

Reversible Reforms With Irreversible Capital: The Investment Response to Imperfectly Credible Trade Liberalisation

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Abstract: The paper considers the irreversible investment response to trade liberalisation when agents perceive there to be a positive probability that the liberalisation may be reversed. It is shown that even with full credibility the aggregate investment response may be weak since investment will collapse in the unfavoured sector as a result of the change in domestic relative prices. Limited credibility reduces the investment response in the favoured sector and hence reduces aggregate investment. The effect is particularly strong if investment involves delivery lags before new capital becomes productive. The paper also demonstrates a new solution method for irreversible investment problems of this type.

Introduction

Trade liberalisation has been a major component of the economic reforms pursued in many developing countries since the early 1980s. Amongst others, two themes are of interest; firstly a tendency for these liberalisations to be reversed and secondly that the investment response to them has tended to be weak¹.

Calvo (1988) showed that a trade liberalisation that was perceived to be temporary may lead to pressure on the balance of payments that makes it more difficult to sustain. This is because agents have an incentive to accumulate stocks of imported goods, if they are durable, during the liberalisation period when they are cheap in anticipation of an increase in their price if the liberalisation is reversed and tariffs are reimposed. This effect was demonstrated by Reinikka (1996) for a sequence of failed liberalisation attempts in Kenya.

On the investment side the key reference is Rodrik (1991) which discussed the intuitive argument that agents will invest less in response to a reform that has limited credibility if capital is irreversible once installed because of the fear of losses following reform reversal. This effect was demonstrated in a very simple model in which the exact nature of the reform is left open, the reform makes a discrete and constant difference to the return to capital, and agents make a binary decision to invest or not following reform.

The main aim of the current paper is to explore the Rodrik (1991) argument in a richer framework that a) specifies the reform as an imperfectly credible trade liberalisation², b) models investment as a continuous decision variable, in other words the quantity of investment is derived rather than whether it takes place or not, and c) makes the return to capital endogenous to the quantity of investment.

A subsidiary aim is to demonstrate the use of a new solution method for irreversible investment problems involving two sectors first presented for a one sector model in Mash (1996). This method applies to situations in which the return to capital is stationary or trend stationary rather than the difference stationary processes, typically geometric brownian motion, underlying the work of Dixit and Pindyck (1994) and others.

Pattillo (1996) considers the investment response of firms to uncertain reforms, making use of the brownian motion methodology in which reform is modelled as a change in the rate of drift in the process driving the return to capital. In common with the Dixit and Pindyck results, uncertainty increases the trigger value for the return to capital at which investment takes place but the methodology does not readily provide predictions about the aggregate investment response or the sectoral capital stocks that result. Arguably the latter are of more interest than the trigger value for investment. In addition it seems more appropriate to analyse the response to reform initially in a stationary framework in which reform and its reversal change the level of the return to capital rather than its expected rate of change.

¹Collier and Gunning (1994), Gunning (1994).

²Similar results are likely for other reforms involving changes in relative prices.

Collier and Gunning (1996) analyse the composition of the investment response to trade liberalisation between tradeable and non-tradeable capital goods independently of the overall size of investment. The current paper excludes non-tradeable capital goods but including them so as to unite the analysis of the size of the investment response with these compositional effects would clearly be a desirable extension. In addition Collier and Gunning (1995) discuss the concept of an agency of restraint by which governments may bind themselves to lower trade restrictions and hence reduce the perceived probability of reform reversal. The current paper assumes that the probability of reform reversal is an exogenous parameter but given that it leads to a sub-optimal response to reform the potential benefits of agencies of restraint are strongly supported.

The paper is structured as follows. Section 1 introduces the model used throughout the paper. This is a sector specific capital international trade model with endogenous sectoral capital stocks. It is specified in such a way that production and consumption decisions are independent, thus allowing a direct analysis of investment and output without consideration of the Calvo effect outlined above. Clearly a more complex framework in which the consumption and investment responses could be considered simultaneously would be desirable. In addition, while the means of deriving the results are shown using general functional forms, quantitative results are derived by numerical simulation of Cobb-Douglas production technology with standard parameter assumptions. In general the overall signs of the results are intuitive and hence their magnitude and pattern over time are of prime interest.

Section 2 presents a base case or counterfactual in which trade liberalisation is fully credible and traces out the sectoral and aggregate investment responses to reform and their consequences for the sectoral and aggregate capital stocks and welfare. Section 3 considers the response to an imperfectly credible trade liberalisation where the reform is unanticipated. Section 4 extends this to an anticipated liberalisation. This sequence of cases assumes that investment takes place very rapidly so that new capital goods are available and productive immediately. This assumption may be questionable and hence Section 5 analyses what happens if there is a one period delivery lag so that investment decisions must be taken one period before the new capital goods are productive. As may be expected this weakens the investment response to liberalisation given that the reform may be reversed before the new capital goods are productive. Section 6 concludes and discusses possible extensions to the results.

1. The Model

This section outlines the notation and general features of the model used throughout the paper while leaving the derivation of particular results to the relevant sections below. The model is intended to be the simplest possible in which the questions of interest may be addressed in order to facilitate the development of intuition while acknowledging that a more complex framework would naturally provide a richer set of results.

It is assumed that there are two sectors with physical output X and M of the export and import goods respectively. These outputs are produced using Cobb Douglas technology:

$$(1) \quad X = l_x^{\alpha_x} K_x^{\beta_x}$$

(2)

$$M = l_m^{\alpha_m} K_m^{\beta_m}$$

The labour force in the economy is fixed but labour is assumed to be fully mobile between the two sectors so the wage rate in each will equalise at each point in time. Without loss of generality we normalise the measure of the aggregate labour endowment to unity so $l_m = 1 - l_x$.

Capital goods are sector specific and all imported. They are assumed to be available in elastic supply from the world market at constant prices³ P_{Kx} and P_{Km} but completely irreversible once installed so the rates of depreciation, δ_x and δ_m , represent the upper limit on the speed with which the sectoral capital stocks may shrink⁴. These assumptions imply a major asymmetry between the upward and downward flexibility of the sectoral capital stocks.

We also assume that the economy has access to a perfect world capital market with (real) interest rate, r^* . This assumption, together with the absence of non-tradeable capital goods, separates production and consumption decisions in the economy (so that we may focus entirely on the former) and makes risk neutrality an appropriate assumption such that investment decisions will depend solely on expected returns.

It is assumed that there is free entry to each sector which, in relation to the irreversibility and investment literature, means that there is no option value of waiting since if the irreversibility constraint is not binding expected present value net returns will be driven to zero. Irreversibility still matters, however, since there is an entry asymmetry between good and bad states of the world for the return to capital. In a good state firms may enter without any barriers but in a bad state not only will there be no new entry but existing firms cannot exit due to irreversibility. This asymmetry is incorporated in the equilibrium condition for the capital stock by means of taking into account the future entry of new capital in good states when calculating expected returns.

In other contexts it is standard to assume constant returns to scale in labour and capital such that $\alpha + \beta$ equals one in each of the production functions (1) and (2) above but with capital mobile from abroad this assumption would give rise to specialisation of the economy. To allow for interior solutions we assume that $\alpha + \beta$ is less than one in each case and that implicit in (1) and (2) is a third (fixed and constant) factor of production which might be land or sector specific labour with there being constant returns to scale in all three factors. The nature of the fixed factor is not important for what follows and we denote it Z_x and Z_m respectively. Since these are constants, for simplicity we do not include them in the expressions that follow but do present results for what happens to their return during a liberalisation.

The remaining notation comprises P_x and P_m for the world prices of X and M respectively with the domestic price of M when there is a tariff, t_m , in force being $P_m(1 + t_m)$ in the usual way. The output prices determine the economy's position on its production possibility frontier while the prices of capital goods, P_{Kx} and P_{Km} , together with the other parameters determine the position of that

³Non-linear adjustment costs are not considered.

⁴In the simple structure assumed capital always has a positive marginal product so there is never an incentive to scrap it.

frontier given that the sectoral capital stocks are endogenous to the model rather than being fixed endowments. We assume that the domestic prices of the capital goods are constant, implying that there is either no tariff on imported capital goods or that these tariff rates remain constant when the tariff on consumption good M is removed. One of the four world prices may be normalised to unity but an assumption is required for the others. Partly to minimise this problem and partly for clarity we give all results for the variables of interest relative to the values that they would take under perfectly credible free trade (denoted by superscript f). Where this does not remove the prices from the results they appear as the constant, k, which partly determines the allocation of labour where:

$$(3) \quad k = \left(\frac{P_x}{P_{Kx}^{\beta_x}} \right)^{\frac{1}{1-\beta_x}} \cdot \left(\frac{P_{Km}^{\beta_m}}{P_m} \right)^{\frac{1}{1-\beta_m}}$$

Given (3) it would be possible to make assumptions about each of the prices but the procedure followed is to assume an initial value for the allocation of labour to the x sector under perfectly credible free trade, l_x^f , and infer the implicit assumption about k from this. For example, $l_x^f=0.5$ is assumed for the central case which implies symmetry (if the α and β parameters are the same in each sector) and hence $k=1$. This parameter assumption is varied below to confirm that the results are not specific to this particular starting point.

The notation outlined above is set out in Table 1 together with the central value and range assumed for the numerical simulations. A range of parameter values are imposed to check the robustness of the overall results and to analyse the impact of changing each parameter. The values shown under variation (b) in Table 1 reflect the discussion of the prices and k above. It may also be noted that under (g) and (I) the values of the α and β parameters are varied together to make each sector more or less labour intensive while holding the share of the Z factor fixed. This share is varied under (h) and (j) by means of varying the α and β values as shown.

TABLE 1

Parameter		Central Value	Range	
(a) Prob. of reform reversal	p	0.3	0.1	0.5
(b) Credible free trade l_x	l_x^f	0.5	0.3	0.7
© Tariff on imports of M	t_m	0.2	0.1	0.3
(d) K_m rate of depreciation	δ_m	0.1	0.05	0.15
(e) K_x rate of depreciation	δ_x	0.1	0.05	0.15
(f) World interest rate	r^*	3%	1%	5%
(g) M sector technology: (fixed Z_m share)	α_m	0.6	0.7	0.5
	β_m	0.2	0.1	0.3
(h) Share of Z_m where:	$1-\alpha_m+\beta_m$	0.2	0.3	0.1
	α_m	0.6	0.55	0.65
	β_m	0.2	0.15	0.25
(I) X sector technology: (fixed Z_x share)	α_x	0.6	0.7	0.5
	β_x	0.2	0.1	0.3
(j) Share of Z_x where:	$1-\alpha_x+\beta_x$	0.2	0.3	0.1
	α_x	0.6	0.55	0.65
	β_x	0.2	0.15	0.25

2. Fully Credible Trade Liberalisation

This section considers the counterfactual case of a fully credible trade liberalisation in order to provide a point of comparison when analysing the same reform but with limited credibility. It is shown that the change in domestic relative prices induced by trade liberalisation leads to large changes in sectoral capital stocks and investment.

We have the following standard results in which the factor $(1+t_m)$ is included though t_m should be set to zero following trade liberalisation but before any possible reversal. The notation is r_i for the return to a unit of capital in the I sector and c_i is its cost.

$$(4) \quad r_x = \frac{P_x \beta_x l_x^{\alpha_x}}{K_x^{1-\beta_x}}$$

$$(5) \quad r_m = \frac{P_m (1+t_m) \beta_m l_m^{\alpha_m}}{K_m^{1-\beta_m}}$$

$$(6) \quad c_x = P_{Kx} (r^* + \delta_x)$$

$$(7) \quad c_m = P_{Km} (r^* + \delta_m)$$

If the tariff rate t_m is expected to be constant forever (be it zero or otherwise) and the sectoral capital stocks have adjusted to that rate, through depreciation from some higher value if necessary, we have $r_x = c_x$ and $r_m = c_m$. Given (4)-(7) this implies:

$$(8) \quad \frac{K_x}{K_x^f} = \left(\frac{l_x}{l_x^f} \right)^{\frac{\alpha_x}{1-\beta_x}}$$

$$(9) \quad \frac{K_m}{K_m^f} = (1+t_m)^{\frac{1}{1-\beta_m}} \left(\frac{l_m}{l_m^f} \right)^{\frac{\alpha_m}{1-\beta_m}}$$

If $t_m=0$ and expected to remain constant so there is fully credible free trade the right and left hand sides of (8) and (9) will simply be equal to unity.

Given that labour is fully mobile between the two sectors the wage rate, w , will equalise so $w_x = w_m$ and it is straightforward to show that:

$$(10) \quad \frac{l_x^{1-\alpha_x}}{l_m^{1-\alpha_m}} = \frac{P_x \alpha_x K_x^{\beta_x}}{P_m (1+t_m) \alpha_m K_m^{\beta_m}}$$

Since we derive results relative to fully credible free trade, as in (8) and (9) above, it is helpful to change (10) using (4)-(7) to:

$$(11) \quad \frac{I_x^{1-\alpha_x}}{I_m^{1-\alpha_m}} = \frac{k\alpha_x \left(\frac{K_x}{K_f}\right)^{\beta_x} \left[\frac{\beta_x (I_x^f)^{\alpha_x}}{r^* + \delta_x}\right]^{\frac{\beta_x}{1-\beta_x}}}{(1+t_m)\alpha_m \left(\frac{K_m}{K_f}\right)^{\beta_m} \left[\frac{\beta_m (I_m^f)^{\alpha_m}}{r^* + \delta_m}\right]^{\frac{\beta_m}{1-\beta_m}}}$$

Where k is given by (3).

Turning to the response to reform, we assume that the liberalisation is not anticipated in which case before the liberalisation the sectoral capital stocks will have the equilibrium condition that the return to capital (r_x, r_m) is equal to its cost (c_x, c_m) and hence (8) and (9) apply.

The sequencing of the model is such that we assume that reform (or its reversal) is announced at the start of a period and that, until Section 5, the sectoral capital stocks may adjust upwards instantly. If a trade liberalisation occurs the return to capital in the M sector will fall and that in the X sector rise as the M sector releases labour⁵. If initial net returns are zero the M sector capital stock would like to shrink but cannot do so faster than depreciation due to the irreversibility assumption. Hence during the immediate post-reform periods, K_m relative to its free trade value will be given by the left hand side of (9) multiplied by $(1-\delta_m)$ to the power of the number of elapsed time periods. As K_m shrinks, K_x will expand to keep (8) satisfied subject to (11) which determines the allocation of labour between the two sectors. After a certain number of periods, K_m will have depreciated until losses are no longer made and K_m will be given by (9) with $t_m=0$ and K_x will stop adjusting upwards. We refer to this position as the post-reform steady state and with the trade liberalisation fully credible zero net returns are made in both sectors.

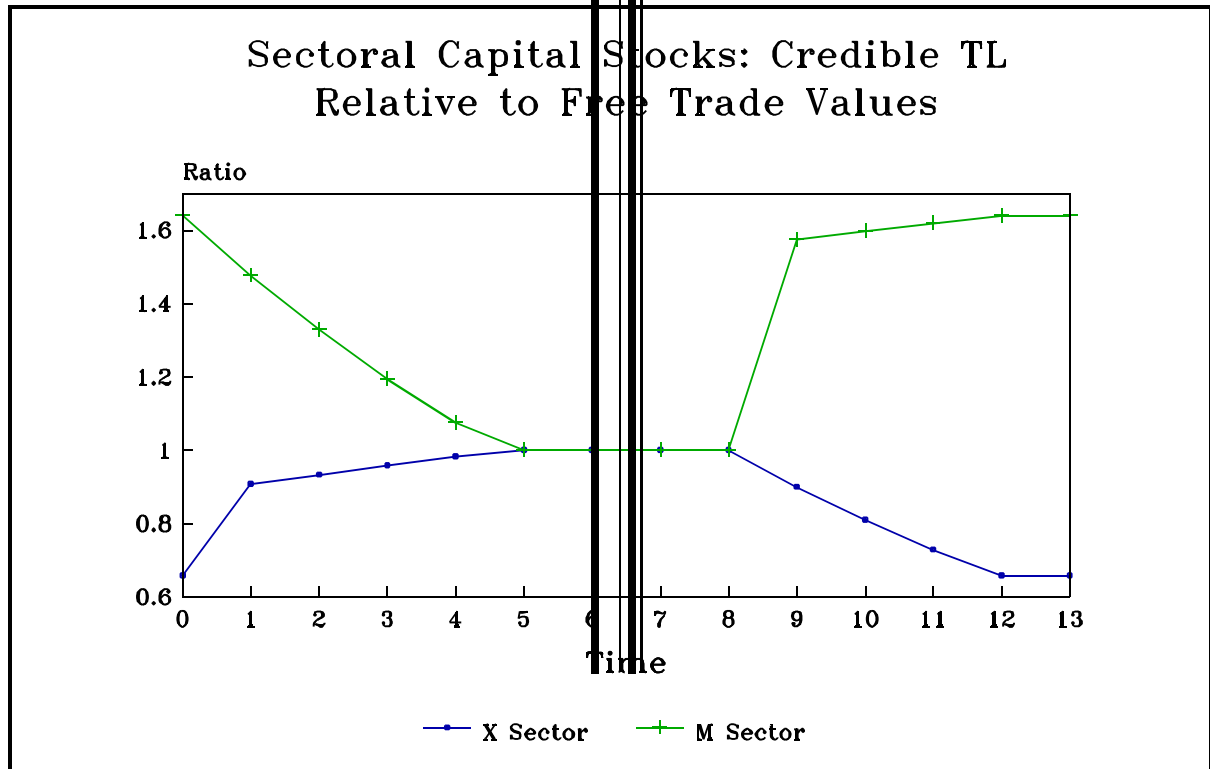
If the liberalisation is reversed, despite the fact that agents placed a zero prior probability on this taking place, essentially the same process occurs in reverse. For simplicity we assume that the same tariff rate is restored and that there is no anticipation of any further liberalisation. K_x will depreciate while K_m will rise according to (8), (9) and (11) with t_m back to its previous value. With no anticipation of further liberalisation the sectoral capital stocks will return to their original values⁶.

Figure 1 shows the results of a numerical simulation of these processes assuming that the parameter values take the central values given in Table 1. The figure assumes that trade liberalisation is fully credible ("Credible TL" in the figures) and takes place at the start of period 1. Hence period 0 represents the situation before the (unanticipated) reform. K_m depreciates from its initial value until it reaches its credible free trade value (a ratio of unity in the figure) by period 5. K_x jumps up in response to reform (due to the immediate gain to the return to capital in the X sector as labour moves in response to the domestic relative

⁵If labour is sector specific the two sectors are independent which is a less interesting case.

⁶The case where liberalisation is anticipated is discussed in Section 4.

FIGURE 1



price change) and subsequently approaches its steady state value, increasing modestly as K_m depreciates and releases labour, thus raising the return to X sector capital for a given K_x and hence stimulating further increases in K_x .

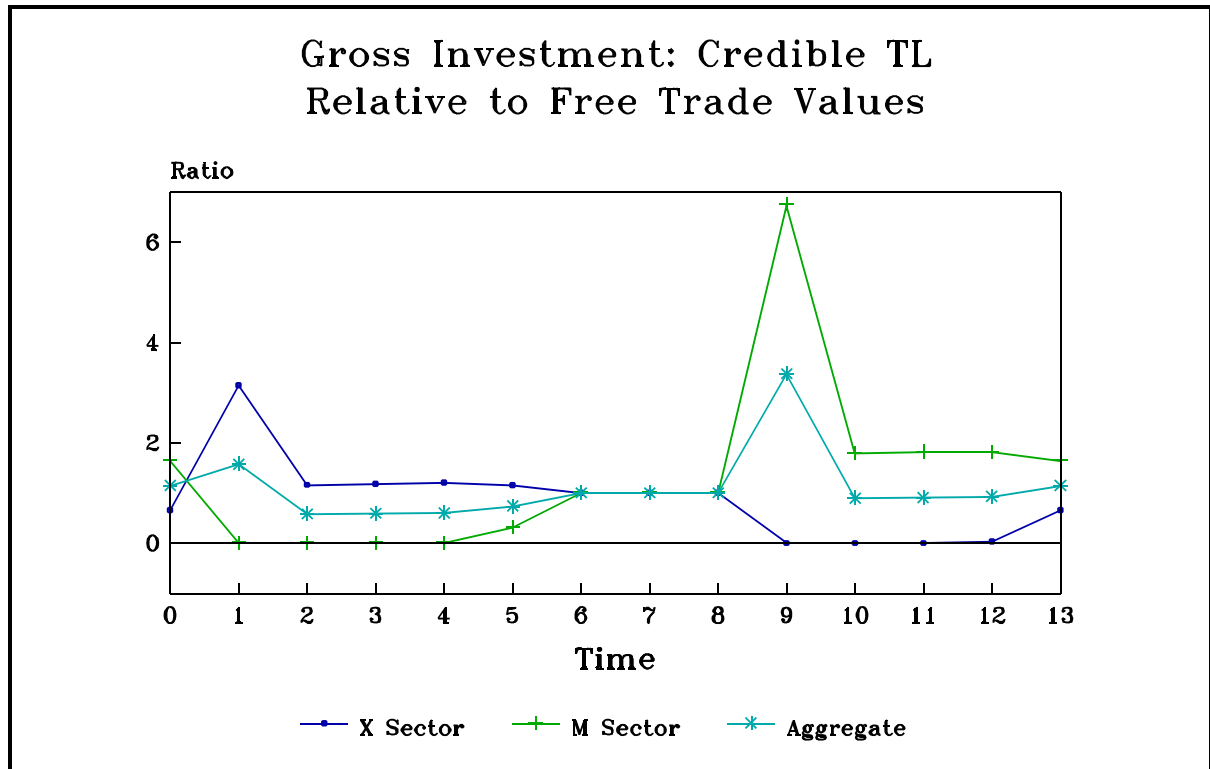
Reform reversal is imposed at the start of period 9 from which point the earlier pattern is repeated in reverse, the capital stocks returning to their initial values. It is, of course, quite possible that reversal will take place during the transition to the post-reform steady state in which case the end point will remain unchanged but the depreciation path of K_x , and hence the expansion of K_m , will differ.

The most striking feature of Figure 1 is the large size of the changes in the sectoral capital stocks given the assumption that the tariff rate before and after liberalisation is 20%. This is a sizeable but by no means unrealistic figure.

Figure 2 shows the time paths of sectoral and aggregate investment corresponding to the capital stocks shown in Figure 1. The derivation of aggregate investment depends on the relative size of the two sectors which in this case have implicitly been assumed to be equal under credible free trade given the symmetry between the central values in Table 1.

Investment in the X sector increases substantially with the announcement of the reform but subsequently is only slightly above its credible free trade level (corresponding to a ratio of one in the figure) as it approaches the post reform steady state in period 6. Following reversal in period 9 there is zero gross investment in the X sector as depreciation reduces

FIGURE 2



K_x before rising to its initial value in period 13 which is when the post reversal steady state is reached.

Investment in the M sector follows a similar pattern in reverse, collapsing after reform as K_m depreciates to the post reform steady state and increasing substantially following reform reversal, particularly in period 9 which is the first after reversal.

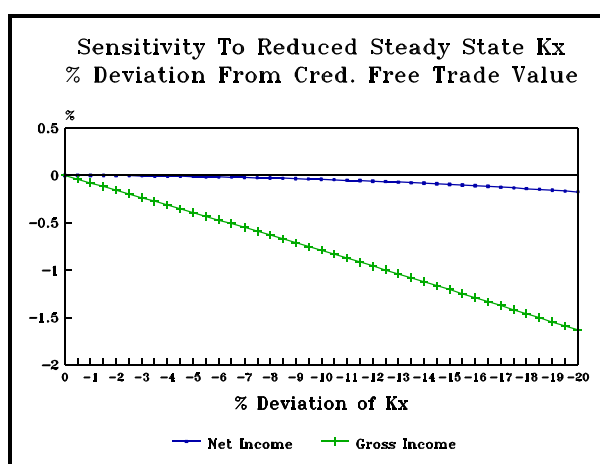
Aggregate investment follows a path between that for each sector, showing an initial increase after reform as K_x expands quickly but thereafter falling below its initial value during the transition to the post reform steady state. This pattern results from the fact that while investment in the X sector expands, that in the M sector collapses and the latter effect dominates for all but the first period of liberalisation. Hence the aggregate investment response to reform may be vigorous at first but subsequently disappoint even with perfect credibility.

While attention in the literature has focused primarily on the investment response to reform it is appropriate to consider welfare also. This is approached by considering the welfare of the representative agent while also assessing what happens to factor returns. Use of the representative agent concept implies that output should be valued at world prices since tariff revenue is simply an internal transfer. The imposition of a tariff does, however, have adverse consequences both by distorting production decisions in the usual way and, given endogenous sectoral capital stocks, by leading to excessive capital formation in the protected sector and insufficient capital formation in the export sector.

Rather than making use of a utility function we focus attention on the level of real income⁷. If the representative agent has risk averse preferences utility will have a monotonic but non-linear relation to real income but for simplicity we consider the latter. While it is the case that income varies with both reform and reversal the introduction of risk aversion seems less appropriate in the current context compared with one involving ongoing volatility in income.

In addition it should be noted that with variable capital stocks, real income cannot be simply equated to the value of output at world prices since the cost of using capital must be taken into account. If the capital stocks were constant this factor would be constant and hence could be ignored when making comparisons across time periods. Hence the proper measure of income is net income and given by the value of output at world prices ($P_x X + P_m M$ = gross income) less the cost of capital ($c_x K_x + c_m K_m$). It may also be noted that there is an envelope theorem effect with this measure since in the absence of distortions or uncertainty we have $r_x = c_x$ and $r_m = c_m$ and hence a change in the sectoral capital stocks away from the credible free trade optimum will have only second order effects on net income. Figure 3 illustrates this point, showing the change in gross and net income for a given change in K_x away from its static optimum with free trade. The figure incorporates the induced change in K_m through the labour market and assumes the central parameter values given in Table 1.

FIGURE 3



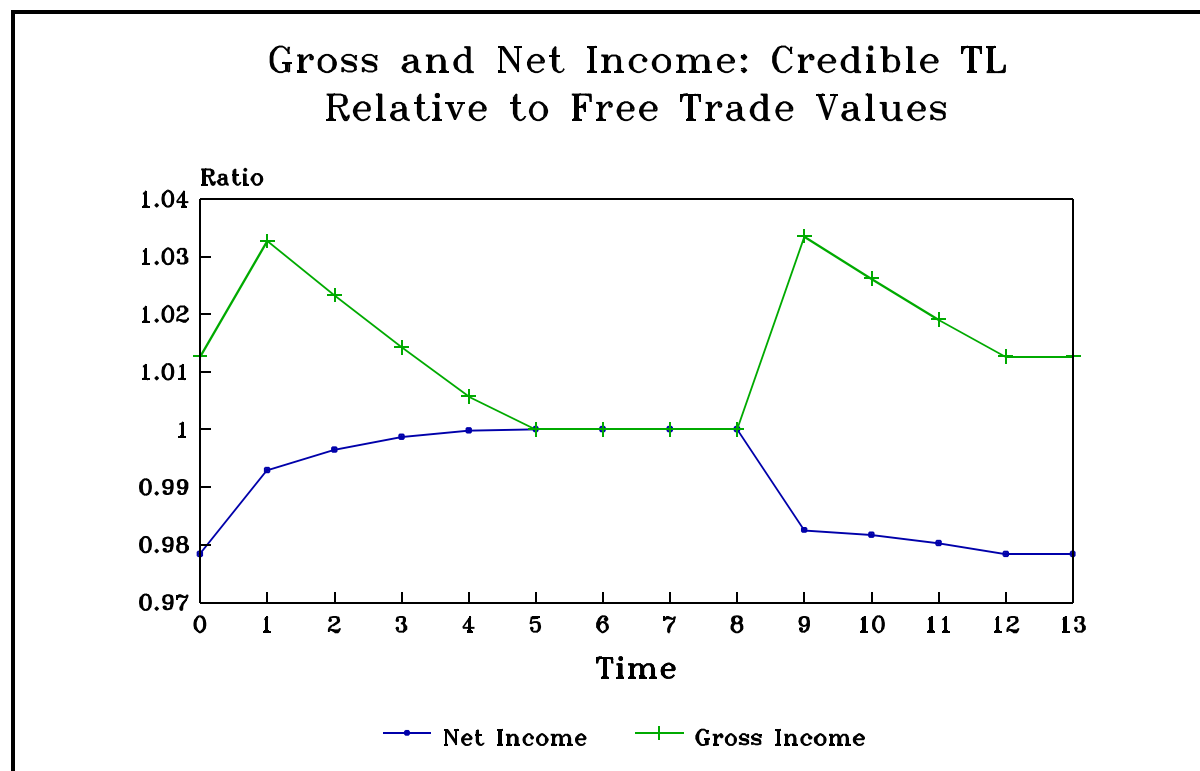
The net income measure of welfare also serves as a reminder that there is a socially optimal value for each sectoral capital stock and that welfare is decreasing as a capital stock increases beyond this point, essentially because the cost of capital rises above the return which is what occurs when a sector is protected. In relation to Figure 1 this implies that net income will increase as the sectoral capital stocks converge to their credible free trade values. In turn this implies that the decline of K_m after liberalisation is socially optimal and hence the weak aggregate investment response to reform in Figure 2, which arises from the collapse of investment in the M sector, should not be seen as sub-optimal.

While income net of the cost of capital is the appropriate income measure when considering underlying welfare, it may be argued that the level of gross income (ignoring the cost of capital) is

⁷Hence the consumption distortion caused by the tariff is not considered.

also of interest since this variable may affect the political economy of whether trade liberalisation is regarded as successful. Hence we also show the outcome for this income measure in Figure 4 which compares the two.

FIGURE 4



The range of variation in Figure 4 is substantially smaller than the earlier figures but the static cost of the tariff in period 0 of a little over 2% is significant. As noted above net income, the preferred measure, increases with liberalisation as the sectoral capital stocks converge to their credible free trade values in Figure 1 and falls again following reform reversal in period 9. This is consistent with the standard case for free trade and results from the fact that there is nothing in the model to make a departure from free trade welfare improving⁸.

The time path of gross income is very different in that it is at a minimum under credible free trade, since the implicit subsidy to M sector capital provided by the tariff has been removed⁹, and rises each time that relative prices change with reform and reversal. The latter results from an expansion of the capital stock of one sector while capital in the other sector declines only slowly. With the current parameter assumptions gross income overshoots on both occasions though this is not

⁸Hence the initial existence of the tariff and the possibility of reversal is implicitly assumed to result from political economy factors.

⁹There is also a removal of the implicit tax on capital in the export sector so the net effect of a tariff on gross income is ambiguous. This is illustrated for some of the parameter combinations shown below where gross income with a tariff is less than its free trade value.

necessarily a general result.

In addition to examining the level of income at the national or representative agent level, the effect of liberalisation and its reversal on factor returns is also of interest. Figure 5 shows the outcome for the nominal return to capital in each sector with the same imposed timings of reform in period 1 and reversal in period 9.

FIGURE 5

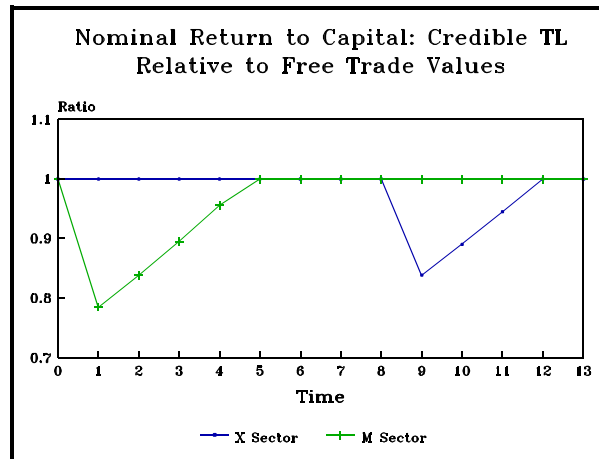
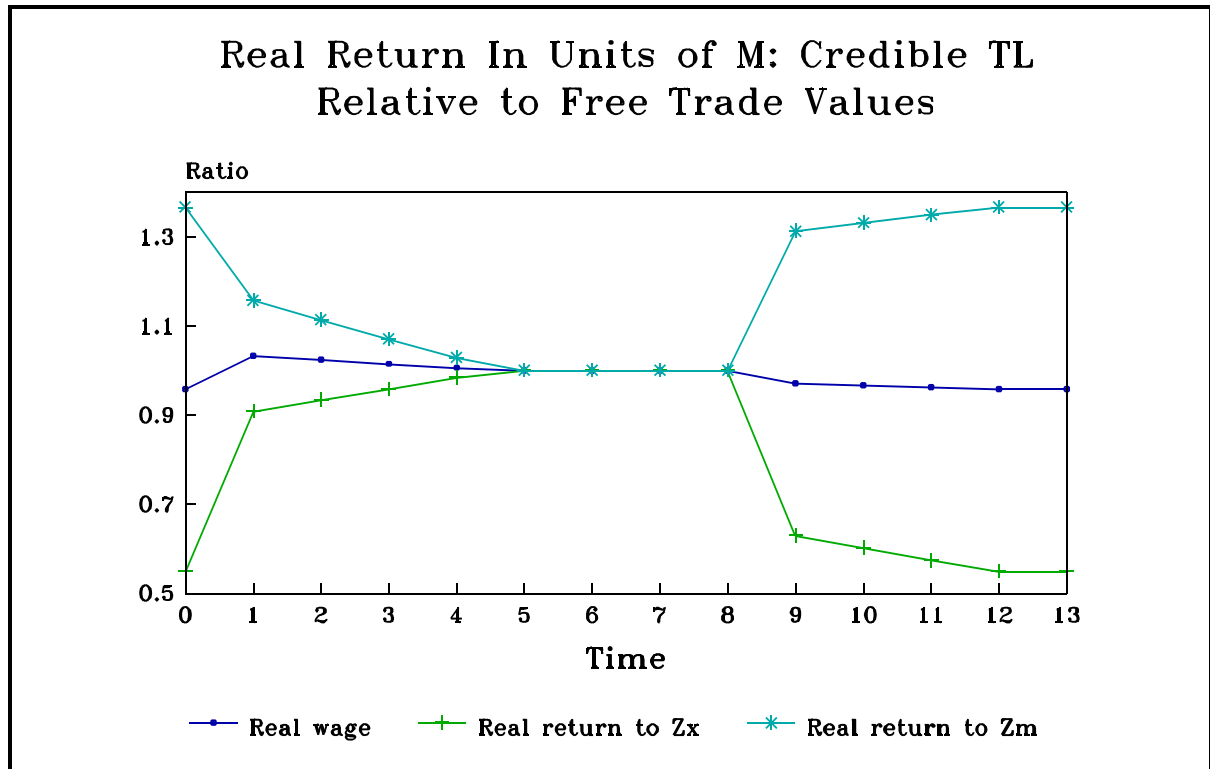


Figure 5 confirms the earlier discussion whereby perfectly credible free trade between periods 1 and 8 inclusive and perfectly credible protection in periods 0 and 9-13 implies that the net return to capital will be zero (as under credible free trade) unless the irreversibility constraint is binding. The constraint binds in the transition following reform for K_m and that following reversal for K_x . The methodology for solving the investment response to an anticipated reform in Section 4 makes use of the fact that M sector capital will need to have a strictly positive net return in period 0 to compensate for the probability of losses in the post reform transition if reform takes place. In addition Section 3 makes use of the fact that X sector capital will require a strictly positive net return following reform to compensate for the losses that will occur if reform is reversed.

The returns to the other factors, labour and the fixed Z factors in each sector, are also of interest. These are shown in Figure 6 with the factor returns expressed in terms of good M. These will correspond to real income if all consumption is of good M. If all consumption was of good X the real return would be higher by the amount of the tariff (20%) in periods 0 and 9-13. If this were the case X would have to become the import good and it is in any case likely that the consumption share of the importable will dominate that for the export good in many developing countries given the concentration of exports in primary commodities.

FIGURE 6



As would be expected, the Z factors have directly opposite interests in trade policy with the owners of Z_m being consistently opposed to the abolition of the tariff given that it reduces the domestic price of good M and leads to a reduction in the M sector labour force and capital stock, both of which reduce the marginal product of Z_m . Given that these factors are assumed fixed, that opposition (and support for free trade from Z_x) will remain in place over time. This will be important for the political economy of trade reform and contrasts with the fact that over time depreciation reduces the losses of capital in the M sector to zero and hence would weaken the opposition of the owners of that capital to liberalisation¹⁰. In addition pressure for continued free trade from the owners of X sector capital will increase as K_x expands and losses would be incurred if reform reversal takes place. This paper treats the probability of reversal as an exogenous constant but there is clearly scope for an interesting political economy model to be developed in order to endogenise the perceived probability of reversal, both in terms of its initial level when liberalisation takes place and how it evolves over time. The argument above suggests that for a constant weighting of different groups in policy decisions it is likely that the static probability of reversal will decline over time. With forward looking expectations this in turn implies that there is likely to be a threshold initial probability of reversal below which reform is likely to be sustained. These arguments are not developed further but their implications are to some extent illustrated below where different values for the perceived probability of reversal are imposed.

Figure 6 also shows the time path of the real wage, again in terms of good M, with an initial

¹⁰Capital in the M sector also retains a zero net return if reform is reversed (in the absence of delivery lags) since K_m expands to maintain $r_m=c_m$.

overshoot (due to the high combined capital stock immediately after reform) followed by decline to a steady state above the initial level. Overshoots of this kind, similar to that for gross income in Figure 4, may partly explain why initial enthusiasm for reform is not fully sustained.

The charts and discussion above have referred to the case where liberalisation is unanticipated but fully credible once it takes place and with no delivery lags for new capital goods. Analysis of anticipated, fully credible liberalisation is left to Section 4 which compares the outcome with the imperfectly credible case and Section 5 does the same for the addition of a delivery lag.

3. Unanticipated, Imperfectly Credible Trade Liberalisation

Having established the base case or counterfactual of an unanticipated, fully credible liberalisation, this section analyses how the response to reform changes if there is a positive perceived probability of reform reversal.

The assumption that reform is unanticipated is retained and hence the pre-reform position (period 0 in the figures) is unchanged. The depreciation of capital in the M sector following reform will also remain though its post reform steady state (defined by $r_m = c_m$) will differ because the steady state level of K_x will be reduced due to the possibility of reform reversal and the losses to the owners of K_x that will occur if this happens. We proceed by analysing the response of K_x to reform and use this to infer the steady state for K_m . The latter is still defined by $r_m = c_m$ because once the post reform steady state has been attained there is no possibility of K_m being bound by the irreversibility constraint since K_m will either remain constant if reform continues or increase if reform is reversed.

This contrasts with the position of K_x which will face a binding irreversibility constraint if reversal occurs and hence the magnitude and probability of the losses that would result must be taken into account in forward looking investment decisions while reform continues.

At a given time, t , following reform but before any reversal and assuming that the initial value of K_x is low enough for the irreversibility constraint not to bind, the desired and actual capital stock in the X sector (assuming risk neutrality) will satisfy:

$$(12) \quad E_t[\sum_{s=t}^{\infty} [(r_x^s(K_x^s) - c_x) (\frac{1-\delta_x}{1+r^*})^{(s-t)}]] = 0$$

This is the standard equilibrium condition by which the expected present value of net returns to a unit of capital invested at some time t is equated to zero. The terms $r_x(\cdot)$ and c_x give the return and cost of a unit of capital and hence the term $(1-\delta_x)^{(s-t)}$ appears because this gives the amount of an initial unit of capital left after $s-t$ periods. It is helpful to separate out the initial period t from (12) which gives:

$$(13) \quad r_x^t(K_x^t) - c_x + E_t[\sum_{s=t+1}^{\infty} [(r_x^s(K_x^s) - c_x) (\frac{1-\delta_x}{1+r^*})^{(s-t)}]] = 0$$

This shows that the current period net return depends on the expected net return in the future. At this point the effect of the entry asymmetry discussed earlier becomes important. If reform continues at $t+1$, free entry means that equilibrium condition (12) will be repeated and hence seen from the perspective of time t , the expected present value of net returns if reform continues must be zero. On the other hand if reform is reversed, irreversibility implies that net returns will become negative for a number of periods before depreciation reduces K_x to the point where net returns are zero once again. This asymmetry implies that a zero should be inserted for the second term of (13) for the scenario where reform continues and only future losses with reform reversal, together with its associated probability, need appear. Denoting T_x as the number of periods when losses are made post reversal and making use of these arguments means that (13) may be transformed to:

$$(14) \quad r_x^t(K_x^t) - c_x + p[\sum_{s=t+1}^{s=t+T_x} [r_x^s(K_x^t(1-\delta_x)^{(s-t)}) - c_x] (\frac{1-\delta_x}{1+r^*})^{(s-t)}] = 0$$

In (14), p is the perceived probability of reform reversal and the K_x term within the summation sign is given in relation to K_x at time t and the number of periods of depreciation because net losses are being made during the interval $t+1$ to $t+T_x$ and investment in the X sector will be zero¹¹.

The equilibrium condition (14) shows that investment will take place at time t to the point where the capital stock gives a net return equal to the present value of the losses that would be incurred if liberalisation is reversed next period weighted by the probability of that event. As the capital stock expands at the start of time t , the current period return will fall and the size of future losses will rise given a higher K_x inherited at the time of reversal. Forward looking investment behaviour will balance the current period return against expected losses which implies that the current period return will not be driven to zero as was the case when the liberalisation was fully credible.

Hence (14) confirms the intuitive idea that an expectation of reversal must weaken the investment response to reform though it also highlights the fact that an improved current period return following liberalisation will encourage investment. Given the assumption that reversal entails a return to the pre-reform situation, (14) implies that the investment response in the X sector must be positive because there is an increased current period return and the worst outcome in the future is the same as before reform. As noted above, however, a positive investment response in the X sector will not necessarily lead to a positive aggregate investment response given that investment in the M sector will be zero during the transition after reform and lower in the steady state than its initial value. In turn a higher K_x and lower K_m implies that net income will increase with liberalisation whatever the perceived probability of reversal.

In order to facilitate numerical simulations we transform (14) by assuming Cobb Douglas technology and also express K_x while reform continues relative to its credible free trade value.

¹¹Expressions of the same type as (14) are discussed at length in Mash (1996).

$$(15) \quad \left(\frac{K_x^t}{K_x^f}\right)^{1-\beta_x} = \frac{\left(\frac{I_x^t}{I_x^f}\right)^{\alpha_x} + p \sum_{s=t+1}^{s=t+T_x} \left(\frac{I_x^s}{I_x^f}\right)^{\alpha_x} \left[\frac{(1-\delta_x)^{\beta_x}}{(1+r^*)}\right]^{s-t}}{1 + p \frac{(1-\delta_x)}{(r^* + \delta_x)} \left[1 - \left(\frac{1-\delta_x}{1+r^*}\right)^{T_x}\right]}$$

The system is completed by the labour allocation given by (11) and the value of K_m which is given by its depreciation path from its initial value until it reaches the post reform steady state given by (9) with $t_m=0$. After reversal (11) continues to hold and K_m is given by (9) with $t_m=t_m$ and K_x by depreciation from its post reform steady state until (8) holds in the post reversal steady state.

We turn to the numerical simulations of the expressions above. Figures 7-12 compare the outcomes for a fully credible trade liberalisation ($p=0$) with one with a perceived probability of reversal of 0.3 each period. As before the figures assume for illustrative purposes that reversal does not take place until the post reform transition is complete. The other parameter assumptions remain the same and are the central values reported in Table 1. Figures for the pre-reform situation and the post reform pre-reversal steady state are also given in Table 2 below with the first two rows being the outcomes compared in the figures that follow.

Figure 7 confirms that a positive probability of reversal reduces the rise in K_x following trade liberalisation, Table 2 showing that its steady state value is 8% below what it would be if the reform had been fully credible which is a significant magnitude. K_m depreciates from its starting value as before though its steady state is 2% higher than with a fully credible reform. This results from the reduced demand for labour in the X sector given the lower K_x though the relative magnitudes show that the link through the labour market leads to a less than proportionate impact on K_m .

Figure 8 gives the corresponding investment responses, that of K_m being the same as it depreciates from its initial value while the response of investment in the X sector is lower as expected though still close to the fully credible case. Sectoral investment figures are not given separately in Table 2 because for the two periods shown they are the same, relative to their respective credible free trade values, as the figures for the sectoral capital stocks.

Figure 9 combines these effects to give aggregate investment which is lower though still following the same pattern as before. Hence introducing a probability of reversal makes a significant difference to the investment response but the dynamics resulting from the swing in relative returns following liberalisation remain a strong factor.

Figure 10 shows that income net of the cost of capital is little affected by the probability of reversal and much less so than for the X sector capital stock. This results from the envelope theorem effect discussed earlier whereby a change in the capital stock away from its credible free trade optimum has only a second order effect on welfare. Table 2 shows that net income, Y_n , is only 0.02% lower than under credible free trade for the central parameter values. The reduced X sector capital stock has a first order effect on gross income since this variable does not reflect the cost of capital but as argued earlier this is not an appropriate measure of welfare even though it may be important for the political economy of reform.

FIGURE 7

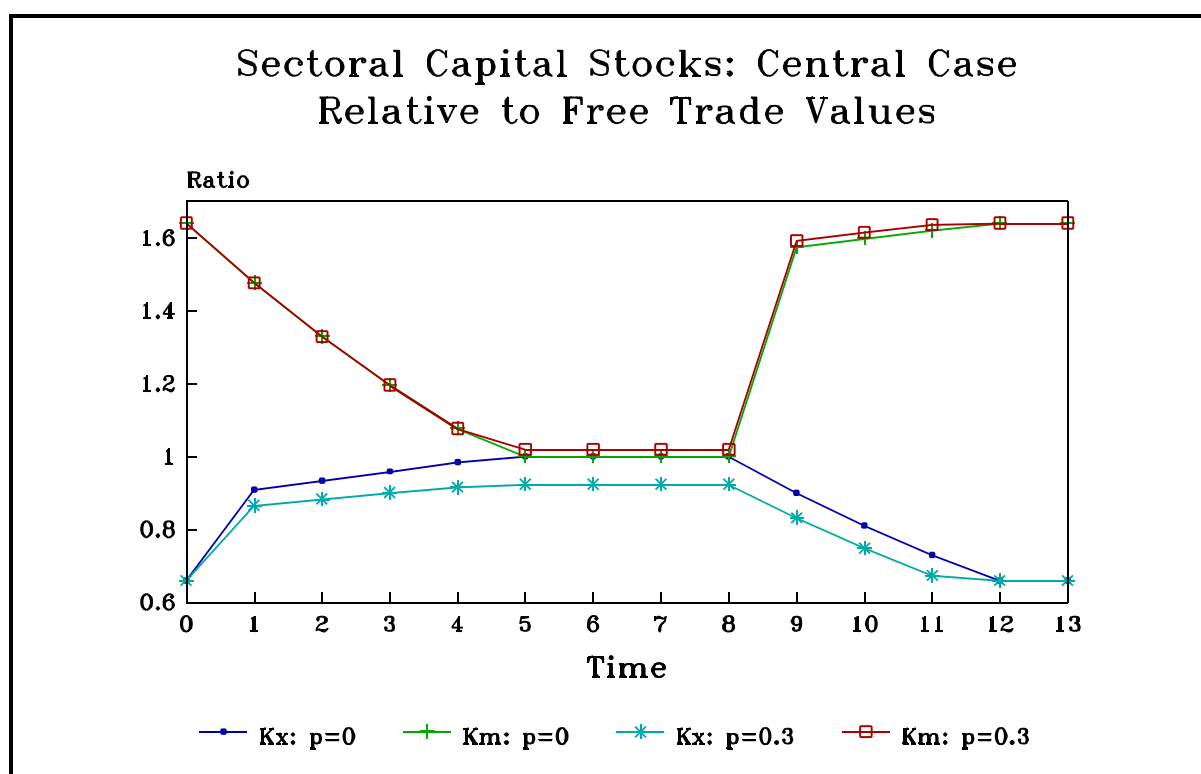


FIGURE 8

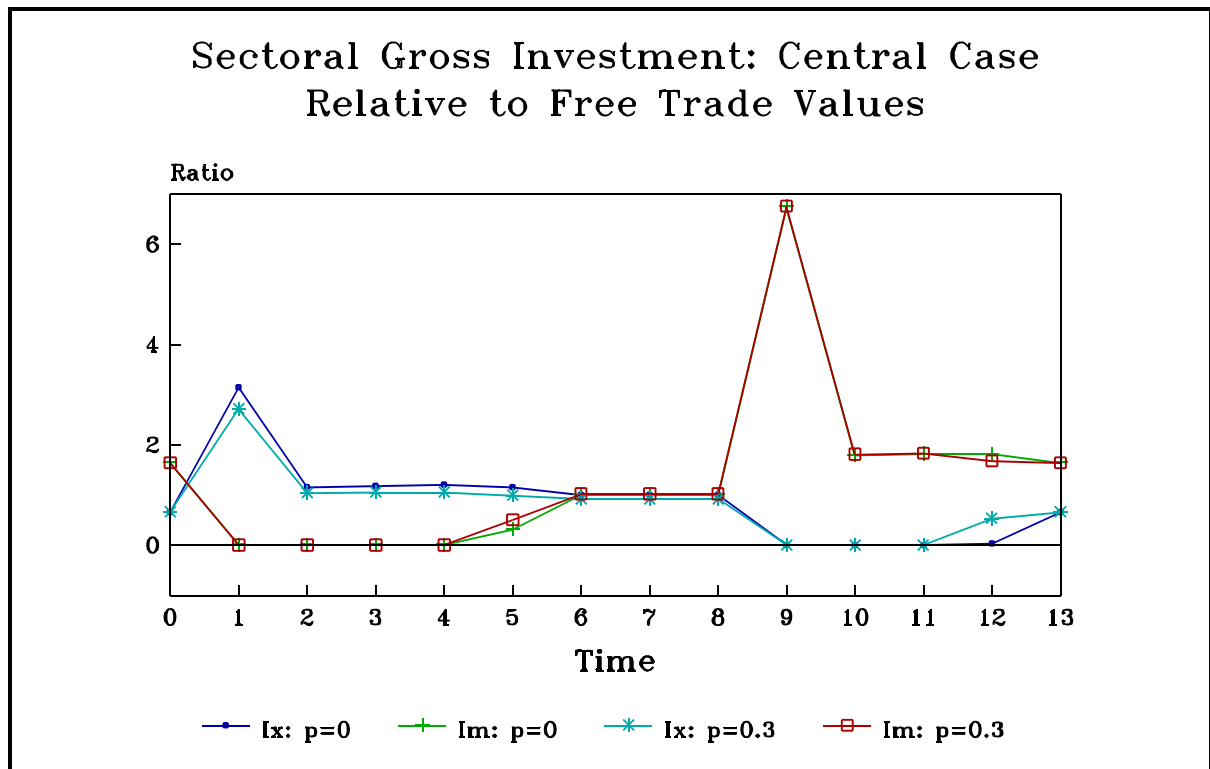


FIGURE 9

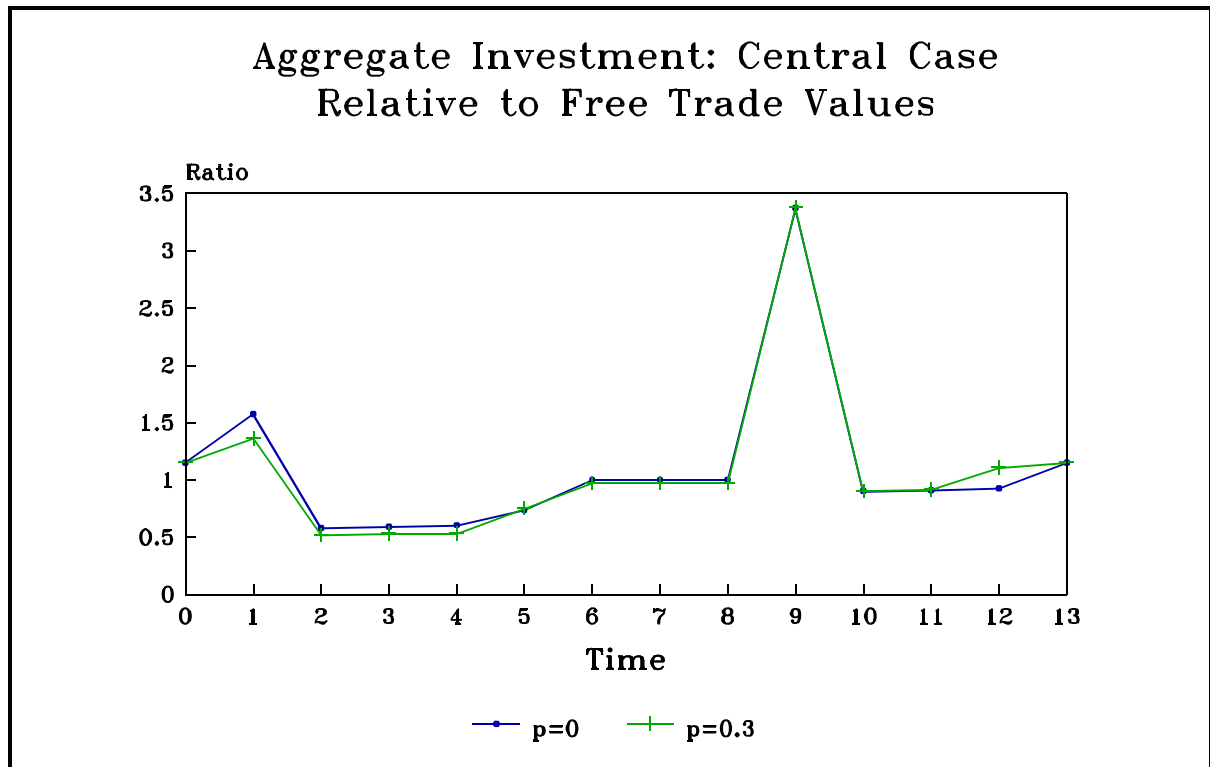


FIGURE 10

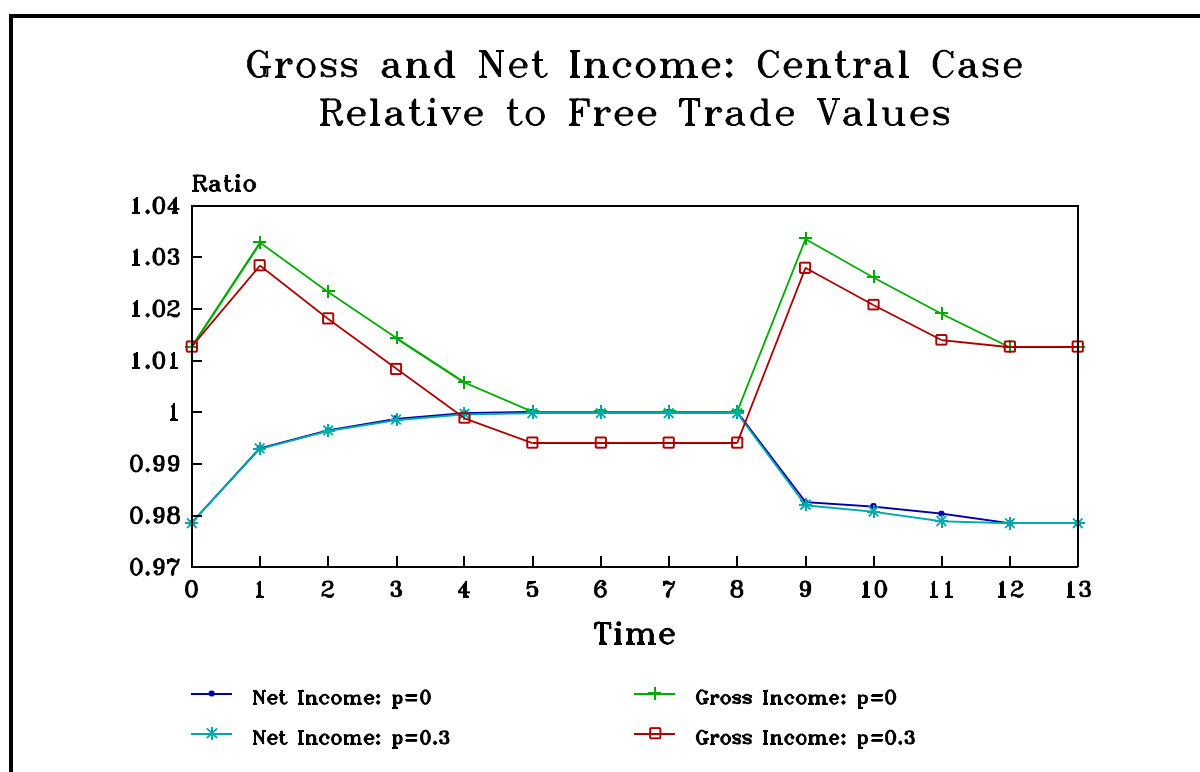


Figure 11 illustrates what happens to the nominal returns to capital in the two sectors with a positive perceived probability of reversal. The main feature is the positive net returns in the X sector following reform which reflects the probability and extent of losses if reversal takes place. Returns in the M sector benefit slightly during the post reform transition because K_x does not expand so much.

Figure 12 gives the corresponding path of the real wage. This is in terms of good M though this is not important when comparing the two lines when the import tariff is zero in periods 1-8. The line for $p=0$ shows more clearly the time path for the real wage in Figure 6. In the post reform steady state Table 2 shows that the real wage is 1% lower as a result of limited credibility which is much larger than the impact on net income but damped relative to the reduction in steady state K_x . Figure 12 and Figure 10 show that the overshooting effect for real wages and gross income remains after the introduction of a positive probability of reversal.

Figures A1-A9 in the appendix illustrate the consequences of varying the parameter assumptions in the manner indicated in Table 1 with the exception of changing the interest rate which makes a negligible difference to the results relative to credible free trade values. Each variation straddles the central case discussed above and the time paths in the charts do likewise. The pre-reform and post reform pre-reversal steady state figures are given in Table 2.

FIGURE 11

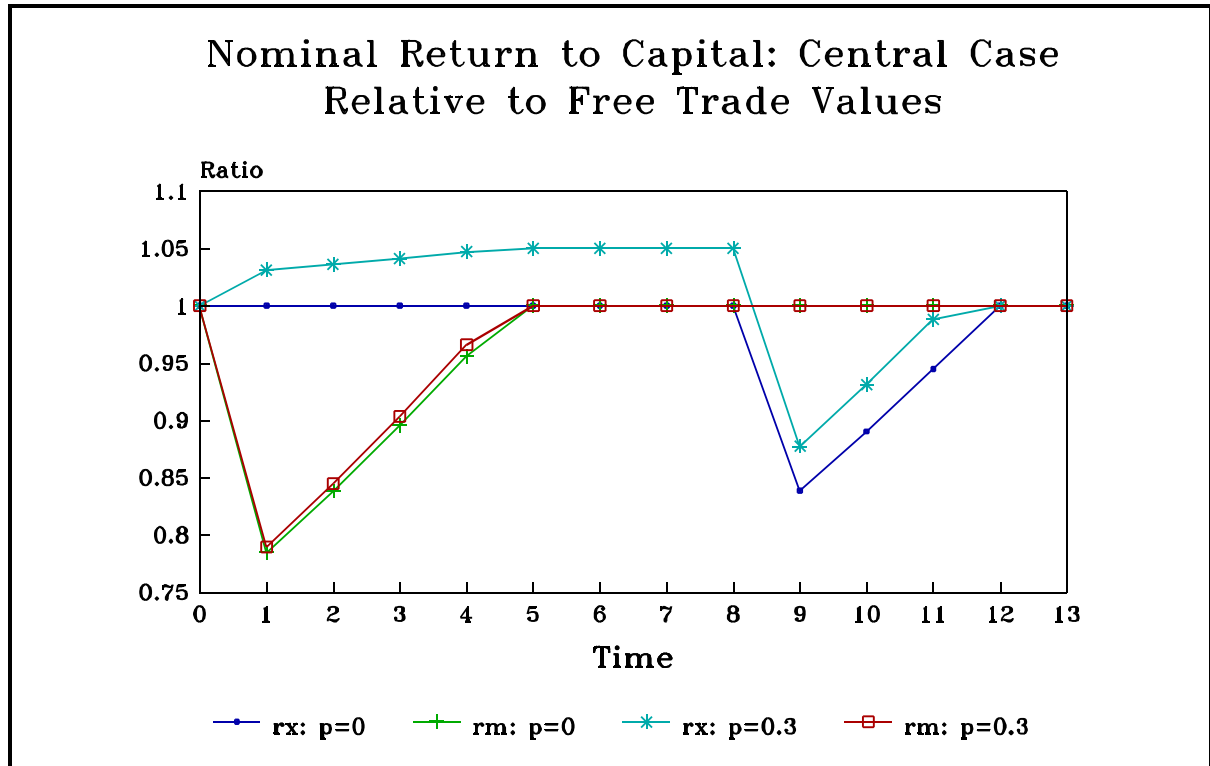
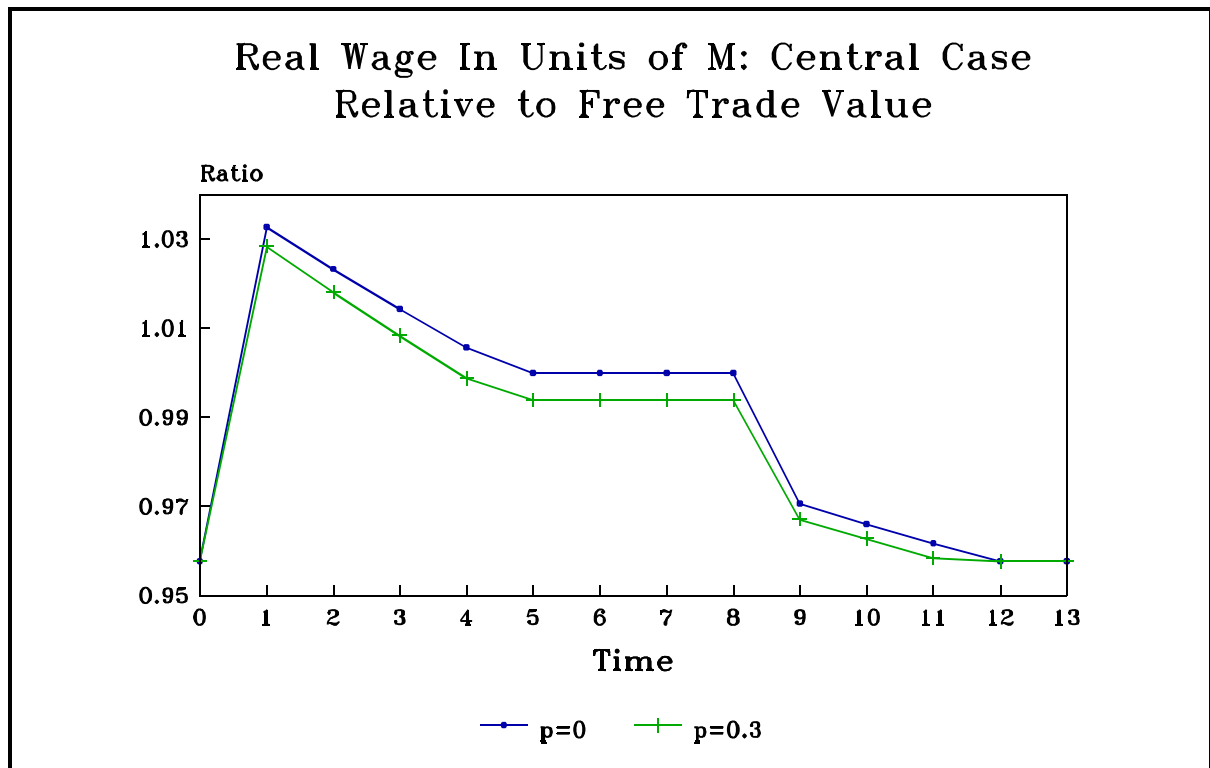


FIGURE 12



Overall the figures show that varying the parameters does not change the main conclusions drawn above though a rich set of effects remain within those limits. Changing the probability of reversal in Figure A1 has the expected effect of varying the investment response of the X sector which makes little difference to net income but does change gross income and the real wage significantly. Figure A2 changes the assumed starting point of the economy on its production possibility frontier which changes the adjustment to reform, particularly of the real wage and the steady state K_x but not net income. The latter in the steady state remains within 0.1% of its credible free trade value across all the parameter combinations. Further assumptions would be required for the exogenous prices in order to weight the sectoral investment figures into an aggregate and hence a chart is not presented for the latter.

Strong effects on the steady state K_x also result from raising the tariff rate in Figure A3 (and hence raising the cost of reversal for X sector capital) and changing the technology parameters in Figures A6-A9. Weaker effects are seen from changing the rates of depreciation in Figures A4 and A5 which is somewhat surprising, particularly for δ_x since a low value for this parameter raises the extent and duration of losses to X sector capital from reform reversal.

TABLE 2

alpha x	beta x	alpha m	beta m	r*	delta x	delta m	tm	p	K _x /K _x ^f Pre-Reform	Steady State	K _m /K _m ^f Pre-Reform	Steady State	Ag.I/Ag.I ^f Pre-Reform	Steady State	Y _n -Y _n ^f (%) Pre-Reform	Steady State	w/w ^f Pre-Reform	Steady State
Base Case (fully credible liberalisation)																		
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.0	0.66	1.00	1.64	1.00	1.15	1.00	-2.15%	0.00%	0.96	1.00
Central Parameter Values																		
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.66	0.92	1.64	1.02	1.15	0.97	-2.15%	-0.02%	0.96	0.99
a) Vary p																		
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.1	0.66	0.97	1.64	1.01	1.15	0.99	-2.15%	-0.00%	0.96	1.00
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.5	0.66	0.90	1.64	1.02	1.15	0.96	-2.15%	-0.04%	0.96	0.99
b) Vary Lfx																		
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.59	0.88	1.46	1.02	-	-	-1.70%	-0.03%	1.00	0.99
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.76	0.96	1.89	1.01	-	-	-2.12%	-0.00%	0.91	1.00
c) Vary tm																		
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.1	0.3	0.82	0.98	1.32	1.00	1.07	0.99	-0.60%	-0.00%	0.97	1.00
0.6	0.2	0.6	0.2	0.03	0.1	0.1	0.3	0.3	0.53	0.85	1.95	1.04	1.24	0.94	-4.25%	-0.09%	0.95	0.99
d) Vary delta m																		
0.6	0.2	0.6	0.2	0.03	0.1	0.05	0.2	0.3	0.61	0.90	1.52	1.02	1.13	0.76	-1.93%	-0.03%	0.98	0.99
0.6	0.2	0.6	0.2	0.03	0.1	0.15	0.2	0.3	0.70	0.94	1.73	1.02	1.15	0.97	-2.22%	-0.01%	0.94	0.99
e) Vary delta x																		
0.6	0.2	0.6	0.2	0.03	0.05	0.1	0.2	0.3	0.71	0.91	1.78	1.03	1.17	0.96	-2.21%	-0.04%	0.93	0.99
0.6	0.2	0.6	0.2	0.03	0.15	0.1	0.2	0.3	0.63	0.94	1.56	1.01	1.15	0.98	-2.01%	-0.01%	0.97	1.00
f) Vary r*																		
0.6	0.2	0.6	0.2	0.01	0.1	0.1	0.2	0.3	0.66	0.92	1.64	1.02	1.15	0.97	-2.15%	-0.02%	0.96	0.99
0.6	0.2	0.6	0.2	0.05	0.1	0.1	0.2	0.3	0.66	0.92	1.64	1.02	1.15	0.97	-2.15%	-0.02%	0.96	0.99
g) Vary alpha m, beta m																		
0.6	0.2	0.7	0.1	0.03	0.1	0.1	0.2	0.3	0.68	0.93	1.59	1.02	0.95	0.96	-1.66%	-0.01%	0.95	1.00
0.6	0.2	0.5	0.3	0.03	0.1	0.1	0.2	0.3	0.59	0.89	1.61	1.02	1.32	0.98	-2.74%	-0.03%	0.99	0.99
h) Vary alpha m + beta m																		
0.6	0.2	0.55	0.15	0.03	0.1	0.1	0.2	0.3	0.76	0.96	1.55	1.01	1.06	0.98	-1.53%	-0.00%	0.91	1.00
0.6	0.2	0.65	0.25	0.03	0.1	0.1	0.2	0.3	0.54	0.85	1.63	1.03	1.26	0.97	-2.54%	-0.06%	1.02	1.00
I) Vary alpha x, beta x																		
0.7	0.1	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.62	0.91	1.66	1.01	1.35	0.98	-2.30%	-0.01%	0.95	1.00
0.5	0.3	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.73	0.95	1.71	1.02	1.00	0.97	-2.03%	-0.01%	0.94	0.99
j) Vary alpha x + beta x																		
0.55	0.15	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.74	0.95	1.51	1.01	1.22	0.99	-1.62%	-0.00%	0.99	1.00
0.65	0.25	0.6	0.2	0.03	0.1	0.1	0.2	0.3	0.59	0.90	1.95	1.05	1.04	0.95	-3.06%	-0.06%	0.90	0.99

4. Anticipated, Imperfectly Credible Trade Liberalisation

Having analysed the case where the trade liberalisation was not anticipated we turn to what happens if, ex ante, agents place a positive probability on reform taking place before it occurs. In general terms the main effect will be to reduce the pre-reform capital stock in the M sector since the owners of this capital will suffer losses if reform takes place. A smaller initial K_m will imply a slightly larger initial K_x through the labour market link between the two.

Given the lower initial K_m we would expect on that account a larger response of K_x to reform but since the latter is higher pre-reform the net effect on the investment response of K_x and hence the aggregate response (since M sector investment is zero for several periods) is ambiguous a priori. It will be the case, however, that there is a quicker approach to the post reform steady state since this period is determined by the depreciation path of K_m from its lower initial value. Once the steady state is reached the anticipation of reform is no longer material and hence we need examine only the response to reform since the response to reversal, assuming that the steady state is reached, will be the same as before.

We denote the perceived probability of reform, pre-reform, by p' and present numerical simulations for simplicity only for the central case parameter values in Table 1. The simulation is conceptually similar to that above for an unanticipated reform except that an expression of the form of (15) must be used for M sector capital pre-reform (with p' in place of p and the M sector parameters in place of X sector ones) with (15) repeated for K_x post reform. Together with the standard labour market clearing condition these two expressions are simulated simultaneously since the pre-reform level of K_m depends on the post-reform response of K_x and vice versa. This is done for the base case where reform is fully credible once it occurs ($p=0$) and for the limited credibility case ($p=0.3$).

Figure 13 gives the first of these for the sectoral capital stocks and Figure 14 the corresponding aggregate investment response. Figure 13 shows a reduction in the initial value of K_m with increasing p' as expected, together with a damped effect on K_x . Figure 14 shows the aggregate investment response is in fact slightly higher as the perceived probability of reform increases. This is because K_m is on a lower depreciation path as p' increases and this effect dominates that arising from a slightly higher initial K_x . In some ways this is a counterintuitive result but it should be noted that the assumptions of free entry and constant capital goods prices imply that there is no advantage to higher investment in the X sector pre-reform due to the anticipation of reform over and above the cheaper labour resulting from a lower K_m at that time. Despite these differences the aggregate investment responses are very similar except in so far as a higher perceived probability of reform leads to a quicker approach to the steady state.

Figures 15 and 16 show the equivalent charts for the limited credibility case. The pattern is essentially the same though, as before, K_x approaches a steady state value significantly below what it would be if liberalisation was fully credible and the overall investment response is weaker.

FIGURE 13

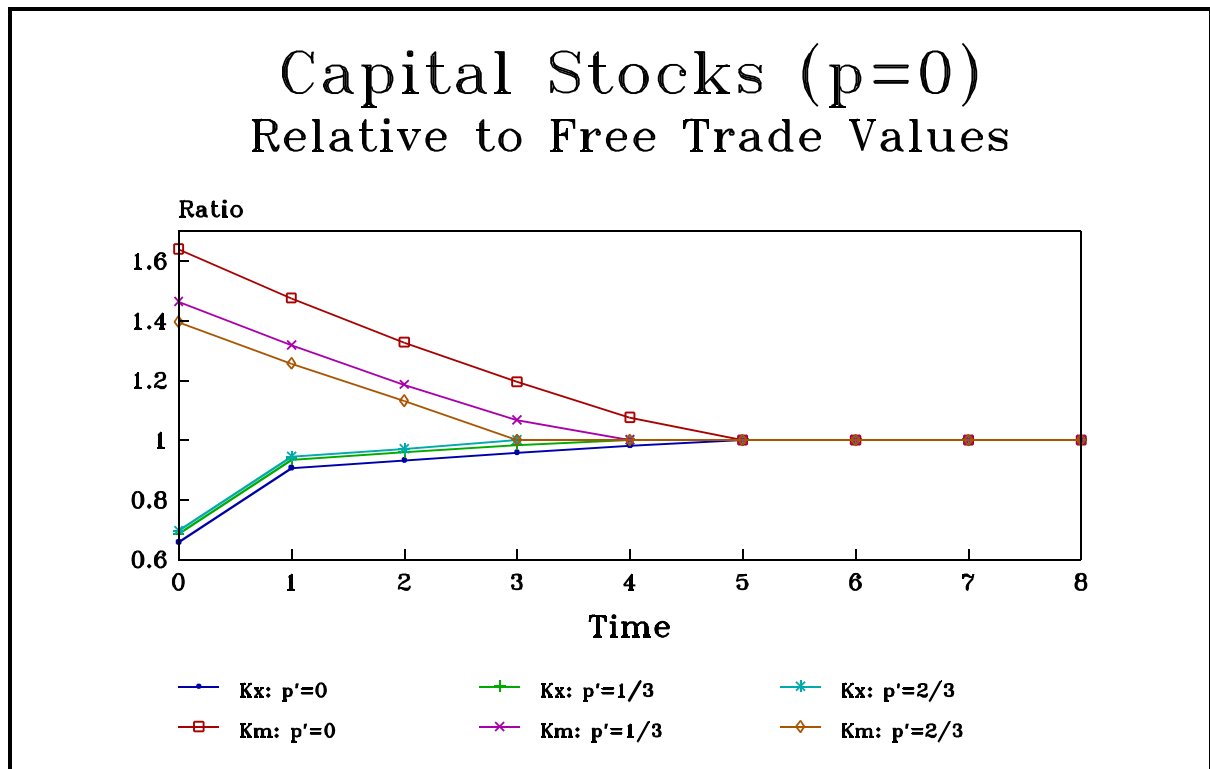


FIGURE 14

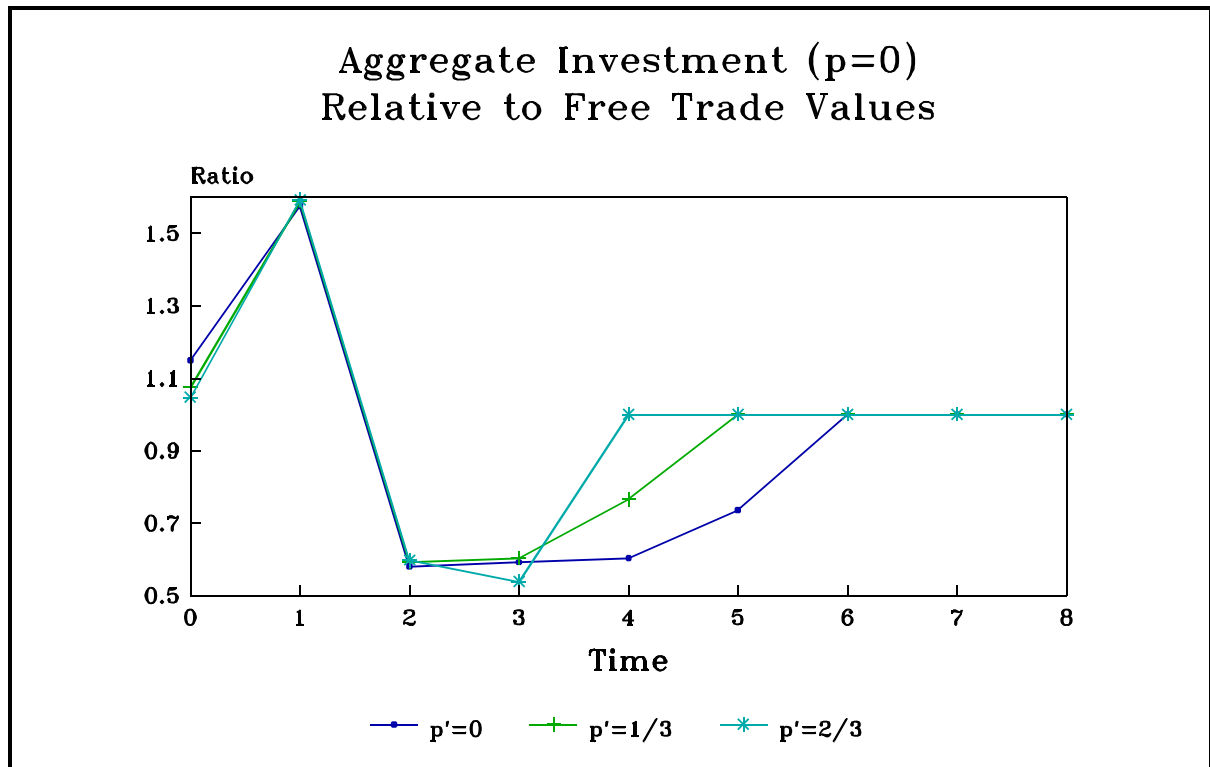


FIGURE 15

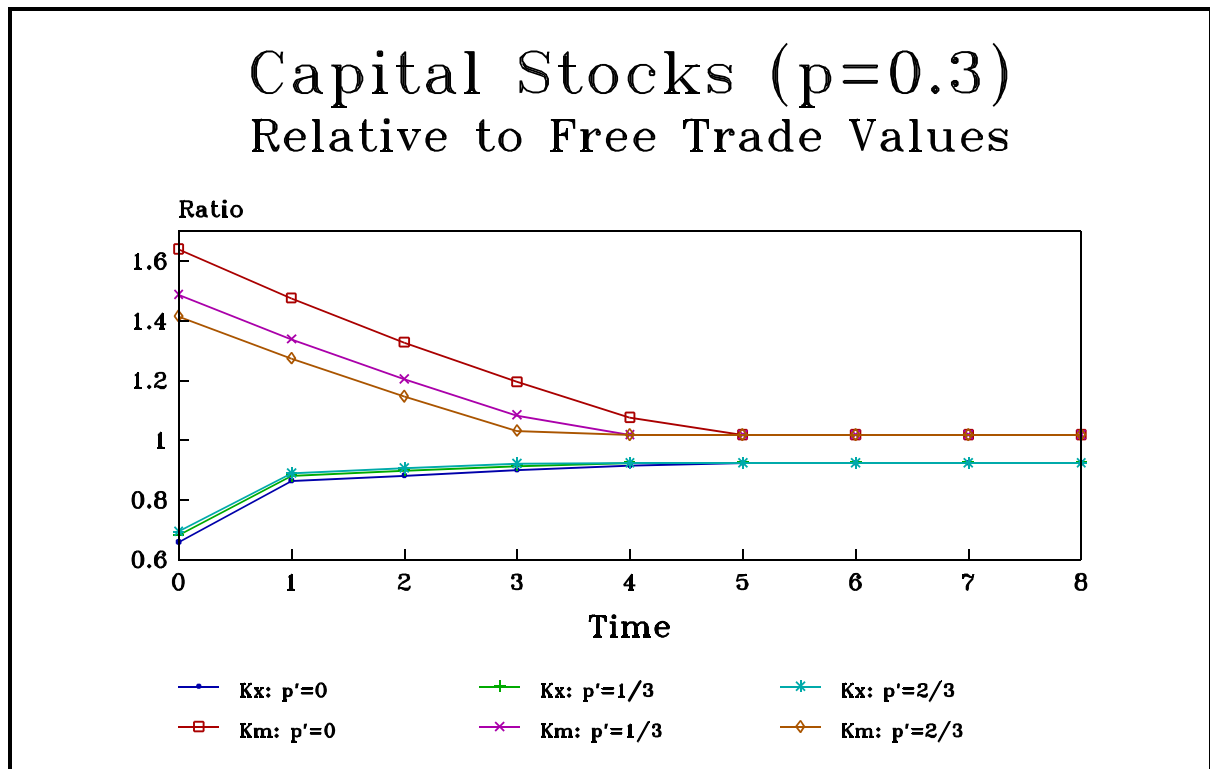
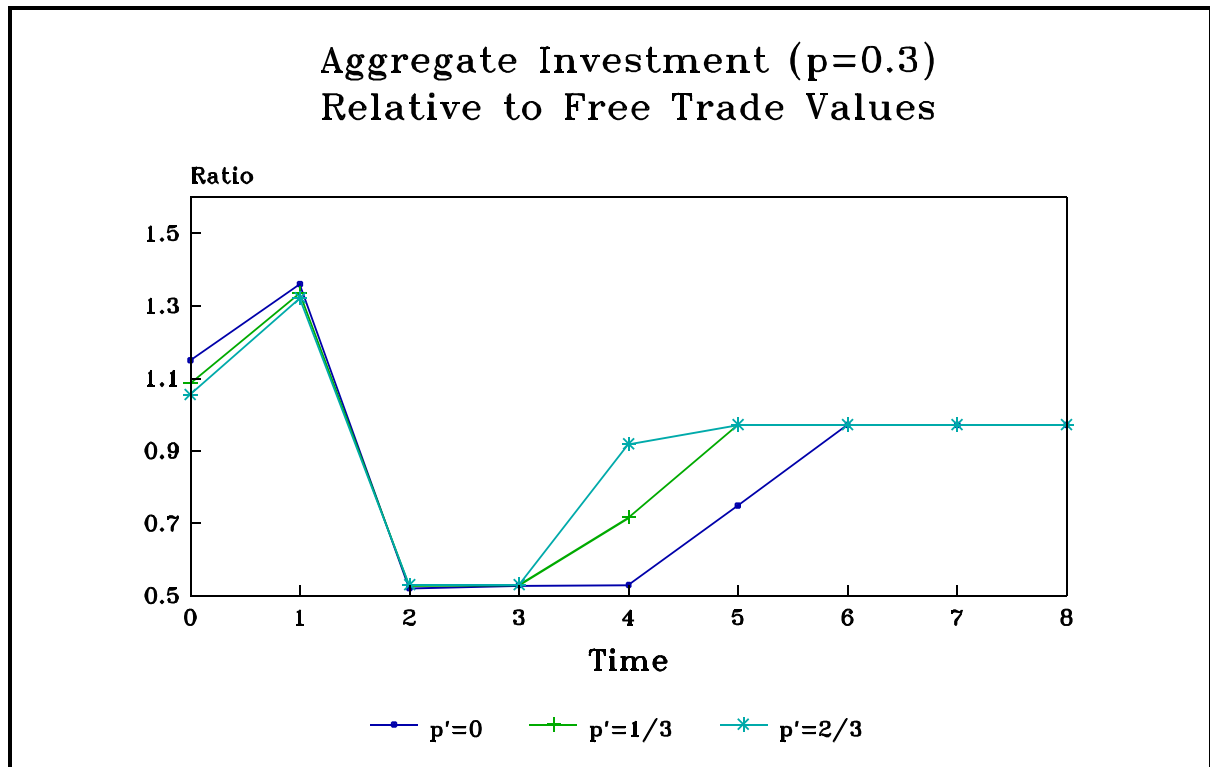


FIGURE 16



5. One Period Delivery Lag

The discussion above has all been based on the assumption that investment can take place very rapidly such that new capital goods may be installed and made productive immediately at the start of each period, including the period at the start of which reform is announced. This section replaces this assumption by one that imposes a one period delay in the delivery of capital goods such that decisions about investment must be taken one period in advance of the new capital goods becoming productive. It is assumed that investment decisions are irreversible so orders cannot be cancelled since otherwise the model would effectively return to its previous specification.

In general a delivery lag would be expected to reduce the desired X sector capital stock following reform since the lag implies that the reform may in fact be reversed just as the new capital goods are becoming productive rather than having at least one period of free trade before the reversal probability applies.

For simplicity we return to the assumption that reform is unanticipated so the initial value of K_m and its depreciation path following reform are the same as in Section 3. To derive the optimal response of K_x to reform, equation (12) must be modified such that expectations must be taken one period in advance given the delivery lag. Following similar steps to the derivation of (15) we have:

$$(16) \quad \left(\frac{K_x^t}{K_x^f}\right)^{1-\beta_x} = \frac{(1-p)\left(\frac{l_x^C}{l_x^f}\right)^{\alpha_x} + p \sum_{s=t}^{s=t+T_x} \left(\frac{l_x^R}{l_x^f}\right)^{\alpha_x} \left[\frac{(1-\delta_x)^{\beta_x}}{(1+r^*)}\right]^{s-t}}{1-p + p \frac{[1 - (\frac{1-\delta_x}{1+r^*})^{T_x+1}]}{1 - (\frac{1-\delta_x}{1+r^*})}}$$

Equation (16) differs from (15) mainly by the terms in $(1-p)$ which is the probability of reform continuing. This is because if reform continues there will be one period in which the capital stock will not expand beyond the level set by the previous period's decisions. l^C refers to the allocation of labour to the X sector at time t if reform has continued whereas l^R is the allocation if reform is reversed. Both are present because at the time that investment decisions are taken and K_x in period t is determined it is not known whether the liberalisation will have been reversed or not. For the same reason the summation in the numerator is from period t rather than $t+1$ and the same change gives rise to the difference in the denominator compared with (15). In order to bring out the pure effect of the timing of decisions we assume that capital goods are only paid for once they have been delivered and are productive. It is more likely in practice that expenditures are incurred earlier but we ignore this possibility since it would amount to changing the cost of capital goods at the same time as introducing the delivery lag.

For simplicity the numerical simulations again make use only of the central parameter values in Table 1. Outcomes for the sectoral capital stocks and aggregate investment are shown in Figures 17 and 18.

Figure 17 assumes a perceived probability of reversal of 0.3 and compares the responses of capital in each sector to reform and reversal. Given the delivery lag there is no response in period 1 when reform is announced and thereafter K_x approaches a steady state value substantially below that without the delivery lag. This results from the reduced expected returns to investing in the X sector when liberalisation may have been reversed by the time that new capital goods become productive. M sector capital on the other hand is much higher with the lag than otherwise. This partly reflects the lower K_x , though as noted before the link through the labour market tends to be weak, but is mainly due to the fact that if reform is reversed existing M sector capital will benefit for one period before K_m expands. Despite these movements away from the credible free trade values the steady state level of net income is still within 1% of its credible free trade value.

Figure 18 combines the aggregate investment response implied by Figure 17 with that for a credible liberalisation, with and without a delivery lag. For clarity the figure shows only the period of reform and the approach to the post reform steady state. With $p=0$ the investment response is essentially delayed by one period as expected. It is assumed that it is only investment decisions, not investment itself, that occurs one period in advance. With a probability of reversal ($p=0.3$) the delivery lag entirely removes the positive aggregate investment response to reform.

FIGURE 17

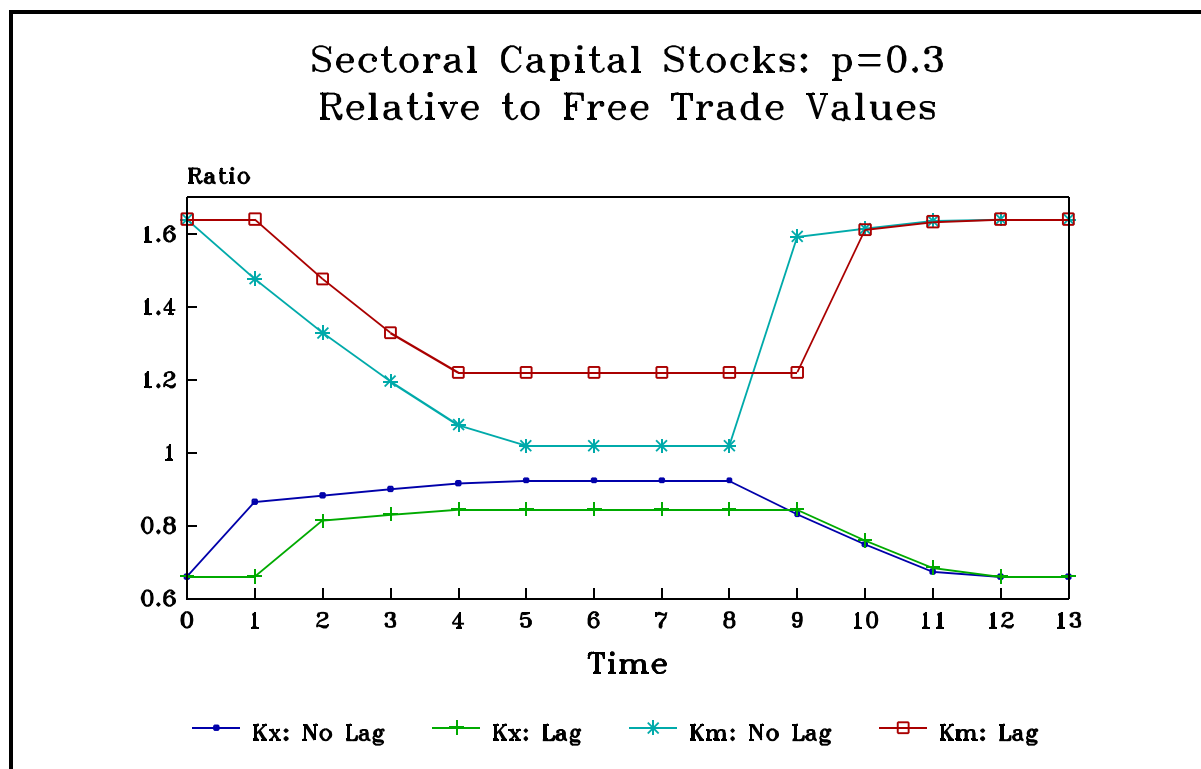
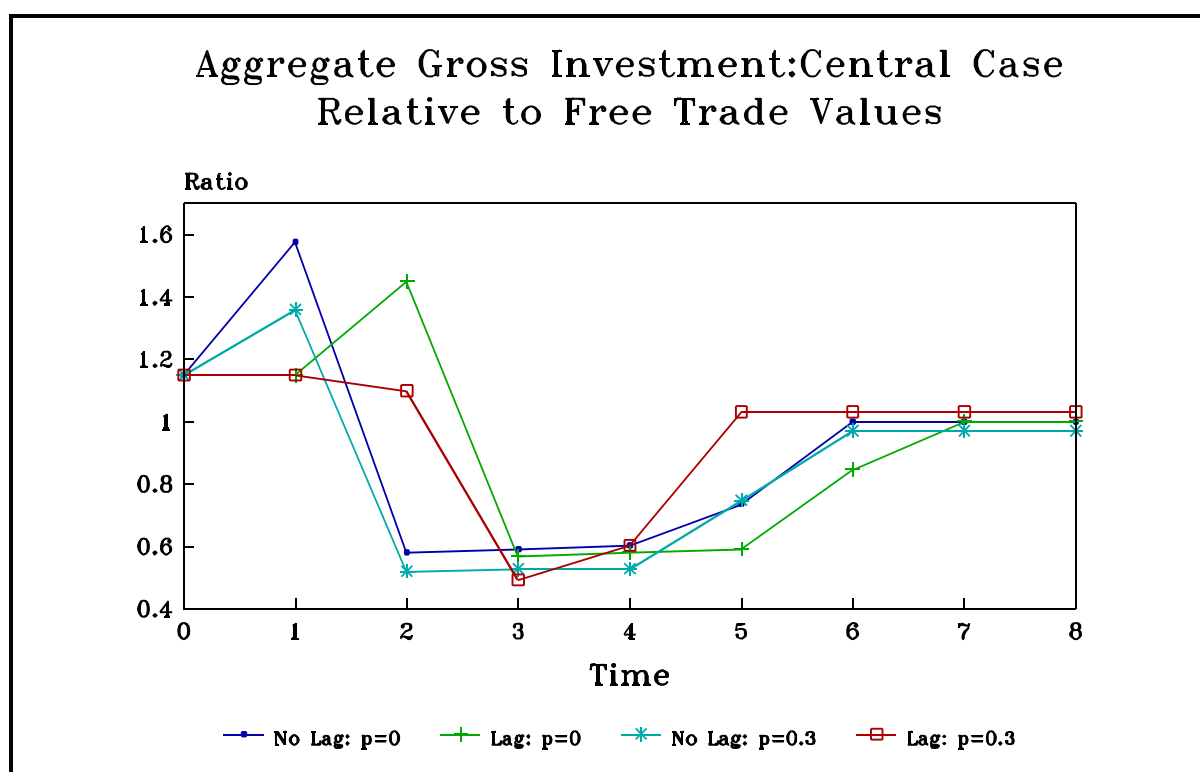


FIGURE 18



6. Conclusion

The paper has analysed the impact of trade liberalisation when agents perceive that the reform may be reversed, comparing outcomes with the full credibility case. The paper has also demonstrated a new solution method for irreversible investment problems of this type and made use of it to generate quantitative simulations of the responses to reform.

It was shown that even with perfect credibility the strong domestic relative price changes induced by liberalisation give rise to powerful dynamic effects on sectoral investment. M sector investment collapses for several periods as the capital stock in the importables sector adjusts downwards through depreciation. Investment in the favoured export sector is strongly positive but the net effect of the two is weak, particularly after the first period which is when the major part of the X sector adjustment takes place.

Introducing a perceived probability of reversal reduces the export sector investment response as expected and this effect is strongly reinforced if there are delivery lags in the investment process. Only modest differences arise according to whether the reform was anticipated or not though the adjustment to reform is slower in the latter case.

Reductions in the post reform capital stock in the export sector has negative first order effects on the post reform real wage and value of output at world prices. A more appropriate measure of aggregate welfare or efficiency is the value of output at world prices net of the cost of capital and

a reduced capital stock has only second order effects on this variable. While the magnitudes are small, welfare always increases even with an imperfectly credible trade liberalisation since the removal of tariffs always raises X sector capital towards its optimal value to some extent (as long as the post reversal tariff is no larger than the pre-liberalisation tariff) and reduces the excessively high M sector capital stock.

By tracing out the response of factor returns to liberalisation the paper provides promising foundations for further work on the political economy of trade reform by which the probability of reform reversal may be endogenised. In particular political pressures for reform reversal are likely to decline over time as the structure of the economy adjusts to the new trade regime.

A number of extensions would be desirable. Firstly the scope of the model, which considered solely investment responses, may be integrated with the consumption and savings response to reform to take account of the Calvo effect and also to explore removing the assumption of a perfect world capital market which would make interest rates endogenous. Secondly the introduction of non-tradeable capital goods would permit consideration of the investment composition effects studied by Collier and Gunning (1996) side by side with the aggregate response analysed above. Introducing non-tradeable capital goods would also give rise to an endogenous capital goods price as well as affecting the labour market as that sector absorbed or released labour.

Collier and Gunning also draw attention to the importance of whether the trade liberalisation removes tariffs on consumer goods alone or also on capital goods. The paper has assumed that any tariffs on capital goods were either zero to begin with or remain in place but if not a positive probability of reform reversal is likely to strengthen the investment response through the capital goods equivalent of the Calvo effect as agents perceive that the domestic price of capital goods may be temporarily low.

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APPENDIX

FIGURE A1a

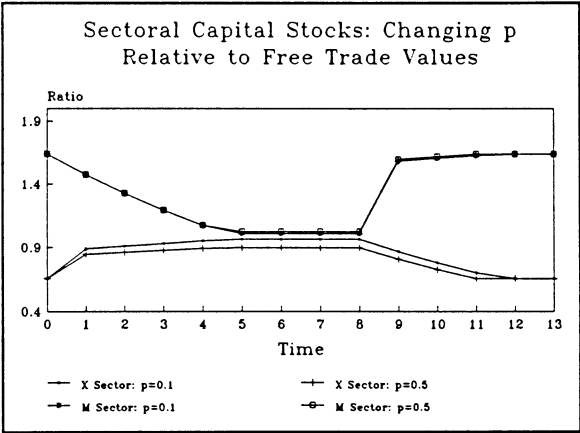


FIGURE A1b

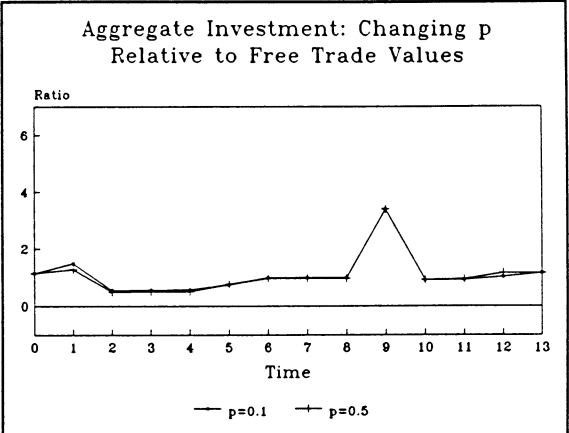


FIGURE A1c

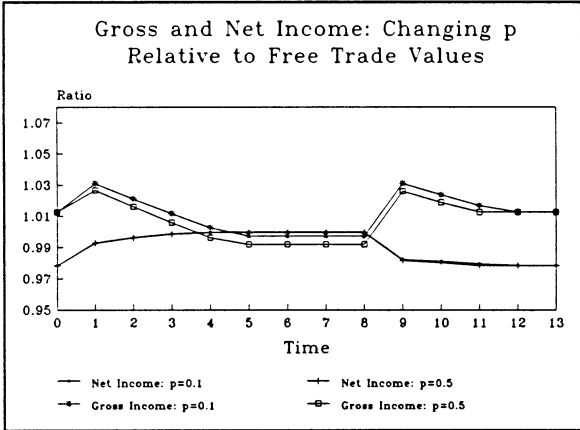


FIGURE A1d

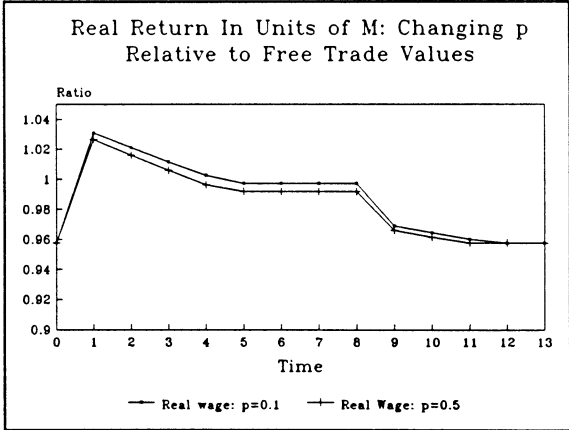


FIGURE A2a

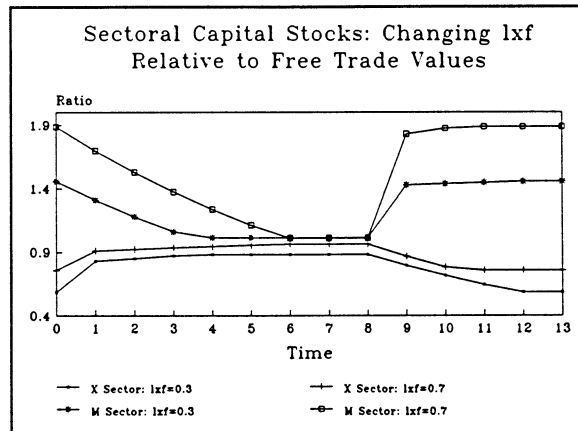


FIGURE A2b

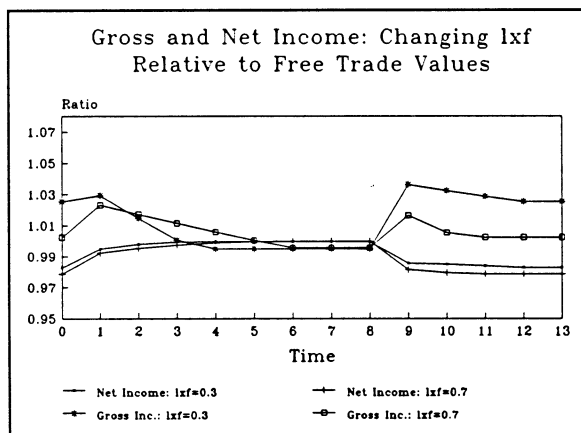


FIGURE A2c

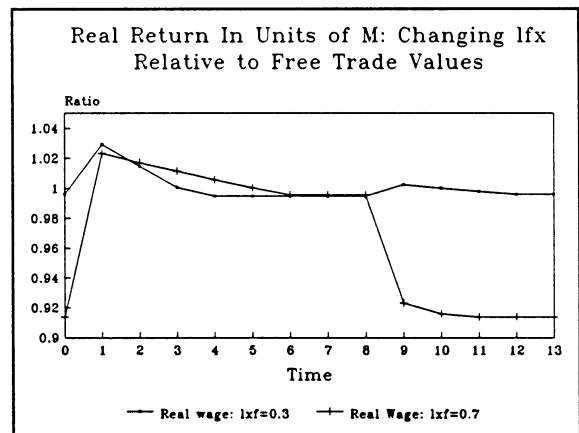


FIGURE A3a

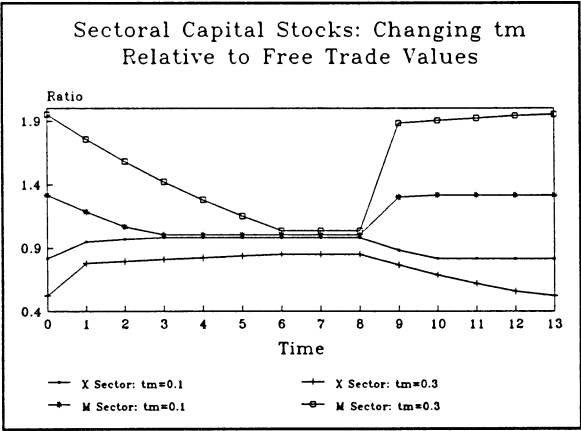


FIGURE A3b

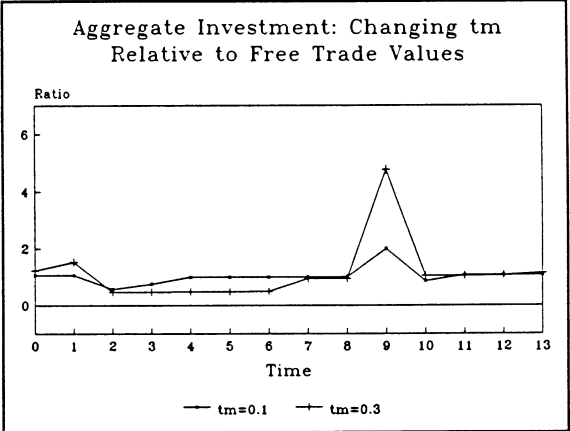


FIGURE A3c

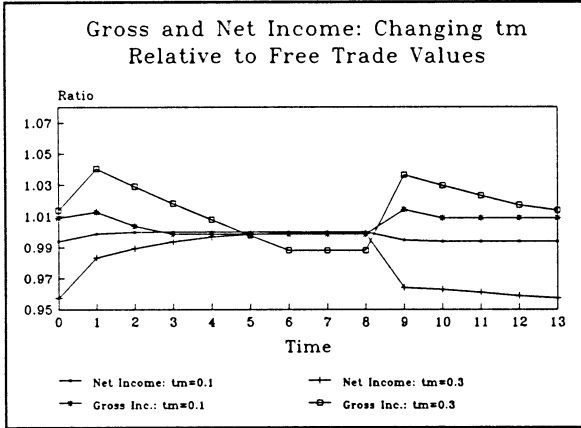


FIGURE A3d

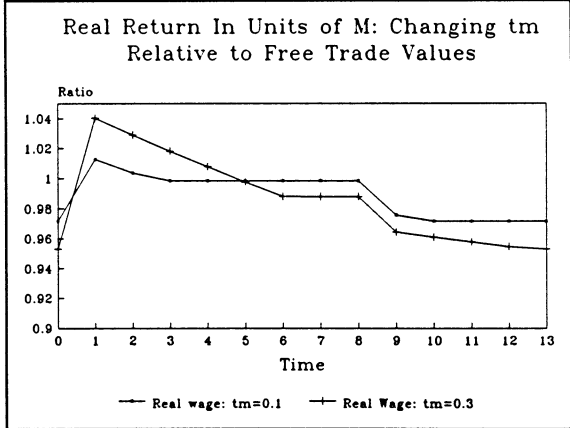


FIGURE A4a

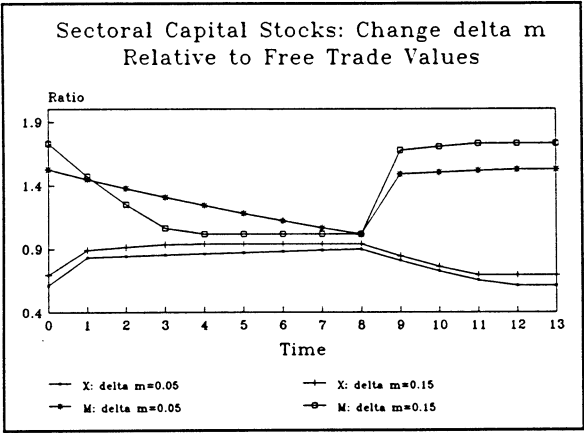


FIGURE A4b

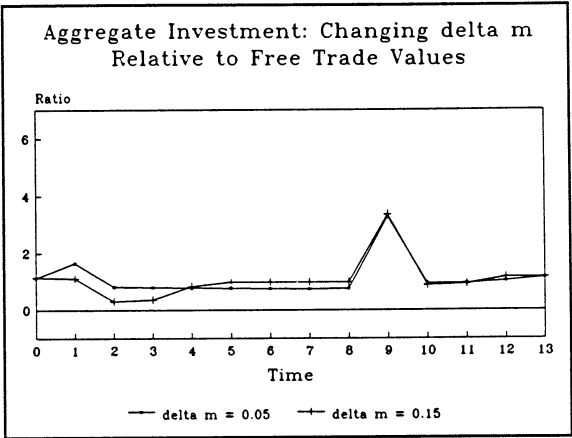


FIGURE A4c

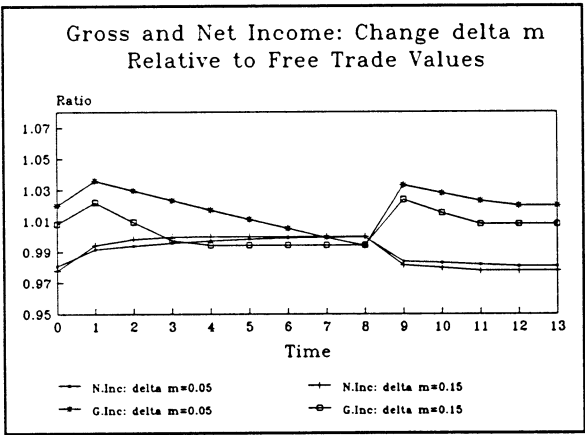


FIGURE A4d

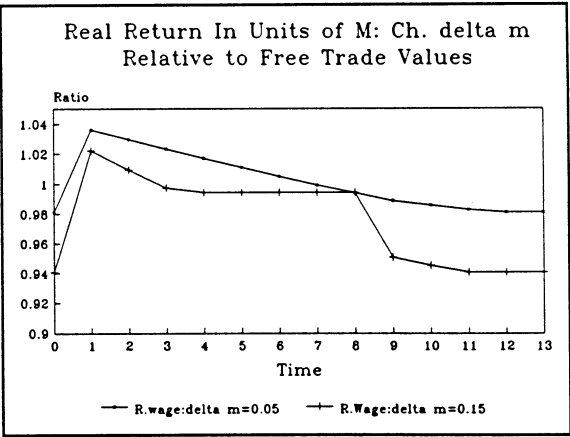


FIGURE A5a

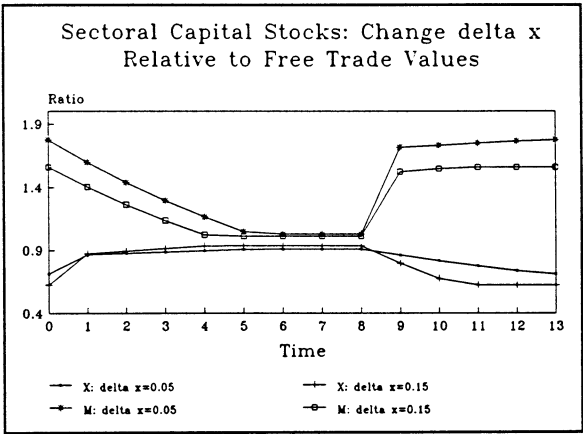


FIGURE A5b

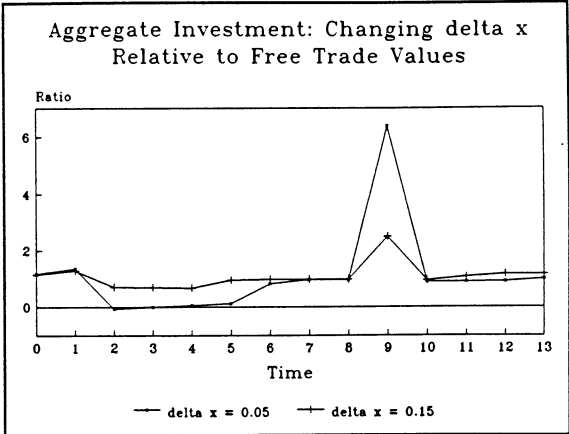


FIGURE A5c

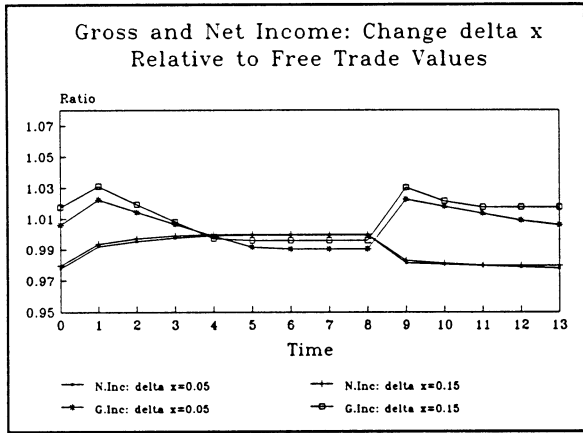


FIGURE A5d

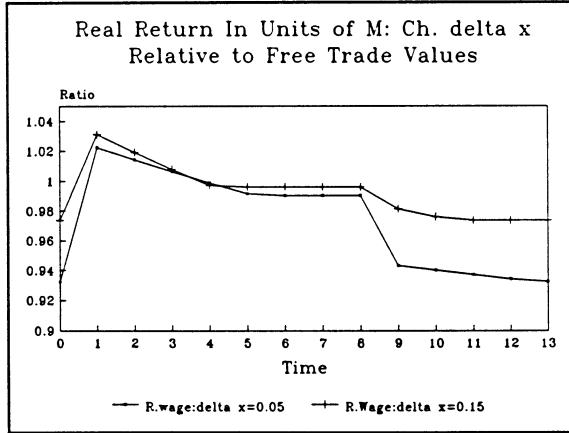


FIGURE A6a

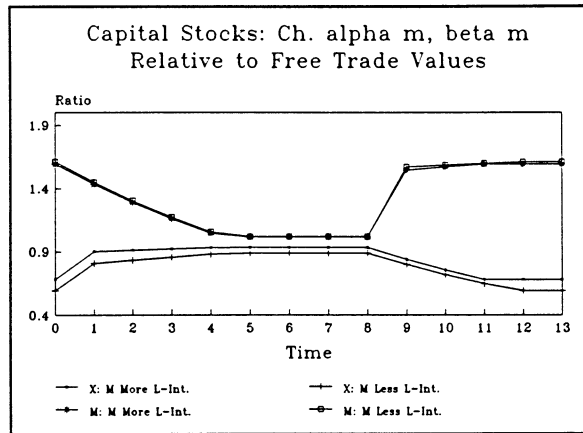


FIGURE A6b

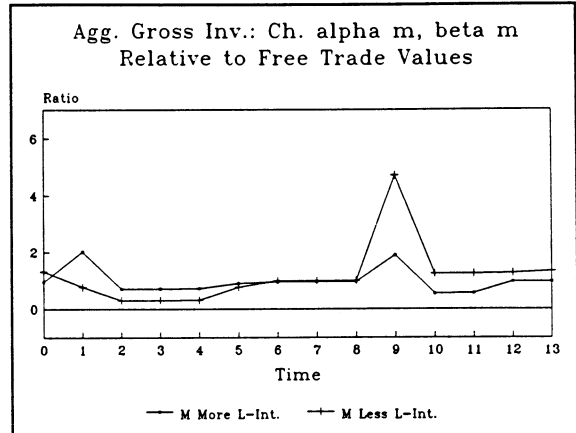


FIGURE A6c

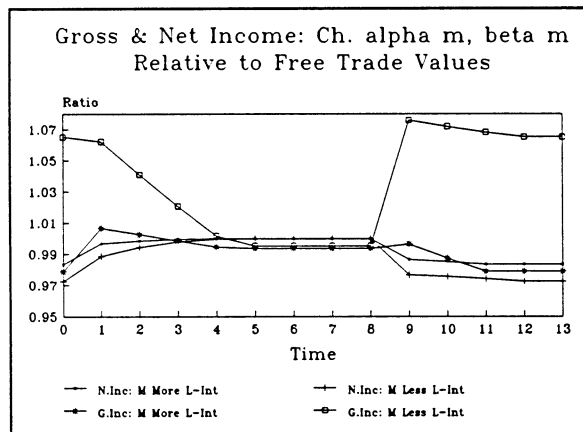


FIGURE A6d

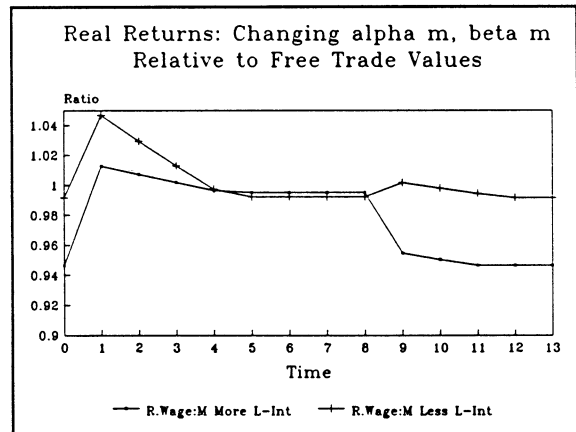


FIGURE A7a

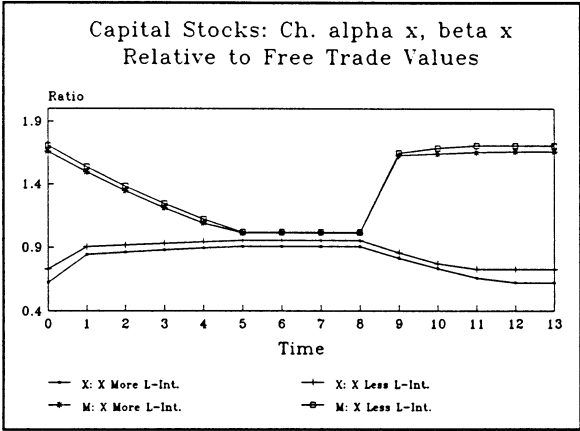


FIGURE A7b

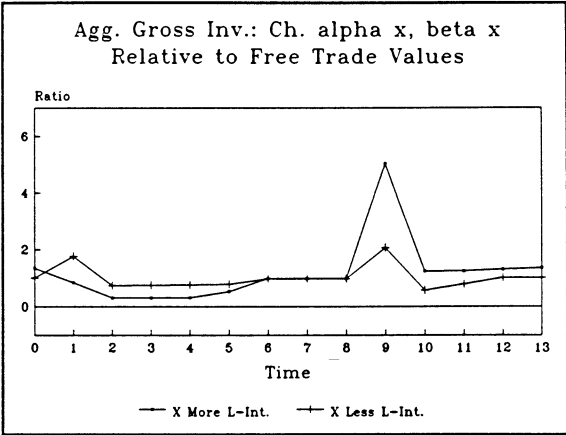


FIGURE A7c

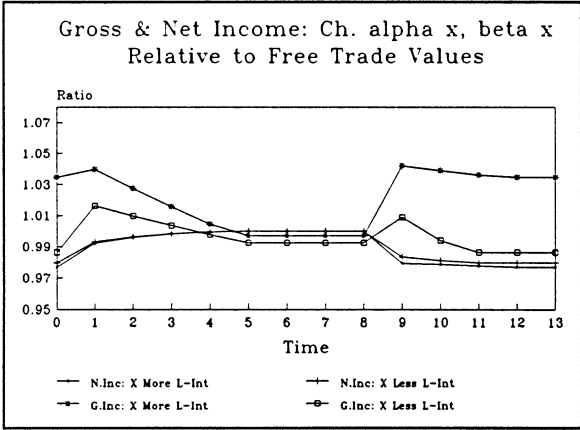


FIGURE A7d

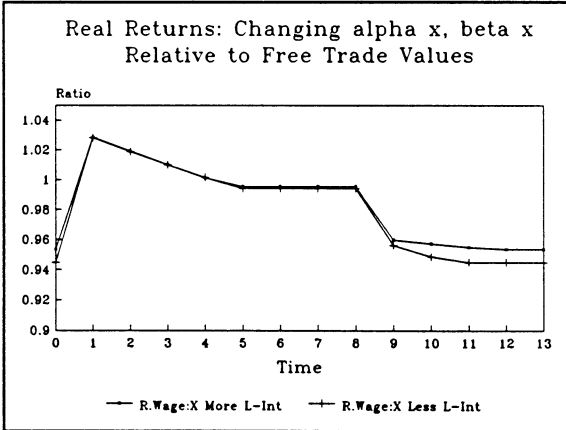


FIGURE A8a

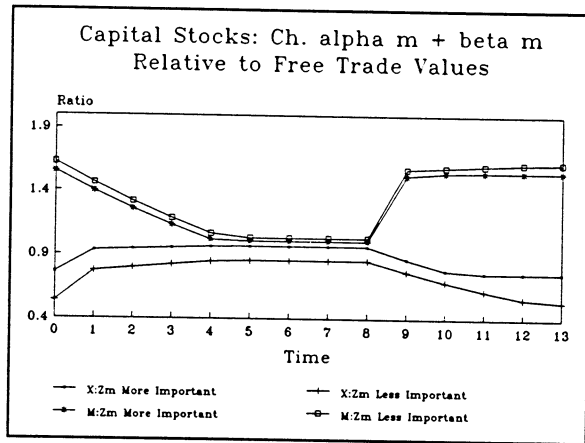


FIGURE A8b

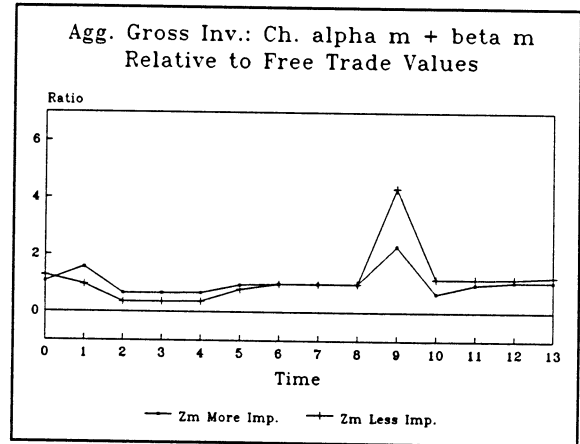


FIGURE A8c

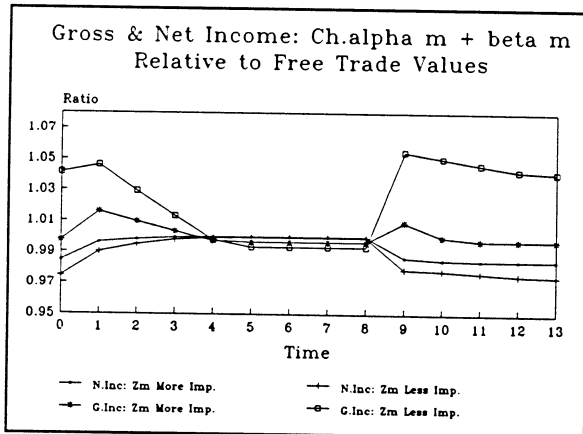


FIGURE A8d

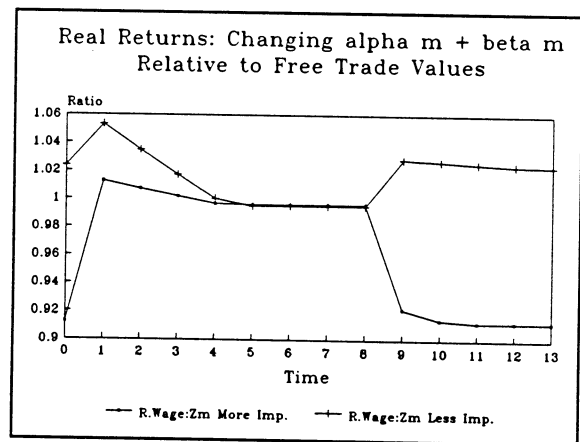


FIGURE A9a

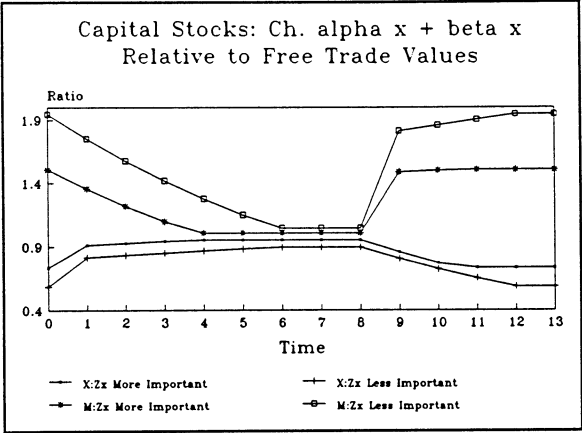


FIGURE A9b

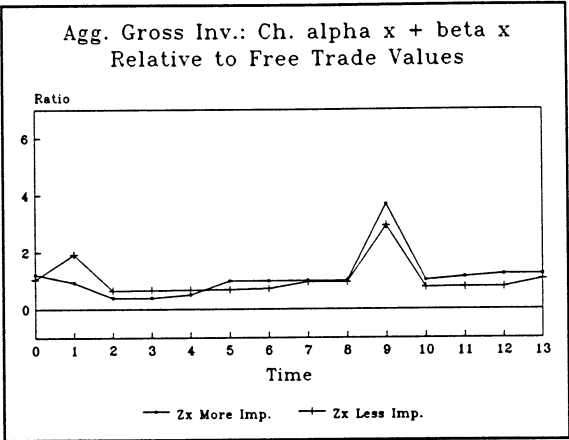


FIGURE A9c

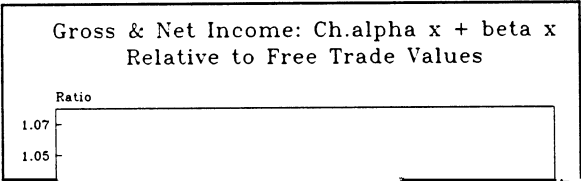


FIGURE A9d

