methods fix each region's total capital stock exogenously and therefore are short-run in nature.

Other methods currently being used and developed for examining the long-run effects of a shock include Arndt, Hertel, Dimaranan, Huff and McDougall (1997), Francois, MacDonald and Nordström (1996) and McDougall and Ianchovichina (1996). Arndt et al. (1997) use exogenous shocks to forecast the long-run effects of China's growth on the world economy, while Francois, et al. (1996) have developed a comparative static long-run closure in which capital stocks are endogenised, but not mobile across regions. Finally, McDougall and Ianchovichina (1996) are currently undertaking research into a dynamic version of the GTAP model in which capital accumulates over time.

[*] Department of Economics, Monash University, Clayton, VIC, 3168, Australia.
Email: Terrie.Walmsley@BusEco.monash.edu.au.

[1] The standard GTAP model is documented in Hertel (1997). The GEMPACK program, from which the GTAP model is run is documented in Harrison and Pearson (1996).

[2] Unless otherwise noted, "percentage change" in this paper means "percentage deviation from base case", not percentage point. Similarly "change" in this paper usually means percentage deviation from base case.

The purpose of this paper is to outline a comparative static long-run extension to the GTAP model which allows capital stocks to be endogenised. This extension consists of some minor additions to and modifications of GTAP's structural form and the development of a new closure. This long-run closure for the GTAP model is based on the long-run closure developed by Dixon, Parmenter and Rimmer (1981) and Horridge and Powell (1984) for the ORANI model. In common with closures developed by Francois et al. (1996), this long-run closure retains the comparative static nature of the GTAP model.

The comparative static long-run closure developed here defines the long run in terms of the steady state. In order to use the method of comparative steady states, the database must reflect steady state conditions; this restricts the ratios between investments and capital stocks. Additionally, due to the assumption of perfect capital mobility, all rates of return, net of risk premia, must be equal. The standard benchmark database[3] does not satisfy these conditions. In the case of investments and capital stocks, exogenous growth rates can be shocked so as to produce a new (steady state) database in which investment and capital stocks are consistent with the steady state assumptions. In the case of rates of return, the differentials can be assumed to reflect risk premia, so that no further adjustment to the database is required (although an alternative treatment is also considered in which shocks are applied to equate rates of return across regions).

Having obtained an initial steady state database, and having adopted a closure which includes all the steady state requirements, it is a simple matter to inject an Asia-Pacific trade liberalisation shock and so compute a new steady state solution, thus allowing valid comparative statics.

The closures discussed in this·paper represent initial research into the development of a full long-run closure which will take into account the foreign ownership of capital and land, and the presence of foreign workers. Consequently, the results reported here should be interpreted literally as increases in capital stocks *located within a region;* additions to stocks within a region may not be owned by the residents of that region and therefore changes in gross domestic product are unlikely to be a useful indicator of the welfare effects of the shock.

The paper is divided into six sections. The second section outlines some of the existing approaches to determining the long-run effects of a shock. In particular the long-run closure developed by Francois, MacDonald and Nordström (1996) is compared with the long-run closures developed in this paper.

In the third and fourth sections, four treatments of the long run are developed. Section three commences by outlining an initial simple treatment of the long run for the GTAP model. This is followed by a critical assessment of underlying assumptions which points to conflict between the standard benchmark database and one which is compatible with balanced growth in the long run. In the fourth section it is found that the simple initial treatment of the long run, developed in section two, does not respect

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[3] The "standard benchmark database" is used in this paper to refer to the standard (version 3) GTAP database, compiled by the Global Trade Analysis Project, Purdue University (McDougall, 1997).

the principle that, for comparative static solutions to be valid, all levels equations must be satisfied in the standard benchmark database (as well as in the post-shock database). Two issues are addressed: firstly, the need for growth rates to reflect the steady state; and secondly, the need for equality across regional rates of return. Modifications are made to the GTAP Tablo file and shocks are applied to the standard benchmark database to create a new steady state database. Two revised treatments of the long run, which conform with the steady state and perfect capital mobility conditions, are given.

The contents of section five are displayed in Table 1. In the first sub-section the results of simulations of APEC trade liberalisation are compared under two closures, but no changes are made to the database. Then the creation of new steady state databases is described, two treatments being offered: in one, the differences in regional rates of return can persist indefinitely due to fixed risk premia; in the other, there are no risk premia. In the final sub-section APEC results are compared for simulations launched from the old, as well as from the new steady state databases. Results are given for both treatments of risk.

Table 1: Contents of Section 5

Sub-section	Simulation			
5.1	**APEC Trade Liberalisation Simulations Using Standard Benchmark Database**			
	Standard GTAP model and short-run closure (RORDELTA=1).		Modified theory and new long-run closure.	
5.2	**Creating a Steady State Database**			
	With exogenous risk premia separating regional rates of return in the long-run.		No risk premia.	
5.3	**APEC Trade Liberalisation Simulations Using Modified Theory and Long-Run Closure**			
	Using Steady State Database		**Using Standard Benchmark Database**	
	With risk premia.	No risk premia.	With risk premia.	No risk premia.

The final section summarises and concludes the paper. In this conclusion an outline of further research required into comparative static long-run closures is given and a brief summary is made of the research currently being undertaken into a dynamic version of the GTAP model.

Unless otherwise stated, GTAP conventions have been retained where possible: lower case letters represent percentage changes, while upper case represents the actual values.

2. *Existing Approaches to Long-Run Closures of the GTAP Model*

Currently in the GTAP literature there are a number of papers which seek to determine the long-run effects of a shock. This research has progressed in three directions with:

1. the use of exogenous forecasts (Arndt, Hertel, Dimaranan, Huff and McDougall, 1997);

2. small changes to the GTAP model to incorporate comparative static steady state closures (Francois, Nordström and MacDonald, 1996); and

3. more significant changes to the GTAP model to incorporate dynamic behaviour (McDougall and Ianchovichina, 1996).

In the first approach, forecasts of various regional macro variables are used to incorporate some of the long-run changes expected in the global economy. Arndt et al. (1997) implement forecasts of changes to physical and human capital, agricultural land, population, labour force and Uruguay tariff reductions as exogenous shocks to the GTAP model to determine the long-run effects of China's growth on the world economy. Although intuitively appealing, this method does not consider the source of these exogenous changes in the capital stocks, nor does it allow capital stocks to respond endogenously to the 'China grows' shock itself.

In the second approach, comparative static long-run effects are determined by allowing capital stocks to respond endogenously to the shock. Endogenisation of capital is achieved by incorporating additional equations, which reflect long-run or steady state conditions, into the GTAP model. The primary benefit of this and the previous approach is that they retain the comparative static nature of the GTAP model and are therefore simple in comparison with the more complicated dynamic extensions of the model. The steady state closures developed by Francois et al. (1996) are examples of this comparative static steady state approach. I will outline these long-run closures developed by Francois et al. (1996) and compare them with the approach taken in this paper later in this section.

In the final approach, undertaken by McDougall and Ianchovichina (1996), some dynamic investment behaviour has been incorporated into the GTAP model. In this dynamic version of GTAP, time is included as a variable. This allows investment undertaken during each time period to add to the level of capital stocks available in subsequent time periods; thus in the dynamic model capital accumulates over time both in response to the shock and as a result of the passing of time itself. The global economy starts from its current position, represented by the standard benchmark database, and gradually moves over time towards the steady state, in which expected and actual rates of return converge on a common target rate of return. Therefore, simulation results of the dynamic model do not represent comparative static deviations from control, but instead are reported as growth rates over time which incorporate both the effects of the shock and the effects of a movement towards the steady state. This is one of the benefits of the dynamic model as it allows the time paths of each of the variables to be determined. In addition the dynamic version of the GTAP model also includes an accounting framework which keeps track of changes in the ownership of

capital and hence rental incomes earned. This accounting framework thus allows gross national product to be used to determine the effects on welfare, rather than gross domestic product.

In the remainder of this section I will concentrate on the steady state closures developed by Francois et al. (1996), since these closures and the ones developed in this paper are both comparative static in nature and allow capital stocks to be determined endogenously within the GTAP model.

Francois et al. (1996) argue that the standard short-run GTAP closure does not take into account the dynamic benefits of trade liberalisation. They recognise three distinct gains from the liberalisation of trade: a static gain and two types of dynamic gains. An outline of these three gains is given below:

1. *Francois et al. (1996) Static Gain*

(Exogenous capital stocks, trade balance and saving rate)

The size of this gain is determined by implementing the trade liberalisation shock under the standard GTAP closure[4], with regional capital stocks fixed exogenously; it refers to improvements in income resulting from a more efficient allocation of fixed regional endowments of labour, capital and land consequent to the liberalisation of trade.

Francois et al. (1996) state that if the global economy were initially in steady state, this static gain would be equivalent to a move away from the steady state. The steady state, as defined by Francois et al. (1996), is a situation where investment equals the rate of depreciation on capital and therefore the growth rate of capital equals zero. With the 'static gain' improvements in income, saving and hence investment increases and becomes greater than the amount by which capital stocks are depreciating; thus the growth rate of capital increases above the steady state rate.

2. *Francois et al.'s (1996) First Dynamic Gain*

(endogenous capital stocks and exogenous trade balance and saving rate)

This gain is the result of endogenising changes in the beginning-of-period capital stocks and thus allowing them to grow until the higher 'static gain' growth rates of capital in each region fall back to their steady state rates of growth (of zero percent).

In this steady state closure, percentage changes in capital stocks are equated to percentage changes in investment (equation (2.1): where EXPAND("capital",r)[5] is exogenously equal to 0). As a result investment (qcgds(r)) and capital stocks (kb(r)) change by the same amount (equation (2.1)). Thus the percentage change, in the solution period, of the growth rate of capital equals zero and the growth rate of capital in each region returns to that rate which prevailed prior to the shock. When the initial

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[4] But with the trade balance (DTBAL(r)) fixed.

[5] Note that although written in upper case, EXPAND("capital",r) is a percentage change variable.

database is a grow-less steady state, the growth rate of capital returns to a rate of zero percent[6]. The result is a change in the steady state *levels* of capital and income.

$$EXPAND(i,r) = qcgds(r) - qo(i,r) \qquad (2.1)$$

where: i = "capital".

An important distinction between this comparative static steady state closure developed by Francois et al. (1996) and the long-run closures outlined below is that the balance of trade (DTBAL(r)) is exogenous under the Francois closure. This is achieved by endogenising the slack variable in the capital goods industry (cgdslack(r)). As a result of this assumption, the percentage change in the expected rates of return will equate with the percentage change in the current rates of return; however they will not equate across regions in the long run (as is the case in the closures developed below).

The basis for this assumption is that investment must be financed solely from domestic saving and thus capital is not mobile across regions. The rationale for fixing the trade balance is firstly, empirically there has been a tendency for domestic saving to finance domestic investment; and secondly, by removing all capital flows there are no changes in the foreign ownership of capital and hence results can be interpreted as changes in welfare.

3. Francois et al.'s (1996) Second Dynamic Gain

(endogenous capital stocks and saving rate and exogenous trade balance)

This gain is the result of endogenising the savings rate. Francois et al. (1996) argue that trade liberalisation is likely to result in a higher expected global rate of return which may induce households to increase the portion of income which is saved (an event which requires the standard GTAP consumption function to be "turned off"). Under this closure the marginal propensity to save adjusts until the percentage change in the real current rate of return equals zero.

A larger propensity to save would lead to even greater investment and hence higher steady state levels of capital and income. This dynamic gain is not considered in the long-run analysis discussed in sections 3, 4 and 5 below, where the Cobb-Douglas treatment of utility (and its implied constant average propensity to save) is retained throughout.

Unlike the Francois et al. (1996) closures, the closures developed below assume that capital is mobile across regions and therefore rates of return will equate across regions with the convergence of growth rates in the steady state. In respect to the mobility of capital, the closures developed below are similar to the research currently being

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[6] Whilst Francois et al. (1996) favour a zero growth rate to apply in their steady state, they do not attempt to adjust the standard benchmark database to reflect this assumption; instead they refer to research which show that trade reforms undertaken during the transition to steady state result in the benefits of trade reform being brought forward to an earlier date. With the assumption of zero growth not reflected in the standard benchmark database, the final database, resulting from the implementation of the shock, will also fail to reflect the steady state assumption of zero growth.

undertaken by McDougall and Ianchovichina (1996) into a dynamic version of the GTAP model, where some capital is mobile[7].

This assumption, that capital is perfectly mobile across regions, does have important implications for welfare analysis and ideally an accounting framework, similar to the one in the dynamic version of GTAP, is required to take account of this. I am currently working on such an extension to these long-run closures which will address these ownership issues explicitly. For the time being, however, the results reported here should be interpreted carefully. It must be remembered that increases in capital stocks located within the region may not be owned by residents of that region and therefore changes in gross domestic product are unlikely to be a good indication of the welfare effects of the shock[8].

3. Incorporating the Long Run into the GTAP Model

3.1. An Initial Simple Treatment of the Long Run

The long run is defined as that period of time long enough for capital stocks to have adjusted to the shock and be available for production in the region. The notion of capital stock adjustment here is one of achieving equality between rates of return across regions and across time. Thus a long-run analysis must encapsulate two effects:

1. The Investment (or Short-Run) Effect

This effect is equivalent to the total effect in the standard GTAP short-run closure[9]. The short run is defined as that period of time before new investment adds to the total availability of capital for production within regions. This period

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[7] This capital mobility applies to only a portion of investible funds. In the dynamic model the majority of funds are invested in the domestic economy; this is consistent with empirical evidence.

[8] This issue is partially addressed in the SIMPLE version of the GTAP model (Francois, MacDonald and Nordström, 1997) by the incorporation of an equation which reduces the percentage change in income by the differences between the percentage changes in domestic saving (qsave(r)) and capital stocks (qo("capital",r)) and between the percentage changes in the global (rorg) and current (rorc(r)) rates of return (shown below). This is achieved by exogenising the change (not percentage change) in the variable flow(r) and endogenising incomeslack(r).

$$\text{flow}(r) = \sum_{h \in \text{ENDWC}} \text{VOA}(h,r) \times [\text{qsave}(r) - \text{qo}(h,r) + \text{rorg} - \text{rorc}(r)]$$

$$- \text{INCOME}(r) \times \text{incomeslack}(r)$$

Incorporation of this flow equation into the steady state closures below causes Walras' law to be violated. This causes problems when applied to some of the long-run closures discussed below, while in the other closures the additional equation seems to give fairly reasonable results. In footnote (22) below, the effects on regional income, of adding this equation into these long-run closures, are given.

[9] This short-run effect is similar to the static gain outlined by Francois et al. (1996), with the exception that the trade balance is fixed and thus the percentage changes in the expected rates of return do not equate across regions.

is long enough, however, for the industrial profile of the capital stock within any given region to respond to the shock. In this case investment in each region is determined by allocating global savings to each region in such a way as to equate the *expected* rates of return across regions. In percentage change form:

$$rore(r) = rorg \qquad (3.1)$$

This investment effect includes the change in investment discussed above, but notionally keeps the capital stocks in use at their control values.

2. *The Accumulation (or Long-Run) Effect*

In this case, sufficient time passes for changes in investment to result in changes to regional capital available for production[10]. Endogenously determined capital stocks adjust to changes in demand for capital. This accumulation effect is determined by setting the current regional rates of return in the period simulated equal to the expected regional rates of return. With this additional restriction, shown below in percentage change form for the GTAP model, the percentage change in beginning-of-period capital stocks (kb(r)) can be determined endogenously. This accumulation effect reflects the changes in capital stocks necessary for equating rates of return across time.

$$rorc(r) = rore(r) \qquad (3.2)$$

This simple initial treatment of the long run is referred to below as the "non-risk-adjusted method with standard benchmark database", as the long-run equations in percentage change form have been applied to the standard GTAP model and standard benchmark database with no adjustments made for risk premia. The reason for this title will become more apparent in section 3 below. All alterations made to the standard GTAP Tablo code, parameter and data files are listed in Appendix 1.

3.2. *Steady State Assumptions of the Comparative Static Long Run*

The non-risk-adjusted method introduced above is based on the long-run closure developed by Dixon, Parmenter and Rimmer (1981) and Horridge and Powell (1984) for the model (ORANI), where the percentage change in capital stocks is endogenised and the percentage change in the current rate of return exogenously equated to zero.

Dixon, Parmenter, Sutton and Vincent (1982) describe the rate of return as the "natural replacement" to capital stocks as an exogenous variable. With capital stocks fixed in the short run, a shock is expected to alter the rates of return to different types[11] of capital. With the relative and absolute sizes of capital stocks free to vary in the long run

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[10] This accumulation effect is similar to the first dynamic gain, outlined by Francois et al. (1996), with both resulting in the growth rates of capital reverting back to their initial database levels in the long run. In the Francois et al. (1996) closure, however, the trade balance is fixed and therefore the percentage change in each regions current and expected rates of return do not equate across regions in the long run.

[11] In the case of the ORANI model "different types" refers to industry specific capital, while in the GTAP model "different types" refers to region specific capital stocks.

however, rates of return would revert to their original values and hence percentage changes in the rates of return would be driven to zero. This assumption holds well for the single small country model (like ORANI) where the expected global rate of return is assumed to remain unchanged as a result of an economy specific shock. In the case of a global model, however, where the shock under consideration affects a large number of countries, the assumed zero change in the expected global rate of return may be invalid. In this non-risk-adjusted method, percentage change deviations from control in regional rates of return current in the solution period (rorc(r)) have been equated to the corresponding percentage change deviations in the rates of return expected to apply in the period following the solution period (rore(r)) which are equal across all regions (rorg). Within the limitations of a one-period model, rates of return have been set to equality over time. Perfect capital mobility is sufficient (although not in general necessary) for equality across regions of rates of return in the long run. Such mobility is assumed in the long-run closures developed here.

In addition to the assumption of perfect capital mobility, the closure also assumes that growth rates (but not levels) of capital revert to the values which would have prevailed had there been no shock. In order to examine this assumption in greater detail we will firstly outline the mathematics which equates the percentage changes in the current and expected rates of return. Following this, the assumption is illustrated graphically.

Firstly, the value of end-of-period capital (KE(r)) is related to the beginning-of-period capital (KB(r)) by 1 plus the growth rate of capital (KBGROWTH(r); henceforth labelled as the power of the growth rate):

$$KE(r) = KBGROWTH(r) \times KB(r) \qquad (3.3)$$

where:

$$KBGROWTH(r) = 1 + \frac{NETINV(r)}{VKB(r)} \qquad (3.4)$$

In addition the expected and current rates of return are related in the following way (see appendix 2)[12]:

$$\frac{ROREXP(r)}{RORCUR(r)} = \left[\frac{KE(r)}{KB(r) \times AVGROWTH} \right]^{-RORFLEX(r)} \qquad (3.5)$$

where: ROREXP(r) is the expected rate of return in region r in the period following the solution period.

RORCUR(r) is the current rate of return in region r.

AVGROWTH is 1 plus the average growth rate of capital across all regions (power of the average growth rate). This power of the average growth rate of capital is determined by equation (3.6):

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[12] This equation differs from the one it replaces in the GTAP Tablo file in that it includes the power of the average growth rate of capital (AVGROWTH). This is discussed further in Appendix 2.

$$\text{AVGROWTH} = \sum_{r \in \text{REG}} \frac{\text{VKB(r)}}{\text{GLOBKB}} \times \text{KBGROWTH(r)} \qquad (3.6)$$

where: GLOBKB is the total value of all capital stocks.

In percentage change form:

$$\text{avgrow} = \sum_{r \in \text{REG}} \frac{\text{VKE(r)}}{\text{GLOBKE}} \times \left[\text{kb(r)} + \text{pcgds(r)} + \text{kbgrow(r)} \right]$$

$$\qquad (3.7)$$

$$- \sum_{r \in \text{REG}} \frac{\text{VKB(r)}}{\text{GLOBKB}} \times \left[\text{kb(r)} + \text{pcgds(r)} \right] + \text{growavslack}$$

where: avgrow is the percentage change in the power of the average growth rate of capital (AVGROWTH).

kbgrow(r) is the percentage change in the power of the regional growth rates of capital (KBGROWTH(r)).

growavslack is a slack variable. This slack variable is usually exogenous (and set to zero) unless the user wishes to exogenously specify the percentage change in the power of the average growth rate of capital.

Substituting equation (3.3) into (3.5) and converting to percentage change form:

$$\text{rore(r)} = \text{rorc(r)} - \text{RORFLEX(r)} \times \left[\text{kbgrow(r)} - \text{avgrow} \right] \qquad (3.8)$$

In the long-run closure with standard benchmark data kbgrow(r) (for all regions) and avgrow[13] are set exogenously to zero so that the term in the square parentheses on the right of equation (3.8) vanishes, thus equating rore(r) and rorc(r) for all regions. Thus in the long-run closure the percentage change in the growth rate of capital relative to control is zero percent.

Figure 3.1 below, is used to illustrate this assumption graphically. For any given region, capital stocks at a future solution period are determined by a growth path ("control" path) whose end points, $K(\tau)$ and $K(0)$, are related by:

$$K(\tau) = K(0) \times (\text{SRGROWTH})^{\tau} \qquad (3.9)$$

where: SRGROWTH represents 1 plus the average rate of growth in capital over the period of length τ between the imposition of the shock and the realisation of the solution (power of the short-run average growth rate of regional capital). A

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[13] If the percentage change in the regional growth rates of capital were all exogenously equated to zero, we would expect that the percentage change in the power of the average growth rate of capital would also be equal to zero. However the percentage change in the power of the average growth rate of capital (equation (3.7)) is only equal to zero if each region's share of net investment (or end-of-period capital stocks) is equal to its share of the beginning-of-period capital stocks. In the standard benchmark database these weights differ and therefore the percentage change in the power of the average growth rate must be exogenously equated to zero in order to drive rore(r) to equality with rorc(r) in equation (3.8).

shock may cause capital stocks to alter and follow a different path over time, the "shocked" path.

Figure 3.1: An Illustration of Deviations from Control Versus Changes in Growth Rates
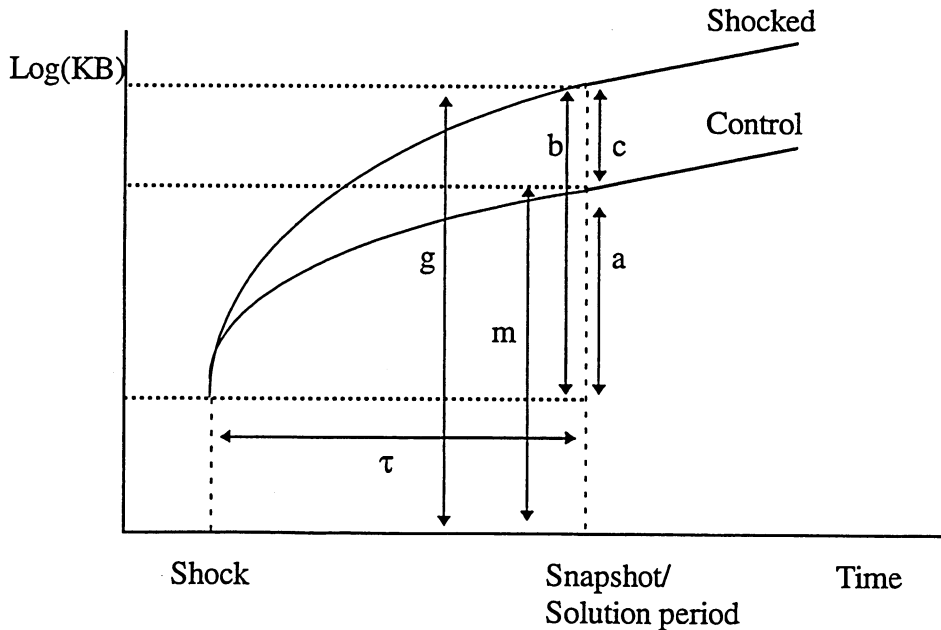
After Powell and Murphy (1995), p. 359 (modified).

Figure 3.1 shows that, relative to the control path, capital changes by $[100(c\,/\,m) \equiv 100(g-m)\,/\,m]$ percent in the solution period, as a result of the shock. It is this deviation from control which is determined by the simulation.

The growth rate of capital is the slope of the curve at any given point in time. In the case of the control path, the average growth rate of capital between the shock and the snapshot period was equal to $a\,/\,\tau$. Along the shocked path, the average growth rate of capital between the base and snapshot period rose to $b\,/\,\tau$. The percentage change in the growth rate is thus $[100(b-a)\,/\,\tau \equiv 100c\,/\,\tau]$ percent. In the short run the shock is expected to affect the growth rate of capital formation (reflected in Figure 3.1 by the difference in the slopes of the two trajectories) and thus alter the relative sizes of capital stocks at all points of time after the shock.

In the long run (i.e., by the snapshot period), however, the growth rates of capital stocks and of aggregate investment are expected to return to those values which would have prevailed had there been no shock; that is the growth rates of capital, in the solution period, of both the shocked and control paths are equal and the two curves become parallel. Hence in the long run the percentage change in growth rate of capital is equal to zero. The relative size differences in the capital stocks however, persist into the long run.

Is it reasonable to assume that the percentage deviation in the rate of growth of capital stocks in each region is equal to zero in the long run?

In static applied general equilibrium modelling a shock is expected to alter the long-run composition of capital only to the extent that the post-shock rates of return differ across regions in the short run. Provided the shock does not alter the underlying determinants of the long-run growth rate of capital, the rates of return will equate and the rate of capital accumulation will return to its control path rate; as a result only the relative sizes of capital stocks between regions will have altered.

In terms of the 'old' growth theory literature, the only long-run dynamic equilibrium that is sustainable is a balanced growth path in which the growth rates of every type of capital are the same and equal to the natural growth rate of the economy at large. The natural growth rate of the economy is the sum of the rate of growth of the work force and the Harrod-neutral rate of technical progress. Thus the only shocks which could permanently affect growth rates are ones affecting the demography and/or the technology. If we rule these out, the proposal to set the change in the growth rate of capital exogenously equal to zero seems reasonable.

In most cases it is reasonable to assume that a shock will not alter the rate of technical improvement or the rate of population growth. There may be circumstances however, such as the integration of the Chinese market into the world economy, where a shock may alter the underlying growth rate of technological efficiency and hence the long-run size of the capital stock and just possibly also its rate of growth. If this is the case then the change in the long-run rate of growth of capital may not equal zero.

Alternatively, it can be argued that most changes to the growth rate of capital stocks would have occurred in the long run regardless of the occurrence of the shock and thus should have been incorporated into the control path of capital accumulation. In this case, the change in the growth rate of capital relative to the control path, remains equal to zero in the long run. In other (and presumably rare) circumstances, in which a shock has altered the rate of population growth and/or the rate of technological change, or in which endogenous growth mechanisms[14] come into play, the assumption that the change in the rate of capital accumulation is zero in the long run may be invalid.

4. A Steady State Database

The long run described above, which equates the rates of return across regions and the growth rate of capital to the sum of the rate of growth in the population and the rate of technological change, is equivalent to a steady state in which balanced growth pertains and capital is perfectly mobile. For solutions to be valid the structural form equations and the database must be consistent. That is, both the levels equations and the database must represent the steady state. The standard benchmark database does not reflect these steady state conditions; thus in the method described above, steady state equations are

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[14] For example, where additional dynamic gains are thought to exist in the case of trade liberalisation (Feder, 1982) or where trade liberalisation may endogenously alter the growth rate of technology (Lucas, 1988 and Romer, 1986).

applied to a non-steady state database; this is illustrated in Figure 4.1 as a move from (A) to (C). As a result the solution may not respect all levels equations of the model.

Figure 4.1: Incorporating a Steady State Database

The direct move from (A) to (C) respects the percentage change form of equations of the expanded model, but neither (A) nor (C) respects all levels equations of the expanded model. When (C) is reached via (B), however, it does respect all levels equations of the expanded model.
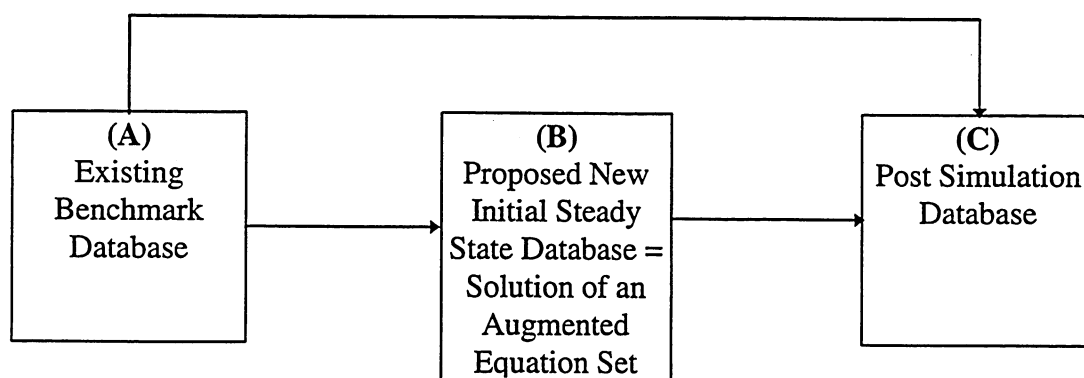
Adjusting for this problem involves converting the standard benchmark database into a steady state database. This is illustrated in Figure 4.1 as a move from (A) to (B). Once a steady state database has been obtained, the long-run effects of a shock (in this case an APEC trade liberalisation shock) can be determined by using the new steady state database as the initial database. This represents a move from (B) to (C) in Figure 4.1.

There are two issues which need to be considered here in order to create this new intermediate steady state database:

1. the equalisation of the power of the growth rates of capital and hence the equating of current and expected rates of return within regions and

2. the equalisation of the expected rates of return across regions.

It should not be surprising that the standard benchmark database does not conform with the steady state since this database is a true representation of the global economy at a single point in time (1992 in the case of the current version 3 GTAP database). In the real world we never have truly long-run data since shocks continually buffet the world economy. Over the lengths of run in real time that conditions remain stable, we note that although there is considerable mobility of capital between countries[15], it is not perfect, with some well established tendencies for savers to prefer to invest at home[16]. The steady state, however, is an idealisation reflecting how we would expect the world economy to look if we were able to enjoy an indefinitely long period without any shock

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[15] For example, foreign capital is believed to have been an important factor in contributing to the high growth rates (and possibly also the recent decline) of the Asia-Pacific.

[16] Feldstein and Horioka (1980) showed that regional saving and investment were highly correlated, suggesting that capital was not perfectly mobile. Lucas (1988) and Goulder and Eichengreen (1992) also refer to this tendency for saving to be invested in the home country.

impinging on the economy other than the original shock under analysis. It is reasonable (at least as a hypothetical construct) to suppose that over such a period capital movements between regions would eliminate differences in rates of return and economies would converge towards a balanced growth path.

In sub-sections 4.1 and 4.2 below two methods are provided for removing the inconsistencies between the standard benchmark database and the steady state, outlined above. An alternative method might be to alter either the regional values of capital stocks or the values of rental services in the standard benchmark database to ensure that the ratio of the value of rental services to the value of capital conforms with the steady state. This method was not chosen here for two reasons: firstly, the current capital stock data was assumed to be reasonably reliable in the sense that, with relatively few exceptions, they are consistent with prior beliefs about risk premia. Secondly, manipulation of only one of these variables assumes that all other variables in the database are consistent with a steady state. As mentioned above, however, it is unlikely that the world economy is currently, or even will be at any particular point in time in the future, in steady state.

4.1. Equalisation of the Growth Rates of Capital

In the steady state the growth rate of capital is equal to the natural rate of growth of the economy which depends on the population growth rate and technological growth. In the current database the growth rates of capital do not conform to the steady state.

For regional growth rates to be consistent with the steady state, capital stocks and investment need to be adjusted. The assumption is made that in the steady state the power of the regional growth rates of capital (KBGROWTH(r)) will be equal across all regions to the power of a global steady state growth rate (SSGROWTH):

$$KBGROWTH(r) = \left(1 + \frac{NETINV(r)}{VKB(r)}\right) = SSGROWTH \qquad (4.1)$$

In this paper the power of the steady state growth rate of capital (SSGROWTH) is assumed to be equal to the power of the average growth rate of capital (AVGROWTH) in the standard benchmark database. Although the average growth rate of capital from the standard benchmark database is used here, the same system of equations can be used to create a steady state database in which the growth rates of capital are equal to another value chosen by the user[17].

In order to equate the regional growth rates of capital in the GTAP database to this common steady state rate, KBGROWTH(r) (1 plus the growth rates of capital) are shocked in all regions. These shocks can be determined directly from the standard

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[17] Additional simulations were undertaken to test the sensitivity of the results to the choice of steady state growth rate. The results of these simulations are discussed in footnote (24).

benchmark database. The shocks.tab facility has been altered to create a shock file for this purpose (Appendix 3)[18].

The shocks to the growth rates of capital are simulated using the long-run closure, where beginning-of-period capital stocks are endogenous. In this way both investment and capital stocks adjust to equate the growth rates of capital across regions. In addition, as can be seen from equation (2.5), equating the growth rates across regions will also equate the current and expected rates of return within each region[19].

4.2. *Equalisation of the Expected Rates of Return Across Regions*

In the non-risk-adjusted method, introduced in section 2, the percentage change form of the equations equates the expected rates of return across regions. In the standard benchmark database, however, the levels form of these expected rates of return are not equal across regions. Two methods are outlined below for dealing with these differences in expected rates of return.

Under the *first method* these differences in the expected rates of return across regions are explained using differential risk premia[20]. This involves altering the equations in the Tablo file and the inclusion of another coefficient in the GTAP database.

The current rate of return in region r (RORCUR(r)) is equal to the risk-free rate of return (RORCFREE(r)) plus a premia for risk (RISK(r)).

$$RORCUR(r) = RORCFREE(r) + RISK(r) \qquad (4.2)$$

In change form this is:

$$RORCUR(r) \times rorc(r) = RORCFREE(r) \times rorcf(r) + RISK(r) \times rsk(r) \qquad (4.3)$$

where: rorcf(r) is the percentage change in the current risk-free rate of return (RORCFREE(r)), and rsk(r) is the percentage change in the risk premia (RISK(r)).

Similarly, the expected rate of return (ROREXP(r)) is equal to a risk-free return (ROREFREE(r)) plus risk premia (RISK(r)).

$$ROREXP(r) = ROREFREE(r) + RISK(r) \qquad (4.4)$$

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[18] Note that the shocks.tab facility has been altered to give the shocks which equate the regional growth rates to the average growth rate of capital. If the user wishes to apply a steady state growth rate of capital other than this average then the shocks.tab file must be altered. Currently, this is done by removing the equation equating SSGROWTH to AVGROWTH and including code which allows you to read in the power of the steady state growth rate from a parameter file.

[19] This is the case even if the power of the growth rates (KBGROWTH(r)) are equated across all regions to a power other than the power of the average growth rate (AVGROWTH) in the standard benchmark database. Since in the steady state, all growth rates are equal across regions, the power of the steady state growth rate is also the power of the average growth rate of capital in the steady state database (e.g. if all growth rates are zero in the steady state, the average must also equal zero).

[20] Risk premia were also implemented, using a similar method, in Baldwin and Francois (1996).

In change form:

$$ROREXP(r) \times rore(r) = ROREFREE(r) \times roref(r) + RISK(r) \times rsk(r) \tag{4.5}$$

where: $roref(r)$ is the percentage change in the expected risk-free rate of return $(ROREFREE(r))$.

The distinction between the risk-free and risk components of the current and expected rates of return has implications for some of the existing equations in the GTAP model. The short-run equations equating the expected and global rates of return now apply to the risk-free components of the expected and global rates of return:

$$roref(r) = rorgf \tag{4.6}$$

where: $rorgf$ is the percentage change in the global risk-free rate of return.

The relationship between the expected and current rates of return is now between the risk-free components of these rates of return:

$$ROREFREE(r) = RORCFREE(r) \times \left[\frac{KE(r)}{KB(r) \times AVGROWTH}\right]^{-RORFLEX(r)} \tag{4.7}$$

The risk-free component of the expected rates of return $(ROREFREE(r))$ is equal across all regions and is specified in the standard benchmark database at a value of 4 percent[21]. The current risk-free rate of return is then found using equation (4.7). In the standard benchmark database, where growth rates differ across regions, the risk-free current and risk-free expected rates of return will differ[22].

In percentage change form:

$$roref(r) = rorcf(r) - RORFLEX(r) \times [kbgrow(r) - avgrow] \tag{4.8}$$

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[21] The new data, the expected risk-free rate of return (equal to 0.04 in all regions), is added to the standard benchmark database using the "MODHAR" program and the file SSADJ.STI. The expected risk-free rate of return is then updated by any changes in the expected risk-free rate of return $(roref(r))$. Alternatively if estimates of risk premia were available, these could be used to find the expected risk-free rates of return. Differences in these risk-free rates of return across regions could then be removed via shocks to the expected risk-free rates of return in much the same way as shocks are implemented to equate expected rates of return in the second method outlined below. This approach would require two shocks, one to equate growth rates across regions and a second to equate expected risk-free rates of return. Implementation of this method may cause problems if the new risk premia data suggests that expected risk-free rates of return are negative. Removal of such negative expected risk-free rates of return would require some alterations to the GTAP database, in order to ensure that the rates of return suggested by the GTAP database were consistent with the additional data acquired on risk premia.

A case in point is China, where the expected rate of return in the GTAP database is relatively small compared to rates for other regions, whereas external evidence is likely to suggest that risk premia for China are very large relative to the risk premia of other regions. This could result in a negative expected risk-free rate of return when the above approach is used.

[22] If all regions growth rates are the same, that is, if $[KE(r)/KB(r)] = AVGROWTH$, then the term in the square parentheses on the right of equation (3.7) is unity. If not, then $RORCFREE(r) \neq ROREFREE(r)$.

Finally, the current rate of return, determined by the rental price and cost of capital goods, must be linked to the current risk-free rate of return. In order to do this we assume that a shock does not affect the risk component of the current rate of return (i.e. $rsk(r) = 0$). As a result the absolute (or percentage point) change in the current rate of return must equal the absolute change in the risk-free component of the current rate of return for each region:

$$RORCUR(r) \times rorc(r) = RORCFREE(r) \times rorcf(r) \qquad (4.9)$$

Alterations made to the standard GTAP Tablo code, parameter and data files are listed in Appendix 1.

Under the *second method* these differences in expected rates of return across regions are removed by implementing shocks to equate the expected rates of return across regions.

These shocks equate the expected rates of return in all regions to an average expected rate of return (AVROREXP: equation 4.10). Whilst in principle the choice of a common rate of return is up to the user, here the rate selected is just the average across regions of the rates of return in the existing GTAP database. These shocks to the expected rates of return are obtained from a modified version of the shocks.tab facility (Appendix 3).

$$AVROREXP = \sum_{r \in REG} \left[\frac{VKB(r)}{\sum\limits_{k \in REG} VKB(k)} \right] \times ROREXP(r) \qquad (4.10)$$

In order to equate the expected rates of return across regions in the levels form, percentage changes in the expected rate of return can no longer be equated to the percentage change in the expected global rate of return. Equation (4.11), can be "turned off" by endogenising the slack variable (cgdslack(r)). This slack variable is usually exogenous. In the case where the expected rates of return are being shocked however, cgdslack(r) is endogenous and rore(r) is exogenous.

$$rore(r) = rorg + cgdslack(r) \qquad (4.11)$$

In addition to this equation, the percentage changes in the growth rates of capital (kbgrow(r)) are assumed to be equal across all regions. In this case the variable kbgrow(r) is endogenous and growslack(r) is exogenous. This slack variable growslack(r) is endogenous unless (as in the present case) the user wishes to equate percentage changes in the growth rates of capital in all regions.

$$kbgrow(r) = growth + growslack(r) \qquad (4.12)$$

The final variable swap is to exogenise the expected global rate of return (rorg) and endogenise the single growth rate of capital (growth). Alterations made to the standard GTAP Tablo code, parameter and data files are listed in Appendix 1.

4.3. Conclusion

In this section, two methods of obtaining a steady state database have been outlined. These two methods are summarised below:

1. *The Risk-Adjusted Steady State Database.* Under this method the equations of the model are modified to incorporate risk premia (sub-section 4.2, first method) and then the powers of the growth rates of capital are shocked to equate the growth rates of capital (in the levels) across regions and thus the current and expected Risk-free rates of return within regions (sub-section 4.1). See column 3 of Table 2 for the closure used for this shock.

2. *The Non-Risk-Adjusted Steady State Database.* Under this method two sequentially applied shocks are required to create the steady state database. The first, equates the growth rates of capital across regions (sub-section 4.1), thus ensuring that the current and expected rates of return equate within regions, while the second equates the expected rates of return across regions (sub-section 4.2, second method). See columns 3 and 4 of Table 2 for the closures used for these two shock.

Table 2: Alternative Closures (Exogenous Variables)

Standard Benchmark Database		Steady State		
Short-Run	**Long-Run**	**rore shock**	**kbgrow shock**	**Long-Run**
tms txs	tms txs	tms txs	tms txs	tms txs
pop	pop	pop	pop	pop
psave	psave	psave	psave	psave
profitslack	profitslack	profitslack	profitslack	profitslack
incomeslack	incomeslack	incomeslack	incomeslack	incomeslack
endwslack	endwslack	endwslack	endwslack	endwslack
saveslack	saveslack	saveslack	saveslack	saveslack
govslack	govslack	govslack	govslack	govslack
tradslack	tradslack	tradslack	tradslack	tradslack
ao af afe ava atr	ao af afe ava	ao af afe ava	ao af afe ava	ao af afe ava
to tx tm	atr	atr	atr	atr
qo("labor",r)	to tx tm	to tx tm	to tx tm	to tx tm
qo("land",r)	qo("labor",r)	qo("labor",r)	qo("labor",r)	qo("labor",r)
rsk(r)	qo("land",r)	qo("land",r)	qo("land",r)	qo("land",r)
	rsk(r)	rsk(r)	rsk(r)	rsk(r)
qo("capital",r)	kbgrow(r)	growslack(r)	kbgrow(r)	kbgrow(r)
growavslack	avgrow	growavslack	growavslack	growavslack
cgdslack(r)	cgdslack(r)	rore(r)	cgdslack(r)	cgdslack(r)
growth	growth	rorg	growth	growth

The results of these two methods are outlined below. Once a steady state database has been created, the APEC trade liberalisation shock can then simulated using the steady state database as its initial database.

5.   Simulation Results

This section is divided into three sub-sections (outlined in Table 1). Sub-section 5.1 compares the short- and long-run effects of an APEC trade liberalisation shock. The short-run results are obtained using the non-risk-adjusted method (short-run closure where RORDELTA = 1)[23]. The long-run results are obtained from implementing the long-run closure of the non-risk-adjusted method developed in section 2. Both sets of simulations are launched from the standard benchmark database.

Sub-section 5.2 examines the steady state databases created from the two alternative methods discussed in section 5, comparing them with the standard benchmark database from which they were derived.

Finally, sub-section 5.3 examines the effects of the APEC shock using four treatments of the long run (Table 1) which take into account the changes required to achieve both equations and a database which are consistent with the steady state.

The trade liberalisation shock simulated here is based on simulations undertaken by Young and Huff (1997) on a 3 by 3 aggregation of the GTAP database and by Adams, Huff, McDougall, Pearson and Powell (forthcoming) on an 11 by 37 aggregation. In these simulations an 11 region by 8 commodity aggregation of the GTAP database (version 3) is used. The 11 regions and 8 commodities are listed in Appendix 4. In this shock, trade is assumed to be liberalised within the Asia-Pacific region only. Thus tariffs are reduced on commodities imported by APEC regions from other APEC regions. In the case of the 11 region database used here the APEC regions consist of the first 10 regions listed in Appendix 4. The APEC simulations were performed on a post-NAFTA database[24]. Both the APEC and NAFTA tariffs reductions were determined using the shocks.tab facility, supplied by Young and Huff (1996). The post-NAFTA average tariff rates by region and commodity are listed in Table 3.

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[23] Using the non-risk-adjusted model (short-run closure and RORDELTA = 1) with the standard benchmark database is equivalent to the short-run closure in the standard GTAP model.

[24] The post-NAFTA database was determined by applying a NAFTA trade liberalisation shock to the standard GTAP model (or the non-risk-adjusted model with the short-run closure and RORDELTA = 1). In this way all long-run treatments begin with the same post-NAFTA database, upon which APEC or steady state shocks are then applied.

Table 3: Average Tariff Rates by Region and Commodity

Region[a] (Dest)	agr	lvst	food	res	prcres	mnfcs	text	svces
NAM	34.68	1.43	10.03	0.47	3.35	7.46	13.2	0
JPN	126.8	0.762	121	2.39	2.74	2.15	11.46	0
AUS	2.98	0	4.78	0.208	8.51	12.64	34.24	0
NZL	2.07	0	4.65	0.16	4.22	7.93	13.34	0
CHN_HKG	0	0	18.7	3.35	10.7	20.7	35.45	0
SKOR	161.3	100	54.35	4.72	12.95	16.51	19.9	0
TWN	157.7	3.66	32.84	6.13	5.72	6.73	7.0	0
MYS_SGP	65.7	33.35	33.7	0.411	4.62	3.71	7.05	0
THA_PHL	124.9	107.8	61.86	18.22	20.95	33.99	49.07	0
IDN	39.36	5.37	11.86	1.544	7.99	14.23	27.0	0
ROW	34.36	7.73	25.58	3.02	8.90	11.4	17.7	0

[a] Obtained from Post-NAFTA Database.

5.1. A Comparison of the Short- and Long-Run Results of an APEC Trade liberalisation Shock Using the Standard Benchmark GTAP Database

In this sub-section, two simulations are undertaken representing the short- and long-run effects of Asia-Pacific trade liberalisation. The short-run results were obtained from implementing the APEC trade liberalisation shock using the non-risk-adjusted method with standard benchmark database (short-run closure and RORDELTA = 1). The long-run results of APEC trade liberalisation were obtained from implementing the non-risk-adjusted method, developed in section 2, with a long-run closure and the standard benchmark database. The closures of these two simulations are listed in the first two columns of Table 2.

Table 4 depicts the percentage changes in real GDP for both the short- and long run, as well as the long-run changes in capital stocks and short-run changes in the current rates of return. In most cases (North America and the Rest of World excluded), real GDP improves as a result of trade liberalisation within the Asia-Pacific region. A comparison of the results shows that these improvements in real GDP tend to be greater in the long run with the endogenisation of capital. There also appears to be some trade diversion, with the Rest of World being made worse off by the APEC trade liberalisation. The extent of this trade diversion is greater in the long run.

Table 4: Short-Run and Long-Run Results of APEC Trade Liberalisation Shock with Standard Benchmark Data

Region[*]	Short-Run[a]		Long-Run[b]	
	Real GDP (qgdp)	Current rate of return (rorc)	Real GDP (qgdp)	Capital (kb)
NAM	0.04	1.29	-0.48	-1.35
JPN	1.15	2.67	1.35	0.48
AUS	0.38	7.30	2.48	5.79
NZL	0.44	8.3	2.56	5.95
CHN_HKG	1.27	11.14	5.62	11.23
SKOR	3.40	10.84	10.67	15.84
TWN	3.56	9.36	8.17	11.70
MYS_SGP	2.06	12.34	13.50	21.00
THA_PHL	3.48	25.61	43.62	63.99
IDN	0.51	4.81	4.81	7.43
ROW	-0.07	-0.42	-1.80	-3.96
rorg	1.72		2.34	
avgrow	1.61		0[c]	
kb_tot[d]	0		-1.19	
globalcgds	0.41		1.06	

[*] Results represent percentage changes from control.

[a] The short-run results are obtained from the short-run closure with RORDELTA equal to 1 (non risk adjusted method with standard benchmark database). This is equivalent to equating the expected rates of return across regions.

[b] The long-run results here are obtained from the long-run closure discussed in section 2 (non risk adjusted method with standard benchmark database). This closure equates the percentage changes in the current and expected rates of return to the percentage change in the global rate of return.

[c] Exogenous

[d] kb_tot is an additional variable in the GTAP model which determines the total change in global capital stocks as a weighted average of the percentage changes in regional capital stocks, where the weights are the value of capital stock in region r relative to the value of global capital stocks in all regions. In the short-run, with the change in regional capital stocks fixed, kb_tot equals zero. In the long-run, kb_tot is equal to the sum of weighted changes in the beginning-of-period capital stocks.

There is a moderate positive correlation (approx 0.69) across regions between the percentage changes in the short- and long-run real GDP. Allowing capital stocks to adjust to the shock has had a significant effect on the change in real GDP in the long run. This is evidenced by the strong linear relationship (correlation = 0.99) between long-run changes in real GDP and in the capital stocks.

Table 4 also reports the percentage changes in the global rates of return and global investment and capital stocks resulting from the Asia-Pacific shock, for the two simulations. The results show that capital is generally more productive with a 2.34 percent (not percentage point) increase in the expected global rate of return in the long run. While most regions experience increases in capital stocks, the change in global net investment (globalcgds = 1.06) or global capital (kb_tot = −1.19) is unclear. Global net investment and capital stocks are found by summing across regions weighted percentage changes in the regions' investment or capital respectively. Even though the percentage

change in gross investment is equal to the percentage change in the capital stocks for each region[25], the standard benchmark database is inconsistent with the steady state and thus the investment and capital stock weights differ, giving different results for the global percentage changes in net investment and capital.

For all APEC economies there is a positive change in the short-run current rates of return, due to improvements in the rental price of capital. The significant increase in the current rate of return in Thailand-Philippines is the result of both a rise in the rental price and a decline in the price of capital goods (pcgds(r)). The latter is due in part to firstly, the relatively high tariffs that Thailand-Philippines levied on imported capital inputs prior to the trade liberalisation (Table 2); and secondly, the high share (approx. 40 percent) of these imported inputs in the production of capital goods (Adams, Huff, McDougall, Pearson and Powell, forthcoming). The results also show that the long-run changes in capital stocks are highly correlated with changes in the current rate of return in the short run (0.96).

The strong relationships between percentage changes in real GDP and capital, and between percentage changes in the short-run current rates of return and long-run capital stocks can be explained in two stages:

1. The liberalisation of trade leads to an increase in demand for commodities and output in APEC countries thus causing demand for capital inputs to rise. In the short run capital stocks within each region are fixed exogenously, so any increase in demand for the services of capital causes its rental price to rise and a reallocation of the fixed regional supply of capital stocks across industries. Production increases but it is constrained by the amount of capital available. As a result the increased demand for capital manifests itself mainly as a change in the current rates of return.

2. In the long run, the availability of capital within a region is no longer fixed. Any increase in demand for domestic production will increase the demand for and hence the supply of capital. The extent to which supply increases is restricted only by the condition that global investment can be financed by global saving. As a result, production is no longer constrained by the fixed supply of capital; real GDP increases further.

5.2. Creating a Steady State Database

In this section the results from the creation of two steady state databases are discussed and compared. These two steady state databases were created using the two methods outlined in section 3 (see columns 3 and 4 of Table 3 for the closures used to implement these shocks):

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[25] In the long-run with rorc(r) = rore(r), the percentage change in the growth rate of capital (kbgrow(r)) must equal zero. For kbgrow(r) to equal 0, beginning of period capital stocks (KB(r)) and gross investment must change by the same amount. Therefore kb(r) = qcgds(r).

- the risk-adjusted steady state database; and

- the non-risk-adjusted steady state database.

Table 5 lists the shocks applied under the two alternative methods. In the case of the risk-adjusted method only one shock to the power of the growth rates of capital is required. In the non-risk-adjusted case two shocks are undertaken: one to the power of the growth rates of capital and another to the expected rates of return. In the remainder of this sub-section the percentage changes resulting from the implementation of these two methods are discussed and compared.

Table 5: Shocks to the Growth Rate and Expected Rates of Return Required to Determine the Steady State Databases

Region[a]	kbgrow[b]	rore[c]
NAM	1.22	-11.05
JPN	-2.03	50.28
AUS	1.48	22.24
NZL	2.46	24.74
CHN_HKG	-4.24	81.98
SKOR	-7.81	49.44
TWN	-4.63	-8.02
MYS_SGP	-4.36	29.07
THA_PHL	-5.88	-6.84
IDN	-5.66	-31.04
ROW	0.58	-11.48

[a] All shocks were determined from using the shocks.tab facility Appendix 3. Shocks represent percentage change from contol.
[b] Shocks to the power of the growth rate of capital (kbgrow(r)) required to equate KBGROWTH(r) across all regions to an AVGROWTH of 1.0318. These shocks are based on the post-NAFTA Database.
[c] Shocks to the expected rate of return (rore(r)) required to equate ROREXP(r) across all regions to an AVROREXP of 8.66%. These shocks are based on the post NAFTA database.

The comparative static results discussed in sub-sections 5.1 above and 5.3 below are interpreted as percentage changes in variables, relative to the control, resulting from the shock. In this case, however, the shock is the equalisation of the growth rates of capital and expected rates of return across regions and hence a move towards steady state. Although perhaps unrealistic as a description of any likely change in the configuration of the world economy[26], the move to the steady state answers the question: how different from its recent actual state would the world economy look if complete convergence in growth rates had been achieved?

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[26] For this reason, results from the steady state experiments and the Asia-Pacific trade liberalisation experiments are considered separately in this section. In appendix 5, however, the cumulative results of the two experiments are given for those interested.

5.2.1. Results for the Creation of a Risk-Adjusted Steady State Database

Examination of the shocks in Table 5 illustrates that in order to achieve a common steady state rate of growth across all regions, growth rates for the Asian economies need to fall while the growth rates of the non-Asian economies must rise. This stems from the relative growth rates of capital in the standard benchmark database; the growth rates of capital in the Asian economies (including Japan) are higher than the average growth rate of capital, while the growth rates of capital for the non-Asian economies are lower than the average growth rate.

Table 6 gives the percentage changes in real GDP, capital stocks, risk-free and actual current rates of return, real rentals and real wages resulting from the implementation of the shock to the powers of the growth rates to achieve the risk-adjusted steady state database. The results show that for those Asian economies in which growth rates were reduced, real GDP and capital increased, while in the non-Asian economies, where growth rates were increased, real GDP and capital stocks declined.

Table 6: Percentage Changes in Real GDP, Capital Stocks, Current Risk-Free Rates of Return, Real Rentals and Real Wages Resulting from the Creation of a Risk-Adjusted Steady State Database

Region[*]	qgdp	kb	rorcf	rorc	real rental[a]	real wages[b]
NAM	-2.35	-7.22	17.38	7.06	3.81	-1.98
JPN	6.06	15.38	-15.39	-10.55	-5.87	3.79
AUS	-3.44	-10.32	20.41	11.38	5.06	-2.27
NZL	-4.57	-13.42	32.50	18.49	8.38	-3.7
CHN_HKG	15.76	43.25	-32.65	-27.10	-17.17	10.7
SKOR	38.29	99.72	-53.92	-36.77	-22.46	21.49
TWN	11.00	29.52	-35.33	-14.84	-11.0	7.42
MYS_SGP	26.44	50.49	-33.48	-19.72	-11.18	14.73
THA_PHL	26.85	46.64	-43.35	-18.45	-11.65	17.01
IDN	26.18	48.32	-41.97	-13.23	-10.8	14.92
ROW	-1.89	-4.64	10.05	4.06	2.3	-1.64
rorgf =roref			3.88			

[*] Results represent percentage changes from control.
[a] Real rental = rental(r) - pgdp(r)
[b] Real wages = ps("labor",r) - pgdp(r)

These results illustrate how crucial it is to distinguish between the growth rate that occurs between the injection of the shock and the steady state and the growth rate of capital which occurs thereafter, in the steady state. In the case of the Asian economies, between the implementation of the shock and the steady state solution period, growth rates of capital increase, thereby causing capital stocks and real GDP to increase. In the solution period, however, with higher steady state levels of capital stocks, the growth rate of capital in the Asian economies falls to the common steady state rate of growth.

The results can be explained by examining how the shocks to the powers of the growth rates of capital affect: the current risk-free rates of return, the current rates of return, the rental prices of capital, the real wage, capital stocks and finally real GDP. This analysis follows closely that process described in Adams, Horridge, Parmenter, and Zhang (1997).

In equation (3.8), the percentage change in the regional powers of the growth rates of capital form a wedge between the current risk-free rates of return (rorcf(r)) and the expected risk-free rates of return (roref(r)). With the percentage change in the power of the average growth rate of capital endogenously equal to zero and the percentage increase in the expected risk-free rates of return (which is common across all regions) equal to 3.88 percent, the percentage changes in the risk-free current rates of return are primarily determined by the exogenous shocks to the growth rates of capital. In the case of the Asian economies, negative shocks to the power of the growth rates of capital lead to falls in the current risk-free rates of return (compare Tables 5 and 6). For the non-Asian economies the current risk-free rates of return rise with the positive shocks to their growth rates.

With equality between absolute changes in the current rates of return (RORCUR(r)×rorc(r)) and the risk-free rates of return (RORCFREE(r)×rorcf(r)) (equation (3.8)), percentage changes in the current rates of return will be positively related to the percentage changes in the current risk-free rates of return; thus the current rates of return in the Asian economies also fall as a result of the steady state shock. The percentage decline in the current rates of return are much smaller than the percentage decline in the risk-free current rates of return as the risk-free current rates of return are smaller than the current rates of return in the levels. In the case of the non-Asian economies the current rates of return increase with the increases in the current risk-free rates of return.

Equation (5.1) illustrates the positive relationship between percentage changes in the current rate of return and the rental price of capital. In the Asian economies the fall in the current rate of return causes the rental price (Table 6) of capital to fall relative to the price of capital goods.

$$rorc(r) = GRNETRATIO(r) \times [rental(r) - pcgds(r)] \qquad (5.1)$$

Since under a shock to the growth rate of capital, the price of capital goods tends to change in line with the price of goods in general, real rentals for the Asian economies fall. The factor price frontier (equation (5.2))[27] shows the negative relationship between percentage changes in real rentals (rental(r) − pgdp(r)) and in real wages (ps("labor",r) − pgdp(r)). In the case of the Asian economies, real rentals decline relative to real wages (Table 6).

$$ps("labor",r) - pgdp(r) = \left[-\frac{VOA("capital",r)}{VOA("labor",r)} \right] \times (rental(r) - pgdp(r)) \qquad (5.2)$$

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[27] This factor price frontier relates to a constant returns to scale model in which there are only two factors. In the GTAP model there is a third factor land which may also affect this relationship.

This differential between the wage rate and the rental price of capital then causes substitution between labour and capital (equation (5.3)). With the supply of labour fixed, lower relative rentals, in the Asian economies, will cause an increase in demand for and thus supply of endogenously determined capital stocks. As a result capital stocks rise in the Asian countries (Table 6). In the non-Asian economies higher relative rental prices cause substitution away from capital; therefore capital stocks fall.

$$\text{rental}(r) - \text{ps}("\text{labor}", r) = \left(\text{qo}("\text{labor}", r) - \text{qo}("\text{capital}", r)\right) / \sigma(r) \tag{5.3}$$

where: $\sigma(r)$ is the average capital to labour substitution elasticity.

Finally, changes in capital stocks are then positively related to changes in real GDP (equation (5.4)). As a result real GDP in the Asian economies increases and real GDP in the non-Asian economies falls.

$$\text{gdp} = S_L\left(\text{qo}("\text{labor}", r)\right) + S_K\left(\text{qo}("\text{capital}", r)\right) + S_N\left(\text{qo}("\text{land}", r)\right) \tag{5.4}$$

where: S_L, S_K and S_N are the shares of labour, capital and land in GDP.

qo("labor",r) and qo("land",r) are exogenously equal to zero in all closures discussed in this paper.

In Table 7 the risk-free current rates of return and risk premia are listed for the post-NAFTA and risk-adjusted steady state databases. As expected the risk premia do not change between the two databases and the risk-free component of the current rate of return converges on 4.16 percent, the value of the risk-free expected rate of return in the steady state database.

Table 7: The Division of the Current Rates of Return into their Risk-free and Risk-Components in the Post-NAFTA and Risk-Adjusted Steady State Databases (percent).

Region[*]	Post-NAFTA Database			Risk Adjusted Steady State Database		
	RORC FREE	RISK	RORCUR	RORC FREE	RISK	RORCUR
NAM	3.5	5.2	8.7	4.16	5.2	9.4
JPN	4.9	2.3	7.2	4.16	2.3	6.4
AUS	3.5	2.7	6.2	4.16	2.7	6.9
NZL	3.1	2.4	5.5	4.16	2.4	6.5
CHN_HKG	6.2	1.3	7.4	4.16	1.3	5.4
SKOR	9.0	4.2	13.2	4.16	4.2	8.4
TWN	6.4	8.9	15.3	4.16	8.9	13.1
MYS_SGP	6.3	4.4	10.6	4.16	4.4	8.5
THA_PHL	7.4	9.9	17.3	4.16	9.9	14.1
IDN	7.2	15.6	22.8	4.16	15.6	19.8
ROW	3.8	5.6	9.4	4.16	5.6	9.7
ROREFREE	4.0[a]			4.16		

[*] All variables in this Table have units of percentages per annum and are levels variables.

[a] Set in the initial database at a value of 4 percent and updated by changes in the risk-free expected rate of return (roref(r)).

While the relative risk premia from this exercise contain some relative surprises (with China-Hong Kong having the lowest risk premia, and North America in the intermediate range), changing this ranking would probably involve major surgery to the capital data in the GTAP database, a project which is beyond the scope of this paper[28].

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[28] Given that the standard benchmark database does not represent the steady state, there are a number of reasons, other than differential risk premiums, why expected rates of return would differ across regions. For example in the case of China (where the erstwhile command economy could be expected to have allocated capital in unproductive ways), a large proportion of its existing capital stock is unproductive (revealed by low rates of return in the database). By obtaining independent estimates of risk premiums, risk-free rates of return could then be determined from the database and shocked to obtain equality in the steady state (see footnote 21).

5.2.2. Results for the Creation of a Non-Risk-Adjusted Steady State Database

In the non-risk-adjusted method two shocks (see Table 5 for shocks) are implemented: firstly, to equalise the growth rates of capital, and secondly, to equalise the expected rates of return. Table 8 shows the percentage changes in the current rates of return, capital stocks and real GDP resulting from these two shocks.

Table 8: Percentage Changes in Real GDP and Capital Stocks Resulting from the Creation of a Non-Risk-Adjusted Steady State Database

Region[*]	Due to shocks to the growth rates of capital (kbgrow)[a]			Due to shocks to the expected rates of return (rore)[a]			Total	
	Real GDP (qgdp)	Current Rate of return (rorc)	Capital (kb)	Real GDP (qgdp)	Current Rate of return (rorc)	Capital (kb)	Real GDP (qgdp)	Capital (kb)
NAM	-4.45	11.53	-12.43	6.57	-11.05	18.61	1.83	3.87
JPN	13.32	-19.61	35.47	-20.75	50.28	-44.18	-10.19	-24.38
AUS	-4.70	14.41	-13.56	-10.49	22.24	-26.05	-14.70	-36.08
NZL	-6.92	25.90	-19.19	-10.57	24.74	-26.39	-16.76	-40.52
CHN_HKG	24.04	-36.01	69.60	-26.24	81.98	-53.56	-8.51	-21.24
SKOR	92.60	-56.22	280.33	-27.82	49.44	-47.59	39.02	99.33
TWN	39.29	-38.56	120.64	5.93	-8.02	13.68	47.55	150.82
MYS_SGP	61.76	-36.80	128.62	-22.61	29.08	-36.54	25.19	45.08
THA_PHL	123.26	-46.17	240.74	6.78	-6.84	9.69	138.40	273.76
IDN	175.79	-44.86	410.69	69.58	-31.04	122.17	367.68	1034.6
ROW	-2.23	4.57	-5.32	8.76	-11.48	20.97	6.33	14.53
rore		-1.30						

[a] See Table 4 for shocks.
[*] Results respresent percentage changes from control.

The results from the **first shock** to the powers of the growth rates of capital are listed in Table 8. These results are similar to those obtained using the risk-adjusted method described above in sub-section 5.2.1; the Asian economies experience significant improvements in real GDP due to a fall in the growth rate of capital and the non-Asian economies experience declines in real GDP as a result of increases in the growth rates of capital. While similar, the percentage changes to the current rates of return are larger in absolute terms (more negative in the case of Asian economies or more positive in the case of the non-Asian economies) under the non-risk-adjusted method (third column of Table 8) than under the risk-adjusted method (fifth column of Table 6).

This is a result of the change in the powers of the growth rates of capital forming a wedge directly between the expected and current rates of return (equation (2.8)), rather than between the risk-free expected and risk-free current rates of return in the risk-adjusted method (equation (3.8)). Thus the percentage change in the current rate of return is determined directly by the percentage change in the power of the growth rate

under the non-risk-adjusted steady state method, while in the risk-adjusted steady state method, percentage changes in the powers of the growth rates determine the percentage change in the risk-free current rate of return. The percentage change in the current rate of return is then a fraction of the percentage change in the risk-free rate of return (equation (3.8)). Thus the changes in the current rates of return, under the non-risk-adjusted method are likely to be larger in absolute terms. As a result the increases in capital stocks and real GDP are also larger under this method.

The **second shock** involves changes which equate the expected rates of return in levels across all regions. Comparison of the shocks to the expected rates of return (rore in Table 5) and the resulting percentage changes in the real GDP (Table 8) show that in those regions where the expected rates of return were reduced, real GDP rose and vice-versa. These results can be explained by examining the relationship between the exogenous shocks to the expected rates of return and the percentage changes in the current rates of return. As illustrated above these changes in the current rates of return then determine the effect on the rental price of capital, real wages, capital stocks and finally real GDP (Adams, Horridge, Parmenter, and Zhang, 1997).

The relationship between the expected and current rate of return is given by equation (2.8). The percentage change in the current rates of return are determined by three variables: the percentage change in the powers of the growth rates of capital, the percentage change in the power of the average growth rate of capital and the percentage changes in the expected rates of return. The percentage change in the powers of the growth rates of capital and the average growth rate of capital (both equal to -0.165 percent in all regions) cancel each other out so that the percentage changes in the current rates of return are equal to the exogenous shocks in the expected rates of return. Thus in those regions where the expected rates of return rise in order to equate the expected rates of return to the average, there is an unambiguous increase in the current rates of return. In regions where the expected rate of return exogenously falls, the percentage change in the current rates of return is negative.

The percentage changes in the current rates of return will then determine the effect on real GDP via the process described above in sub-section 5.2.1. Equation (5.1) shows that changes in the current rates of return are positively related to changes in the rental prices of capital. These percentage changes in the rental price of capital then determine the changes in capital stocks via their effect on real wages and substitution between labour and capital (equations (5.2) and (5.3) respectively). Changes to regional capital stocks will then determine the percentage changes in real GDP via equation (5.4). As a result of this process, increases in the expected rates of return will lead to decreases in real GDP and declines in the expected rates of return will lead to increases in real GDP.

Table 8 also shows the total percentage changes in real GDP and capital stocks resulting from both shocks (Totals columns). Some of the changes in real GDP and capital stocks resulting from the two shocks are very large (in absolute terms). In some cases the shocks to the powers of the growth rates and to the expected rates of return tend to offset each other – this is true for North America, Japan, China-Hong Kong, and a lesser extent for South Korea, Malaysia-Singapore and the Rest of World (see Table 8). The non-risk-adjusted method of determining the steady state nevertheless still results in

some very large changes to the standard benchmark database. In those cases in which the two shocks reinforce each other, the changes can be extreme: see for example the 1035 percent increase in Indonesia's capital (Table 8: Totals). On the other hand, the changes to the database resulting from the risk-adjusted method of determining the steady state are not as large (48 percent in the case of Indonesia – see Table 6).

5.3. *Results of an Asia-Pacific Trade Liberalisation Shock: A Comparison between Long-Run Closure Results*

In this section, an Asia-Pacific trade liberalisation shock is simulated under four alternative treatments of the long run. The four treatments of the long run include:

- **Non-Risk-Adjusted Method with Standard Benchmark Database** – long-run closure equating percentage changes in current and expected rates of return (rorc(r) = rore(r) = rorg), with standard benchmark database (introduced in section 2 and used as the long-run closure in sub-section 5.1).

- **Non-Risk-Adjusted Method with Steady State Database** – long-run closure equating percentage changes in current and expected rates of return (section 2; rorc(r) = rore(r) = rorg), using the non-risk-adjusted steady state database as the initial database (section 3 and 5.2.2).

- **Risk-Adjusted Method with Standard Benchmark Database** – long-run closure equating percentage changes in the risk-free current and expected rates of return (section 3; rorcf(r) = roref(r) = rorgf), with standard benchmark database.

- **Risk-Adjusted Method with Steady State Database** – long-run closure equating percentage changes in the risk-free current and expected rates of return (section 3; rorcf(r) = roref(r) = rorg), with the risk-adjusted steady state database (section 3 and 5.2.1).

The closures for these four treatments of the long run are listed in Table 3. In the remainder of this section, the results of these four treatments are examined and the reasons for any differences between the four simulation results are discussed.

5.3.1. Results of the Four Treatments of the Long Run

Tables 9, 10, 11 and 12 depict the results of the four different treatments of the long run. The results are reasonably consistent over the four alternative treatments of the long run, however the simulations based on the steady state databases tend to result in larger gains in capital stocks and real GDP as a result of the tariff reductions.

Table 9: Results for APEC Trade Liberalisation Non-Risk-Adjusted Method with Standard Benchmark Database

Regions[a]	Share of imported inputs[b]	Price of Capital goods (pcgds)[c]	Current rate of return (rorc)[c]	Rental price of capital (rental)[c]	capital (kb)[c]	Real GDP (qgdp)[c]
NAM	14.2	-2.71	2.34	-1.15	-1.35	-0.48
JPN	2.3	4.84	2.34	6.42	0.48	1.35
AUS	18.5	2.89	2.34	4.35	5.79	2.47
NZL	25.5	2.77	2.34	4.17	5.95	2.56
CHN_HKG	18.8	-1.99	2.34	-0.50	11.23	5.62
SKOR	14.1	1.07	2.34	2.88	15.84	10.67
TWN	25.4	4.68	2.34	6.62	11.70	8.17
MYS_SGP	36.5	-0.34	2.34	1.36	21.00	13.50
THA_PHL	40.6	-12.81	2.34	-11.16	63.99	43.62
IDN	19.7	-0.58	2.34	1.40	7.43	4.81
ROW	11.9	-1.85	2.34	-0.24	-3.96	-1.80

[a] Non-Risk-Adjusted Method with standard benchmark database – long-run closure equating percentage changes in current and expected rates of return, with standard benchmark database.
[b] Share of imported inputs in the production of capital goods (percent). These variables are in levels.
[c] These variables represent percentage changes from control.

Table 10: Results for APEC Trade Liberalisation Non-Risk-Adjusted Method with Steady State Database

Regions[a]	Share of imported inputs[b]	Price of Capital goods (pcgds)[c]	Current Rate of return (rorc)[c]	Rental price of capital (rental)[c]	Capital (kb)[c]	Real GDP (qgdp)[c]
NAM	14.92	-1.89	-0.48	-2.21	3.21	1.20
JPN	2.09	8.02	-0.48	7.66	5.20	3.14
AUS	19.18	4.70	-0.48	4.36	11.38	4.25
NZL	25.37	5.22	-0.48	4.87	11.95	4.50
CHN_HKG	18.84	-0.58	-0.48	-0.91	14.70	6.44
SKOR	12.94	1.76	-0.48	-1.43	26.37	16.46
TWN	24.86	4.50	-0.48	4.15	15.75	10.00
MYS_SGP	36.32	0.56	-0.48	0.23	34.82	21.17
THA_PHL	42.84	-15.42	-0.48	-15.70	102.04	72.61
IDN	19.68	-2.28	-0.48	-2.60	23.51	15.66
ROW	12.37	-0.19	-0.48	-0.52	0.29	0.07

[a] Non-Risk-Adjusted Method with Steady State Database - long-run closure equating percentage changes in current and expected rates of return (section 2), using the non-risk-adjusted steady state database as the initial database (sections 3 and 4.2.2)

[b] Share of imported inputs in the production of capital goods (percent). These variables are in levels.

[c] These variables represent percentage changes from control.

Table 11: Results for APEC Trade Liberalisation Risk-Adjusted Method with Standard Benchmark Database

Regions[a]	Share of imported inputs[b]	Price of Capital goods (pcgds)[c]	Current Rate of Return (rorc)[c]	Rental Price of Capital (rental)[c]	Capital (kb)[c]	Real GDP (qgdp)[c]
NAM	14.2	-2.68	1.82	-1.47	-0.63	-0.20
JPN	2.3	4.79	3.08	6.87	-0.60	0.92
AUS	18.5	2.86	2.50	4.43	5.52	2.38
NZL	25.5	2.79	2.56	4.32	5.65	2.44
CHN_HKG	18.8	-1.91	3.73	0.47	9.12	4.82
SKOR	14.1	1.10	3.06	3.48	14.25	9.96
TWN	25.4	4.65	1.89	6.22	12.52	8.49
MYS_SGP	36.5	-0.29	2.65	1.63	20.37	13.18
THA_PHL	40.6	-12.89	1.91	-11.54	65.81	44.71
IDN	19.7	-0.69	1.42	0.51	10.19	6.41
ROW	11.9	-1.80	1.81	-0.55	-3.17	-1.45

[a] Risk-Adjusted Method with standard benchmark database – long-run closure equating percentage changes in the risk-free current and expected rates of return (section 3), with standard benchmark database.
[b] Share of imported inputs in the production of capital goods (percent). These variables are in the levels.
[c] These variables represent percentage changes from control.

Table 12: Results for APEC Trade Liberalisation Risk-Adjusted Method with Steady State Database

Regions[a]	Share of Imported Inputs[b]	Price of Capital Goods (pcgds)[c]	Current Rate of Return (rorc)[c]	Rental Price of Capital (rental)[c]	Capital (kb)[c]	Real GDP (qgdp)[c]
NAM	14.92	-2.88	-0.28	-3.08	2.81	1.06
JPN	2.02	6.56	-0.41	6.29	5.06	3.20
AUS	19.05	2.98	-0.38	2.73	10.20	4.08
NZL	25.53	3.27	-0.40	3.01	10.65	4.26
CHN_HKG	18.33	-2.19	-0.49	-2.46	16.34	7.76
SKOR	13.01	0.81	-0.32	0.60	25.11	15.94
TWN	25.23	4.47	-0.20	4.31	14.97	9.72
MYS_SGP	36.41	-0.39	-0.31	-0.60	28.46	18.22
THA_PHL	41.32	-14.12	-0.19	-14.25	87.38	59.41
IDN	19.58	-0.62	-0.13	-0.73	17.05	10.72
ROW	12.3	-0.76	-0.27	-0.95	0.003	-0.05

[a] Risk-Adjusted Method with Steady State Database – long-run closure equating percentage changes in the risk free current and expected rates of return (section 3), with the risk-adjusted steady state database (sections 3 and 4.2.1).
[b] Share of imported inputs in the production of capital goods (percent). These variables are in levels.
[c] These variables represent percentage changes from control.

These larger changes in real GDP[29] stem from larger increases in capital stocks under the steady state simulations (both from the non-risk-adjusted and the risk-adjusted methods). In the steady state simulations all APEC regions (including North America) experience increases in their capital stocks and hence improvements in real GDP. In the case of the Rest of World the significant decrease in the long-run real GDP becomes insignificant in the two steady state cases.

Table 13 lists some of the relevant changes in the macro variables such as the rates of return, global investment and global capital stocks. As expected percentage changes in global investment and global capital are pair-wise equal in the two simulations in which steady state databases are used as the initial database. In addition, the percentage change in the average growth rate in the two steady state treatments is equal to zero.

Table 13: Macro Results for the APEC Trade Liberalisation Shock The Four Treatments of the Long Run

	Non Risk Adjusted Benchmark	Non Risk Adjusted Steady State	Risk Adjusted Benchmark	Risk Adjusted Steady State
globalcgds	1.06	4.94	1.07	3.66
kb_tot[a]	-1.19	4.94	-0.85	3.66
rorgf = roref rorcf	n.a	n.a	4.51	-0.64
rorg = rore = rorc	2.34	-0.48	n.a	n.a
avgrow	0[b]	-0.000002	0[c]	0.000007

[a] kb_tot is the percentage change in total global capital stocks. This is equal to the sum across regions of weighted percentage changes in regional capital stocks; where the weight of the value of regional capital in global capital stocks.
[b] Exogenous
[c] Exogenous

In the two simulations based on steady state databases the expected global rate of return falls as a result of the reduction in tariffs, while in the two other simulations the expected global rate of return increases. For example, with the risk-free expected global

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[29] Again it is important to remember that these results are changes in real GDP, they do not take into account changes in the ownership of capital stocks and therefore should not be interpreted as changes in welfare. In footnote (7) above an equation developed by Francois et al. (1997) was discussed which partially accounted for these ownership effects. Although this equation could not be applied to methods using the steady state databases, the equation does work reasonably well with the long-run closures based on the standard benchmark database. In these cases income levels fall for North America (3.5-1.5 percent), China-Hong Kong (5-7 percent), South Korea (9-13 percent), Malaysia-Singapore (12-17 percent) and Indonesia (91-115 percent) and increase for Japan (5-3.5 percent), Australia (2.5-1.5 percent), New Zealand (1-1.5 percent) and the Rest of World (0.77-2.5 percent). For Taiwan the difference is not significant. For Thailand-Philippines the difference increases income significantly (approx. 8 percent) in the risk-adjusted method and reduces income slightly (1 percent) in the non-risk-adjusted method.

rate of return set at 4 percent p.a. in the pre-shock database, the 4.51 percent increase in rorgf translates to a rise in the global risk-free rate of return from 4 percent to $4\times(1+0.0451) = 4.18$ percent p.a (see fourth column of Table 13).

The falls (relative to the non steady state methods based on the benchmark database: Table 13) which occur in the expected global rate of return, when the steady state databases are used, are the result of higher global investment required to equate global saving and global net investment (equation (5.5)).

GLOBAL SAVING = GLOBAL INVESTMENT

$$\sum_{r \in REG}\left(\frac{SAVE(r)}{GLOBALINV} \times qsave(r)\right) = \sum_{r \in REG}\left[\left(\frac{REGINV(r)}{GLOBALINV}\right) \times qcgds(r) - \left(\frac{VDEP(r)}{GLOBALINV}\right) \times kb(r)\right]$$

(5.5)

Equation (5.5) involves the share of regional investment in global investment (right hand side of equation (5.5)) and the share of regional saving in global saving (left hand side of equation (5.5)). As a result of the shocks to achieve the steady state databases (section 5.2), saving increased in most regions, while investment increased only in the non-Asian economies (North America, Australia, New Zealand and the Rest of World). As a result the regional saving shares $\left[\frac{SAVE(r)}{GLOBALINV}\right]$ have not altered significantly. On the other hand, almost without exception, the regional net investment shares $\left[\frac{NETINV(r)}{GLOBALINV}\right]$ in the steady state database captured by the Asian economies have fallen and those shares captured by the non-Asian economies have increased (Table 14). It is these Asian economies which experience the significant increases in investment as a result of the APEC trade liberalisation shock. With lower Asian investment shares in the steady state database, even larger increases in regional investment are required to equate global investment and global saving under these two steady state methods. The fall in the expected global rate of return is a result of these larger increases in investment required to equate global saving and investment.

The lower percentage change in the expected global rate of return (of the two steady state methods) is shock specific. If a pro-North American or European shock (for example NAFTA) had been implemented the percentage change in the expected global rate of return would have been higher in the two steady state methods because less investment would have been required to equate global investment and global saving, since North America and Europe hold larger shares of global investment in the steady state databases.

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Table 14: Share of Regional Net Investment in Total Net Investment

Regions[a]	Post NAFTA Database	Non Risk Adjusted Steady State	Risk Adjusted Steady State
NAM	16.39	26.60	25.89
JPN	29.16	11.09	18.31
AUS	0.78	0.88	1.38
NZL	0.05	0.12	0.19
CHN_HKG	4.47	1.25	2.40
SKOR	3.81	1.59	1.73
TWN	1.46	1.19	0.69
MYS_SGP	1.17	0.59	0.67
THA_PHL	1.76	1.63	0.77
IDN	1.11	3.02	0.51
ROW	39.85	52.02	47.47

[a] These variables are percentage shares of the levels. Note that in the steady state databases these regional net investment shares in global investment will be equal to the shares of regional capital stocks in global capital stocks.

5.3.2. Why do the Changes in Regional Capital Stocks differ between the Simulations?

The results discussed in the previous section show that the changes in capital stocks and real GDP resulting from the tariff shock were larger in the simulations which used the steady state as their initial database. These differences in the percentage changes in capital stocks are caused by differences in the percentage changes in the long-run rentals. In the long run, with changes in the current and expected rates of return (or current and expected risk-free rates of return) equated, changes in the rental price of capital are determined by two variables: the price of capital goods and the current rate of return.

$$\text{rental}(r) = \left[\frac{1}{\text{GRNETRATIO}(r)} \right] \times \text{rorc}(r) + \text{pcgds}(r) \qquad (5.6)$$

1. *Changes in the price of capital goods*

Assuming the current rate of return is unchanged in the long run, the change in the long-run rental price of capital depends only on the change in the price of capital goods.

The price of capital goods changes as a result of two countervailing effects: firstly, the reduction in tariffs on imported inputs into capital goods production tends to decrease the price of capital goods; and secondly, increased demand for inputs tends to increase the price of capital goods. In the case of Thailand-Philippines imported goods account for approximately 40 percent of inputs in the production of capital goods and the initial tariffs on these imported inputs are very high. As a result (and not withstanding the stimulus of increased demand), the price of capital goods falls

significantly in response to the reduction in tariffs on these imported inputs (Adams, Horridge, Parmenter and Zhang, 1997).

2. *Changes in the current rates of return*

The percentage change in the current rate of return forms a wedge between the rental price and price of capital goods (equation (5.6)).

In the two non-risk-adjusted simulations (launched from the benchmark and steady state databases) the percentage changes in the current rates of return are equal across all regions and dependent on the percentage change in the expected rate of return (equation (2.8), where the percentage changes in the growth rates of capital (including the average) are equal to zero).

In the non-risk-adjusted method with standard benchmark database (Table 8), where the percentage change (not percentage point) in the current rate of return of 2.34 percent is non negligible, the percentage change in the rental price will be significantly higher than the percentage changes in the price of capital goods. In the non-risk-adjusted case with the steady state database, the percentage change in the current rate of return is −0.48 percent, which is close to zero. As a result, the change in the long-run rental price will depend mainly on the change in the price of capital goods. As the percentage change in the expected global rate of return is also slightly negative, the percentage change in the long-run rental price will be slightly lower than the percentage change in the price of capital goods.

In the two risk-adjusted simulations (with benchmark and steady state databases) it is the current and expected risk-free rates of return which are equated across regions (roref(r) = rorcf(r) = rorgf). With the absolute (or percentage point) change in the current rate of return equal to the absolute (or percentage point) change in the risk-free rate of return (equation (3.9)), the percentage change in the current rates of return will depend on the percentage change in the current risk-free rate of return (rorcf(r)), the actual current risk-free rate of return (RORCFREE(r)) and the actual current rate of return (RORCUR(r)) (equation (5.7)).

$$rorc(r) = \frac{rorcf(r) \times RORCFREE(r)}{RORCUR(r)} \tag{5.7}$$

When the steady state database is used the percentage change in the current risk-free rate of return (rorcf(r) = -0.64 percent) is much smaller than the percentage change in the current risk-free rate of return using the standard database (rorcf(r) = 4.51 percent). Thus the percentage changes in the current rates of return are lower under the risk-adjusted method with steady state database.

Slight differences also arise because the current rates of return (RORCUR(r)) (and possibly[30] the current risk-free rates of return (RORCFREE(r)) differ across regions. If the actual value of the current rate of return is high, then the percentage change is

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[30] Current risk-free rates of return will differ when the standard benchmark database is used; however they will not differ if the risk-adjusted steady state database is used as the initial database.

likely to be low and vice versa. For example Indonesia has a very high current rate of return and therefore the percentage change in the current rate of return (1.42 percent with the standard benchmark database and 0.13 percent with the steady state database) is very low compared to the other regions in the same simulation.

An absolutely small percentage change in the current rate of return means that the percentage change in the rental price is determined primarily by the price of capital goods. In the steady state simulations (with non-risk-adjusted or risk-adjusted method) the percentage change in the current rates of return are lower than the percentage changes in the current rates of return in both the non-risk-adjusted and the risk-adjusted simulations with standard benchmark data, as a result the percentage changes in the rental prices of capital are also lower.

As discussed previously, the percentage changes in the real rental prices of capital then determine the percentage changes in the real wage (equation (5.2)). With the supply of labour fixed, a decline in the real rental price of capital relative to the real wage rate causes substitution towards capital (equation (5.3)). The increased supply of capital then leads to an increase in real GDP. The lower percentage change in the rental price of capital in the two steady state simulations causes real wages, capital and real GDP to increase further.

To summarise, the larger percentage changes in regional capital and real GDP in the two steady state[31] simulations are the result of the lower percentage changes in the expected global (possibly risk-free) rate of return.

6.   Conclusions

Inconsistency of the standard GTAP database with a steady state   The purpose of this paper has been to incorporate into the GTAP model a comparative static framework for determining the long-run effects of a shock. In this paper a simple long-run comparative static closure, in which percentage changes in the expected and current rates of return are equated across regions, was developed for this purpose. Analysis of the assumptions of this closure exposes an inconsistency between the new long-run equations and the standard GTAP database. This inconsistency is due to the fact that the underlying assumptions of these long-run equations, namely that regional rates of return have converged to a common global rate and that a steady state prevails, do not hold within

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[31] As mentioned above in footnote (17), additional simulations were undertaken to test the sensitivity of the results to the choice of steady state growth rate. These revealed that there was little difference between the results of the Asia-Pacific trade liberalisation shock when a steady state growth rate of 2, 3 or 6 percent was used. Where a steady state growth rate of zero percent (or growth rates of less than approximately 2 percent) were enforced a number of problems arose: including non-convergence of the model to a solution, large changes in the relative investment shares of the regions and current and expected rates of return which were driven below zero. In some of these simulations, where the growth rates were reduced to below 2 percent, the Asia-Pacific trade liberalisation shock resulted in negative changes to capital stocks for North America and the Rest of World. Due to the problems associated with these simulations a conclusion as to the significance of these results cannot be drawn.

the benchmark database. This steady state assumption requires that firstly, the growth rates of capital conform to a balanced growth path and are equal across all regions to a common steady state rate of growth, and secondly, that the expected rates of return are equal across all regions.

In order to remove these inconsistencies in the benchmark database, a new steady state database is created. Two methods are examined for creating this steady state database:

- *The risk-adjusted steady state database.* Under this method growth rates of capital are equated across all regions and the expected and current rates of return are equated within regions; however, rates of return are permitted to differ across regions due to differences in risk premia. Creating the steady state database involved shocking the growth rates of capital after some alterations to the equations to incorporate risk-free rates of return.

- *The non-risk-adjusted steady state database.* Under this method all conditions of the steady state are satisfied; both equality of the growth rates of capital and equality of the expected and current rates of return both within and across regions. This method involved two shocks to the benchmark database: the first, to equate expected rates of return across regions; and the second, to equate the growth rates of capital and therefore the expected rates of return to the current rates of return within regions.

The first method, in which expected rates of return were allowed to differ indefinitely between regions, seemed to be the best option. This risk-adjusted method did not appear to diverge wildly from the benchmark database; there were, however, some surprises in the relative risk premia associated with some of the regions.

Policy interpretation of the comparative steady states results Given that this methodology involves the comparison of two *hypothetical* databases (namely, the newly constructed steady state benchmark and the shocked solution launched from this benchmark), how do we interpret the results for policy makers? The focus of our analysis here is very long run (thirty or more years out, say). We need to compare pictures of the world economy at this horizon with and without the shock (in this paper, APEC trade liberalisation). Our picture of what the world would be like in thirty years time without the shock under analysis *and without any further shocks of any other kind* is one of a steady state in which all (possibly risk-adjusted) rates of return are equal, and growth rates around the globe have converged. Upon this we superimpose a shock of policy interest (such as trade liberalisation) and ask how different the picture would be in thirty years time. The percentage changes reported in this paper quantify these differences which (in part) reflect changes in the regional disposition of capital necessary to equate rates of return.

Caveat on welfare interpretation of results Under this assumption of perfect capital mobility, large changes in the capital stocks of certain regions can occur (they do so in the case of the APEC shock analysed above). This has important implications for interpreting the impact on welfare; in particular, since ownership of capital is not tracked, GDP is not a useful indicator for this purpose. Further research needs to

incorporate an accounting framework which takes into account changes in the ownership of capital and their effect on gross national product and welfare.

Comparison with other approaches The comparative static long-run methods developed here and those developed by Francois et al. (1996) differ in their treatment of capital mobility. In the closures developed in this paper, capital is assumed to be perfectly mobile and thus rates of return do equate across regions in the long run. In the Francois et al. (1996) closures, capital is not mobile across regions and thus any changes in investment must be financed directly from domestic saving. In the dynamic model, currently being developed by McDougall and Ianchovichina (1996), a portion of capital is assumed to be perfectly mobile across regions and the global economy moves from the benchmark database towards a steady state database in which rates of return are equal in all regions. In addition, the dynamic version of the GTAP model takes into account changes in the ownership of capital and the effects of these changes on regional income.

Salient features of results A new approach to the long-run closure of GTAP involving strict comparative statics based on balanced growth paths was investigated. It was found that:

- The method of comparative steady states is a viable tool for long-run analysis with GTAP. Although the standard benchmark GTAP database must first be adjusted to reflect a steady state of balanced growth, this is a relatively easy procedure which ensures valid comparative statics.

The APEC trade liberalisation shock was simulated using the standard GTAP short-run closure and four variations of the long run, including two variations on the model and three different initial databases. The following conclusions were drawn:

- Both the short- and long-run simulations showed an overall improvement in real GDP for the Asia-Pacific economies as a result of the APEC trade liberalisation shock.

- In comparing the short- and long-run effects of Asia-Pacific trade liberalisation, it was found that the Asia-Pacific economies experienced greater increases in real GDP in the long run. These larger increases in real GDP were primarily due to increases in capital stocks within the Asia-Pacific economies.

- The results were fairly consistent across all four treatments of the long run. The incorporation of risk premia had relatively little effect on the long-run results, while the use of a steady state database as the initial database from which the model is implemented, did affect the long-run results. In these closures the resulting changes in capital stocks and in real GDP tended to be even greater than those obtained from the long-run simulations based on the standard benchmark database.

Appendices

Appendix 1: Additions for Determining the Long Run

In this appendix the additions made to the Tablo, data and parameter files to implement all four treatments of the long run are outlined.

TABLO FILE

(GTAPLR.TAB)

Variables

VARIABLE	growavslack

\# Slack variable in equation determining the power of the average growth rate of capital \#

! This variable is exogenous in both the short-run and long-run treatments with steady state database. It is endogenous in the long-run treatments with standard benchmark data.! ;

VARIABLE (All,r,REG)	growslack(r)

\# Slack variable in the equation to equate kbgrow(r) and growth \#

! Usually endogenous unless the user wishes to shock the expected rates of return to equate the expected rates of return in the levels ! ;

VARIABLE (All,r,REG)	growth

\# Single growth rate \#

! Usually exogenous, unless the user wishes to shock the expected rates of return to equate the expected rates of return in the levels, when it is swapped with the global rate of return ! ;

VARIABLE	avgrow

\# Power of the Average Growth rate of capital \#

! This variable is endogenous in both the short-run and long-run closures which are based on an initial steady state database. In the treatments of the long run which use the steady state database as their initial database, avgrow will equal zero. In treatments of the long run which use the standard benchmark database as their initial database avgrow must be set exogenously equal to zero. !;

VARIABLE (All,r,REG)	kbgrow(r)

\# Power of the growth rate of capital in region r \#

! This variable is exogenously equal to zero in long-run closure and endogenous in short-run closure ! ;

VARIABLE	kb_tot

Global stock of capital # ;

VARIABLE	pkb

Price of the Global stock of capital # ;

VARIABLE (All,r,REG)	rsk(r)

Risk premia. # ;

! Usually exogenously equal to zero, unless user wants to alter risk premia. ! ;

VARIABLE (All,r,REG)	rorcf(r)

Risk-free current rate of return. # ;

VARIABLE (All,r,REG)	roref(r)

Risk-free expected rate of return. # ;

VARIABLE	rorgf

global Risk-free rate of return expected on capital. # ;

New Text File

FILE (TEXT) GTAPRISK # A file containing RISKADJ. # ;

COEFFICIENT	RISKADJ

! RISKADJ is a binary coefficient which determines whether the Risk-Adjusted or Non-Risk-Adjusted method is being used. When RISKADJ = 1, rates of return are adjusted for risk. When RISKADJ = 0, rates of return are not adjusted for risk ! ;

READ RISKADJ FROM FILE GTAPRISK ;

Coefficients
Database

COEFFICIENT (All,r,REG)	ROREFREE(r)

! Expected Risk-free rate of return ! ;

UPDATE (All,r,REG)

ROREFREE(r) = roref(r) ;

READ (All,r,REG)	ROREFREE(r)

FROM FILE GTAPDATA HEADER "RREF" ;

Coefficients
Derivatives of the Database

COEFFICIENT (All,r,REG)   KBGROWTH(r)

! Power of Growth rate of capital in region r. ! ;

FORMULA (All,r,REG)

KBGROWTH(r) = 1 + (NETINV(r)/VKB(r)) ;

COEFFICIENT (All,r,REG)   DEPRATE(r)

! Depreciation rate in region r ! ;

FORMULA (All,r,REG)

DEPRATE(r) = VDEP(r)/VKB(r) ;

COEFFICIENT   GLOBKB

! Global Capital Stocks ! ;

FORMULA

GLOBKB = (sum (r,REG, VKB(r)) ;

COEFFICIENT (All,r,REG)   SHR_VKE(r)

! Share of regional net investment in total real net investment ! ;

FORMULA (All,r,REG)

SHR_VKE(r) = NETINV(r)+VKB(r)/

(sum(k,REG, NETINV(k)+VKB(k))) ;

COEFFICIENT (All,r,REG)   SHR_VKB(r)

! Share of regional capital in total capital ! ;

FORMULA (All,r,REG)

SHR_VKB(r) = VKB(r)/GLOBKB ;

COEFFICIENT   AVGROWTH

! Power of Average growth rate of all capital stocks. ! ;

FORMULA

AVGROWTH = (sum(r,REG,
SHR_VKB(r)*KBGROWTH(r))) ;

COEFFICIENT (All,r,REG)   RORCUR(r)

! Current rate of return in region r in levels. !

FORMULA (All,r,REG)

RORCUR(r) = [(sum(h,ENDWC_COMM,
VOA(h,r))/(VKB(r))) - (VDEP(r)/VKB(r))] ;

COEFFICIENT (All,r,REG)   RORCFREE(r)

! Current Risk-free rate of return ! ;

FORMULA (All,r,REG)

$$RORCFREE(r) = [ROREFREE(r) *$$

$$[(VKB(r)+NETINV(r))/(VKB(r)*(AVGROWTH))]$$

$$^{(RORFLEX(r))}] ;$$

COEFFICIENT (All,r,REG)   RISK(r)

! Risk premia. !

FORMULA (All,r,REG)

$$RISK(r) = RORCUR(r) - RORCFREE(r) ;$$

COEFFICIENT (All,r,REG)   ROREXP(r)

! Expected rate of return in region r in levels. !

FORMULA (All,r,REG)

$$ROREXP(r) = (1-RISKADJ)*[[RORCUR(r) *$$

$$[(VKB(r)+NETINV(r))/(VKB(r)*(AVGROWTH))]^$$

$$(-RORFLEX(r))]] + RISKADJ * [ROREFREE(r) + RISK(r)];$$

Equations

EQUATION E_KBGROW

! Expected rate of return depends on the current rate of return and growth rates in the Non-Risk-Adjusted method (RISKADJ=0). In the Risk-Adjusted method the expected Risk-free rate of return depends on the current risk-free rate of return and the growth rates. This equation replaces an existing equation in the model (HT#58)!

(All, r, REG)

$$[1-RISKADJ]*rore(r) + [RISKADJ]*roref(r)$$

$$= [RISKADJ]*\{rorcf(r) - RORFLEX(r) * [kbgrow(r) -avgrow]\}+$$

$$[1-RISKADJ]*\{rorc(r) - RORFLEX(r) * [kbgrow(r) - avgrow]\} ;$$

EQUATION E_KE

! Growth relationship between end-of-period capital and beginning-of-period capital!

(All, r, REG)

$$ke(r) = kb(r) + kbgrow(r) ;$$

EQUATION E_RORE

! This equation computes alternatively the global supply of capital goods (RORDELTA = 0) or the global rate of return (RORDELTA = 1) for either the Non-Risk-Adjusted (RISKADJ = 0) or Risk-Adjusted method (RISKADJ = 1). This equation replaces an existing equation (HT#59) !

(All,r,REG)

$$[1\text{-RISKADJ}]*\{\text{RORDELTA} * [\text{rore}(r)]$$

$$+ [1 - \text{RORDELTA}] * \{[\text{REGINV}(r)/\text{NETINV}(r)] * \text{qcgds}(r)$$

$$- [\text{VDEP}(r)/\text{NETINV}(r)] * \text{kb}(r)\}\}$$

$$+ [\text{RISKADJ}]*\{\text{RORDELTA} * [\text{roref}(r)] + [1 - \text{RORDELTA}]$$

$$* \{[\text{REGINV}(r)/\text{NETINV}(r)] * \text{qcgds}(r) - [\text{VDEP}(r)/\text{NETINV}(r)] * \text{kb}(r)\}\}$$

$$= [1\text{-RISKADJ}]*\{\text{RORDELTA} * \text{rorg} +$$

$$[1 - \text{RORDELTA}] * \text{globalcgds} + \text{cgdslack}(r)\}$$

$$+ [\text{RISKADJ}]*\{\text{RORDELTA} * \text{rorgf}$$

$$+ [1 - \text{RORDELTA}] * \text{globalcgds} + \text{cgdslack}(r)\} \ ;$$

EQUATION E_GLOBALCGDS

! This equation computes: either the change in global investment (when RORDELTA=1), or the change in the expected global rate of return on capital (when RORDELTA=0) under the non-risk-adjusted method (RISKADJ = 0) or risk-adjusted method (RISKADJ=1). This equation replaces an existing equation (HT#11') !

$$[1\text{-RISKADJ}]*\{\text{RORDELTA} * \text{globalcgds} + [1 - \text{RORDELTA}] * \text{rorg}\}$$

$$+ [\text{RISKADJ}]*\{\text{RORDELTA} * \text{globalcgds} + [1 - \text{RORDELTA}] * \text{rorgf}\}$$

$$= [1\text{-RISKADJ}]*\{\text{RORDELTA} * [\text{sum}(r,\text{REG}, \{\text{REGINV}(r)/\text{GLOBINV}\}* \text{qcgds}(r)$$

$$- \{\text{VDEP}(r)/\text{GLOBINV}\} * \text{kb}(r))]$$

$$+ [1 - \text{RORDELTA}] * [\text{sum}(r,\text{REG}, \{\text{NETINV}(r)/\text{GLOBINV}\} * \text{rore}(r))]\}$$

$$+ [\text{RISKADJ}]*\{\text{RORDELTA} * [\text{sum}(r,\text{REG}, \{\text{REGINV}(r)/\text{GLOBINV}\} * \text{qcgds}(r)$$

$$- \{\text{VDEP}(r)/\text{GLOBINV}\} * \text{kb}(r))] +$$

$$[1 - \text{RORDELTA}] * [\text{sum}(r,\text{REG}, \{\text{NETINV}(r)/\text{GLOBINV}\} * \text{roref}(r))]\};$$

EQUATION E_KB_TOT

! Calculates the total percentage change in global capital stocks. !

$$\text{GLOBKB} * kb\_tot = \text{Sum}(r,\text{REG},\text{VKB}(r) * kb(r)) \ ;$$

EQUATION E_PKB

! Calculates the percentage change in the price index for global capital stocks. !

$$pkb = \text{Sum}(r,\text{REG},\text{SHR\_VKB}(r) * pcgds(r)) \ ;$$

EQUATION E_GROWSLACK

! Equates the percentage change in the growth rates of capital to the average growth rate of capital. Used when shocks are applied to equate the expected rates of return across regions !

(All,r,REG)

$$kbgrow(r) = growth + growslack(r) \ ;$$

EQUATION E_AVGROW

! This equation equates the change in growth rates across regions !

$$avgrow = \text{sum}(r,\text{REG}, \text{SHR\_VKE}(r) *$$

$$(kb(r) + pcgds(r) + kbgrow(r))$$

$$- (kb\_tot + pkb) + growavslack \ ;$$

EQUATION E_ROREF

! Equates absolute changes in the expected and expected Risk-free rate of return.!

(All, r, REG)

$$(\text{ROREXP}(r) * rore(r)) = (\text{ROREFREE}(r) * roref(r) + \text{RISK}(r) * rsk(r)) \ ;$$

EQUATION E_RORCF (All,r,REG)

! Equates absolute changes in the current and current Risk-free rate of return !

$$(\text{RORCUR}(r) * rorc(r)) = (\text{RORCFREE}(r) * rorcf(r)) + \text{RISK}(r) * rsk(r) \ ;$$

EQUATION E_RORGF (All,r,REG)

! Equates percentage change in global expected rate of return (risk-adjusted method: RISKADJ=1) or global Risk-free expected rate of return (non-risk-adjusted method: RISKADJ=0). !

$$\text{RISKADJ} * rorg + (1-\text{RISKADJ}) * rorgf$$

$$= \text{sum}(r,\text{REG}, (\text{RISKADJ}) * (\text{NETINV}(r)/\text{GLOBINV}) * rore(r)$$

$$+ (1-\text{RISKADJ})*(\text{NETINV}(r)/\text{GLOBINV})* roref(r))$$

PARAMETER FILE

(GPAR118.DAT)

Changes to Parameter File
RORDELTA = 1

PARAMETER FILE

(GPARRSK.DAT)

New Parameter File
(alternatively this could be affixed to the existing GPAR.DAT file.)

Risk-Adjusted Method	Non-Risk-Adjusted Method
RISKADJ = 1	RISKADJ = 0

DATA FILE

(GDATADJ.HAR)

These additions to the GTAP model requires additional data: the expected risk-free rates of return. This new data is added to the standard GTAP database, prior to any shocks (pre-NAFTA), using MODHAR. An STI file (SSADJ.STI) has been created to do this.

Appendix 2: Assumption of Long-Run Closure

In the standard GTAP model, the expected and current rates of return are related in the following way (equation A2.1):

$$\frac{ROREXP(r)}{RORCUR(r)} = \left[\frac{KE(r)}{KB(r)}\right]^{-RORFLEX(r)} \tag{A2.1}$$

Investors are cautious and the rate of return is expected to decline with increases in the end-of-period capital stock. Therefore the expected rate of return falls if capital stocks grow. The rate of this decline depends on the elasticity of the expected rate of return to the end-of-period capital stock [RORFLEX(r): equation A2.1]. A 1% increase in the end-of-period capital stock is expected to reduce the rate of return on capital by RORFLEX%. If RORFLEX(r) is large, then only a small change in the end-of-period capital stock will result in a large change in the expected rate of return.

In the four treatments of the long run discussed in this paper, this relationship between the expected and current rate of return has been modified (equation A2.2) to include the power of the average growth rate of capital (AVGROWTH). With this modification, the expected rate of return will fall if capital stocks grow at a rate faster than the average rate of growth.

$$\frac{ROREXP(r)}{RORCUR(r)} = \left[\frac{KE(r)}{KB(r) \times AVGROWTH}\right]^{-RORFLEX(r)} \tag{A2.2}$$

Figure A2.1 demonstrates the relationship between the expected and current rate of return within each region. If capital stocks are growing at the average rate of growth then the current rate of return will equal the expected rate of return.

Figure A2. 1: Expected Rate of Return Schedule

$$\left[\frac{KE(r)}{KB(r) \times AVKBGROW} \right]$$
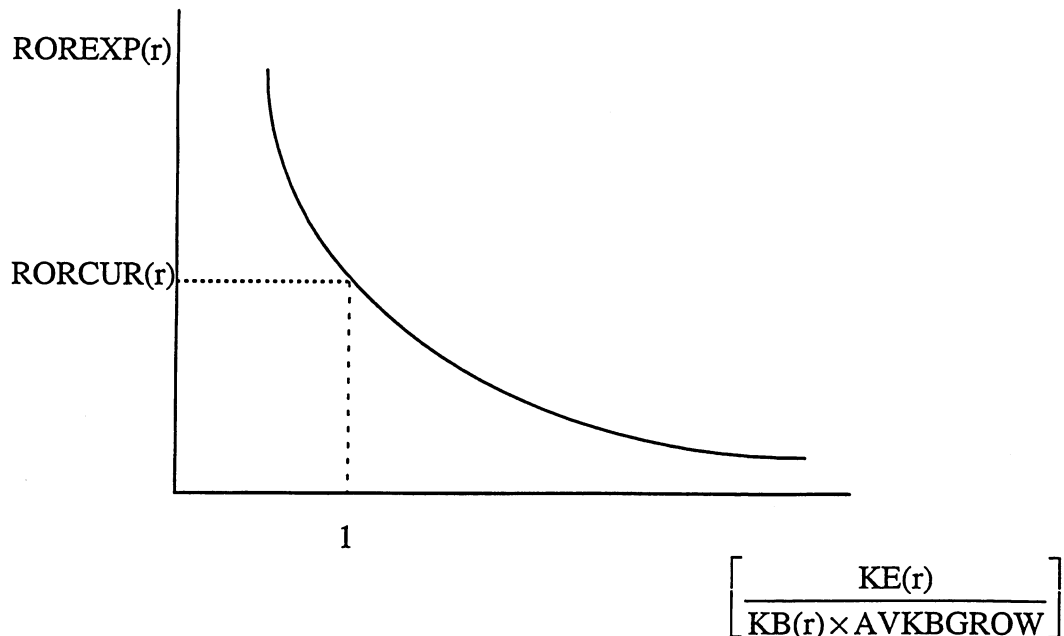
After Dixon, Parmenter, Sutton and Vincent (1981), p. 119 (modified).

Appendix 3: Additions to Shock.Tab File

In this appendix the additions made to the shock.tab and parameter files to determine the steady state shocks to the expected rates of return and growth rates are outlined.

SHOCK TABLO FILE

(SHK118.TAB)

Create and Write File

FILE (TEXT) GTAPPARM

      # The file containing behavioural parameters. # ;

! A new parameter file is now required to read in values for RORFLEX(r). This new parameter file can be obtained from the existing parameter file. Only values for RORFLEX(r) should appear on this parameter file. !

FILE (NEW,TEXT) KBGROW

    # The file with shocks to obtain KBGROWTH = AVGROWTH # ;

WRITE CHGKBGROW to FILE KBGROW ;

FILE (NEW,TEXT) ROREEQ

The file with shocks to obtain RORE = AVROREXP #;

WRITE CHGRORE to FILE ROREEQ ;

Base Revenues and expenditures

COEFFICIENT (All, r, REG)   VKB(r)

   ! value of beginning-of-period capital stock, in region r ! ;

COEFFICIENT (All, r, REG)   VDEP(r)

 ! value of capital depreciation, in r (depreciation rate is exogenous and therefore does not appear in update) ! ;

READ (All,r,REG)   VKB(r)

    FROM FILE GTAPDATA HEADER "VKB" ;

READ (All,r,REG)   VDEP(r)

    FROM FILE GTAPDATA HEADER "VDEP" ;

COEFFICIENT (All, r, REG)   RORFLEX(r)

 ! RORFLEX is the flexibility of expected net rate of return on capital stock, in region r, with respect to investment. If a region's capital stock increases by 1%, then it is expected that the net rate of return on capital will decline by RORFLEX % !
 ;

READ RORFLEX FROM FILE GTAPPARM ;

Derivatives of Database

COEFFICIENT (All, r, REG)   NETINV(r)

! regional NET investment in region r ! ;

FORMULA (All, r, REG)

 NETINV(r) = sum(k,CGDS_COMM, VOA(k,r)) - VDEP(r) ;

COEFFICIENT (All,r,REG)   KBGROWTH(r)

FORMULA (All,r,REG)

    KBGROWTH(r) = 1 + (NETINV(r)/VKB(r)) ;

COEFFICIENT (All,r,REG)   SHR_VKB(r)

FORMULA (All,r,REG)

    SHR_VKB(r) = VKB(r)/GLOBKB ;

COEFFICIENT   AVGROWTH

FORMULA

AVGROWTH = sum(r,REG,SHR_VKB(r)*KBGROWTH(r))

;

COEFFICIENT (All,r,REG)   CHGKBGROW(r)

FORMULA (All,r,REG)

$$CHGKBGROW(r) = ((AVGROWTH - KBGROWTH(r))/KBGROWTH(r)) \times 100 ;$$

COEFFICIENT (All,r,REG)   RORCUR(r)

! Current rate of return in region r. !

FORMULA (All,r,REG)

$$RORCUR(r) = [(sum(h,ENDWC\_COMM, VOA(h,r))/(VKB(r))) - (VDEP(r)/VKB(r))] ;$$

COEFFICIENT (All,r,REG)   ROREXP(r)

! Expected rate of return in region r. !

FORMULA (All,r,REG)

$$ROREXP(r) = [RORCUR(r) * ((VKB(r)+(sum(k,CGDS\_COMM,VOA(k,r))-VDEP(r)))/(VKB(r)*AVGROWTH))^{\wedge}(-RORFLEX(r))] ;$$

COEFFICIENT   AVROREXP

! Average expected rate of return in region r. !

FORMULA

$$AVROREXP = sum(r,REG,SHR\_VKB(r)*ROREXP(r)) ;$$

COEFFICIENT (All,r,REG)   CHGRORE(r)

FORMULA (All,r,REG)

$$CHGRORE(r) = ((AVROREXP - ROREXP(r))/ROREXP(r))*100 ;$$

ADDITIONAL DATA

(RORFLEX.DAT)

The new shock.tab file requires the parameter RORFLEX(r) in order to calculate the expected rate of return. A new parameter file containing only RORFLEX(r) is created (this new parameter file is simply a sub-section of the standard GTAP parameter file).

Appendix 4: Regions and Commodities

Regions in the 11 by 8 GTAP Aggregation

NAM: North America, Canada and Mexico
JPN: Japan
AUS: Australia
NZL: New Zealand
CHN_HKG: Hong Kong
SKOR: South Korea
TWN: Taiwan
MYS_SGP: Malaysia and Singapore
THA_PHL: Thailand and the Philippines
IDN: Indonesia
ROW: Rest of World

Commodities in the 11 by 8 GTAP Aggregation

AGR: Agricultural crops (paddy rice, wheat, grains, non-grain crops)
LVST: Livestock (wool, other livestock)
FOOD: Food Products (proc. rice, meat, milk and other food products, beverages and tobacco)
RES: Resources (coal, oil , gas, other minerals, forestry, fisheries)
PRCRES: Processed Resources (lumber, petroleum and coal, non-metallic minerals, primary ferrous metals and non-ferrous metals)
MNFCS: Manufacturing (pulp & paper, chemicals, rubbers & plastics, machinery & equipment, fabricated metal products, other manufactures and transport industry)
TEXT: Textiles (textiles, wearing apparels, leather)
SVCES: Services (ownership of dwellings, other services (priv & govt), trade & transport, construction and electricity & water)

Appendix 5: Cumulative Results of Steady State and Trade Liberalisation Shocks

In section five of the paper, the results of the steady state and Asia-Pacific trade liberalisation simulations were reported separately. The reason for this separation of the results was to emphasise the idea that steady state results should not be interpreted as some possible future steady state, but instead as a picture of what the global economy might look like today if a steady state had already been achieved. In this appendix, we take the alternative interpretation that the steady state results do represent some future steady state towards which the global economy is headed and which will be realised (at least approximately) in finite time. If this is the case, the results of the steady state simulations and the Asia-Pacific trade liberalisation simulations can be compounded to

give the cumulative long-run results. These cumulative results could then be interpreted as the net result of firstly, the global economy reaching a future steady state and secondly, the global economy once in this steady state moving to a new steady state consistent with the liberalisation of trade within the Asia-Pacific region. These cumulative results are depicted in Table A5.1 below.

Table A5.1: Cumulative Results of Steady State Shocks and Asia-Pacific Trade Liberalisation Simulations For Both the Risk-Adjusted and Non-Risk-Adjusted Methods Based on Steady State Databases

Regions	Risk Adjusted Method[a]		Non-Risk Adjusted Method[b]	
	Capital Stocks kb(r)	Real GDP qgdp(r)	Capital Stocks kb(r)	Real GDP qgdp(r)
NAM	-4.61	-1.32	7.19	3.05
JPN	21.24	9.47	-20.45	-7.36
AUS	-1.18	0.49	-28.81	-11.08
NZL	-4.21	-0.51	-33.41	-13.02
CHN_HKG	66.70	24.76	-9.65	-2.61
SKOR	149.91	60.36	151.79	61.90
TWN	48.91	21.80	190.31	62.32
MYS_SGP	93.35	49.50	95.61	51.69
THA_PHL	174.84	102.29	655.17	311.65
IDN	73.63	39.71	1300.0	440.85
ROW	-4.63	-1.94	14.86	6.41

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[a] Includes the cummulative results of both the shock to equate the growth rates of capital across regions and the Asia-Pacific trade liberalisation tariff shocks. Results are percentage changes from initial benchmark database.

[b] Includes the cummulative results of three shocks; firstly, the shock to equate the growth rates of capital across regions; secondly the shock to equate expected rates of return across regions; and finally, the Asia-Pacific trade liberalisation tariff shocks. Results are percentage changes from initial benchmark database.

References

Adams, P. D., K., Huff, R. McDougall, K. Pearson, and A. A. Powell, (forthcoming): "Medium- and Long-Run Consequences for Australia of an APEC Free Trade Area: CGE Analyses using the GTAP and Monash Models", *Asia-Pacific Economic Review*.

Adams, P. D., K., M. Horridge, B. R. Parmenter, and X. Zhang, (1997): *Effect on China of APEC Trade Liberalisation*, Centre of Policy Studies Seminar Paper, Monash University.

Arndt, C., T. Hertel, B. Dimaranan, K. Huff, and R. McDougall, (1997): *China in 2005: Implications for the Rest of the World*, Centre of Global Trade Analysis, Purdue University.

Baldwin, R. E., and J. F. Francois, (1996): *Scale Economies, Imperfect Competition, and the Eastern European Expansion of the EU*, Paper presented at the Giessen Conference, Frankfurt.

Dixon, P. B., B. R. Parmenter, J. Sutton, and D. P. Vincent, (1982): *ORANI: A Multisectoral Model of the Australian Economy*, Amsterdam: North Holland Publishing Company.

Dixon, P. B., B. R. Parmenter, and R. J. Rimmer, (1981): *Extending the ORANI Model of the Australian Economy: Adding Foreign Investment to a Miniature Version*, Impact Preliminary Working Paper No. OP-31, University of Melbourne.

Feder, G., (1982): "On Exports and Economic Growth", *Journal of Development Economics*, 12, pp. 59-73.

Francois, J. F., B. J. MacDonald, and H. Nordström, (1996): *Trade Liberalisation and Capital Accumulation in the GTAP Model*, GTAP Technical Paper No 7.

Francois, J. F., B. J. MacDonald, and H. Nordström, (1997): "Trade and Investment: Capital Accumulation in Applied Trade Models", in J. F. Francois and K. A. Reinert (editors), *Applied Methods for Trade Policy Analysis: A Handbook*, Cambridge University Press.

Goulder, L. H., and B. Eichengreen, (1992): "Trade Liberalisation in General Equilibrium: Intertemporal and Inter-Industry Effects", *Canadian Journal of Economics*, 25(2), pp. 253-280.

Harrison, J. W., and K. R. Pearson, (1996). "Computing Solutions for Large General Equilibrium Models using GEMPACK", *Computational Economics*, Vol 9, pp. 83-127.

Hertel, T. W., (ed.) (1997): *Global Trade Analysis: Modeling and Applications*, Cambridge: Cambridge University Press.

Hertel, T. W., and M. E. Tsigas, (1997): "Structure of GTAP", in T. W. Hertel (ed.), *Global Trade Analysis: Modeling and Applications*, Cambridge: Cambridge University Press.

Feldstein, M., and C. Horioka, (1980): "Domestic Saving and International Capital Flows", *Economic Journal*, pp. 314-329.

Horridge, M., and A. A. Powell, (1984): *Long-Run Closure of ORANI: A Proposal*, Impact Preliminary Working Paper No. OP-46, University of Melbourne.

Lucas, R. E., (1988): "On the Mechanisms of Economic Development", *Journal of Monetary Economics*, 22(1) pp. 3-42.

McDougall, R., (1997) *Global Trade, Assistance and Protection: The GTAP 3 Data Base*, Purdue University: Centre for Global Trade Analysis.

McDougall, R., and E. Ianchovichina, (1996): *Incorporating Dynamics and International Capital Mobility into the GTAP Model*, Paper presented at the GTAP Follow-Up/50th EAAE Conference, Giessen, Germany, Oct 15-17.

Powell, A. A., and C. W. Murphy, (1995): *Inside a Modern Macroeconomic Model: A Guide to the Murphy Model*, Berlin: Springer-Verlag.

Romer, P. M., (1986): "Increasing Returns and Long-Run Growth", *Journal of Political Economy*, 94(5) pp. 1002-1037.

Young, L. M., and K. Huff, (1997): "Free Trade in the Pacific Rim: On What Basis?", in T. W. Hertel (ed.), *Global Trade Analysis: Modeling and Applications*, Cambridge: Cambridge University Press.