Hysteresis and cyclical adjustment in the stock markets: the macroeconomic effects of technological progress

Saziye Gazioglu
W. David McCausland
Department of Economics
University of Aberdeen

X Congreso Anual de la Academia de Ciencias Administrativas AC (ACACIA)
San Luis Potosí
Mayo 3-5, 2006

Area del conocimiento: Finanzas y Economía
Hysteresis and cyclical adjustment in the stock markets: the macroeconomic effects of technological progress

Saziye Gazioglu
W. David McCausland
Department of Economics
University of Aberdeen

Abstract

The aim of this paper is to investigate the effects of technological change on stock market dynamics. We develop an intertemporal optimising model, the central innovation of which is the distinction between the non-perishables and perishables sectors. We discuss the conditions likely to lead to cyclical stock market behaviour in response to technological shocks. Furthermore, we show that one-off technological advances may have persistent effects giving the country a permanent growth advantage. This gives an alternative mechanism for explaining differential growth rates to that already established in the endogenous growth literature.

Author Keywords: Stock market; Hysteresis

JEL classification codes: E30; G10; O16; O40

Article Outline

1. Introduction
2. The model
3. Policy analysis
   3.1. Cyclical dynamics
   3.2. Saddle-path dynamics
4. Hysteresis and irreversibility
5. Conclusions
Acknowledgements
Appendix A. The Euler equations
Appendix B. Comparative statics
Appendix C. Symbols list
References
1. Introduction

This paper investigates the impact of technological change on the dynamic behaviour of the stock markets. We provide a closed economy extension of [Obstfeld and Rogoff, 1995] intertemporal optimising framework, where our key innovation is the distinction between the non-perishables sector and the perishables sector. We analyse the conditions likely to result in cyclical stock market behaviour in response to technological shocks.

A puzzle that has been perplexing economists for sometime is how to explain divergent growth rates between countries. The endogenous growth literature, for example [Grossman and Helpman, 1990 and Grossman and Helpman, 1991], gives one possible mechanism that attempts to explain this phenomenon. They suggest that countries have different growth rates due to differences in their innovation experience. Furthermore, they argue that large research and development subsidies in the lagging country can be sufficient to overcome their relative inexperience in innovation, and interestingly, the subsidy can be withdrawn after catch-up has taken place without reversing the consequences (there is hysteresis). The model in this paper result in a similar effect, but through a different route obtained through an extension of the new macroeconomics literature, following [Obstfeld and Rogoff, 1995]. We analyse formally the conditions necessary for the existence of multiple economic growth equilibria. Our model suggests an alternative mechanism through which one-off technological change may bring about a permanent growth advantage. In other words, there is hysteresis in the model. The technological advantage gained by the European Union countries in the past has remained until today, despite the high growth rates witnessed from time to time in the newly industrialising countries. However, our paper also highlights the importance of research and development policies within the European Union in securing continued technological advantage.

In Section 2, we develop the model, and then present our analysis in Section 3. Concluding comments are presented in Section 4.

2. The model

Following [Obstfeld and Rogoff, 1995], we consider a continuum of individual producers, indexed by $z \in [0, 1]$. Producers on the interval $[0, n]$ produce differentiated varieties of the non-perishable product (we refer to this as the non-perishables sector), while producers on the interval $[n, 1]$ produce differentiated varieties of the perishable product (we refer to this as the perishables sector). The distinction between the two sectors is clear. In the non-perishables sector, physical inventories can be built up or run down. In the perishables sector, physical inventories do not exist. Financial services, such as banks, fall into the non-perishables sector, since asset stocks may be added to or depleted. On the other hand, software developers fall into the perishables sector, since any assets they have are non-physical (comprise mainly of human capital). We believe that the service (or perishable) sector represents more generally a relatively labour-intensive sector, and the manufacturing (or non-perishable sector) represents more generally a relatively capital-intensive sector. This distinction is often employed in North–South models, as collected in [Currie and Vines, 1988], where southern nations
specialise in labour-intensive production and northern (or western) countries tend to specialise in the production of relatively more capital-intensive goods.

Representative agents maximise time separable utility functions of the form

$$\max_{\{A(t)\}} U = \int_0^\infty U[A(t)] e^{-\beta t} dt$$  \hspace{1cm} (1)

where $A$ represents a consumption index over the $z$ products, and $\beta$ represents the subjective discount rate, subject to the following constraints.\footnote{Firstly, the stock market constraint for the non-perishables sector (non-perishables sector)}

$$V \frac{\hat{X}}{X} = X \frac{\hat{V}}{V} + XD$$  \hspace{1cm} (2)

states\footnote{Secondly, the stock market constraint for the perishables sector (perishables sector)} that the value of a change in the proportion ($X$) of non-perishables firms (in other words, shares: the value of claims to the entire future profits of firms, $V$) owned by a representative agent, $V \frac{\hat{X}}{X}$, is equal to the proportion of the change in the stock market valuation of these shares, $X \frac{\hat{V}}{V}$, plus their proportion of dividends, $XD$. Secondly, the stock market constraint for the perishables sector (perishables sector)

$$P \frac{\hat{S}}{S} = S \frac{\hat{P}}{P} + SQ$$  \hspace{1cm} (3)

states that the value of a change in the proportion ($S$) of perishables providers (in other words, shares: the value of claims to the entire future profits of firms, $P$) owned by a representative agent, $P \frac{\hat{S}}{S}$, is equal to the proportion of the change in the stock market valuation of these shares, $S \frac{\hat{P}}{P}$, plus their proportion of dividends, $SQ$. Using (2) and (3), we may write a combined constraint as

$$\frac{\hat{X}}{X} + \frac{\hat{S}}{S} = Y + RK + X \left( \frac{\hat{V}}{V} + \frac{D}{V} \right) + S \left( \frac{\hat{P}}{P} + \frac{Q}{P} \right) - A - I$$  \hspace{1cm} (4)

where $R$ is the consumption-based real interest rate. In essence, therefore, the right-hand side of the constraint represents ‘income’ (factor earnings, $Y$ and $RK$, return on shares from both the sectors, $X(\frac{\hat{V}}{V} + \frac{D}{V})$ and $S(\frac{\hat{P}}{P} + \frac{Q}{P})$) minus ‘consumption’ (private, $A$, and investment, $I$), reflected by the ‘saving’ (net wealth accumulation, $\frac{\hat{X}}{X} + \frac{\hat{S}}{S}$) on the left-hand side.

Maximising\footnote{Maximising subject to Eq. (4) yields the familiar Euler equations, which can be combined to yield the extended [Blanchard, 1981] arbitrage conditions (which hold only in equilibrium)} Eq. (1) subject to Eq. (4) yields the familiar Euler equations, which can be combined to yield the extended [Blanchard, 1981] arbitrage conditions (which hold only in equilibrium)

$$R = \frac{\hat{V}}{V} + \frac{D}{V}$$  \hspace{1cm} (5)

$$R = \frac{\hat{P}}{P} + \frac{Q}{P}$$  \hspace{1cm} (6)

From Eq. (5), $\frac{\hat{V}}{V} = VR - D(V,P,T)$, since $D_v > 0$ (the stock market valuation of non-perishables firms is in effect the valuation of the entire future profit stream of these firms and is hence
positively related to their own dividends), \(D_P < 0\) (the stock market valuation of perishables providers is in effect the valuation of the entire future profit stream of those firms and is hence negatively related to the dividends of the non-perishables sector due to asset substitutability on the part of investors), and \(D_P > 0\) (exogenous technical progress increases manufacturers dividends since the real return on capital increases), therefore from Eq. (5), we can determine that \(V_P > 0\) and \(V_T < 0\). The sign of \(V_T\) is ambiguous, since from Eq. (5), \(V_T = R - D_T\). We assume to begin with that \(R > D_T\), implying the stock market return of the non-perishables sector dominates the return on capital, therefore \(V_T < 0\). We relax this assumption in Section 4.

From Eq. (6), \(\dot{P} = PR - Q(V, P, T)\), since \(Q < 0\) (again, due to asset substitutability, dividends in the perishables sector are inversely related to the stock market value of the non-perishables sector), \(Q_P > 0\) (the stock market value of the perishables sector is positively related to the stock market value of the perishables sector, since the latter reflects the entire discounted profit stream of that sector), and \(Q_T > 0\) (exogenous technological advances increase the dividends of perishables providers since the real return on capital increases), therefore from Eq. (6), \(V_P > 0\) and \(V_T < 0\). The sign of \(V_T\) is ambiguous, since from Eq. (6), \(V_T = R - Q_T\). We assume to start with that of \(R < Q_T\), i.e., the stock market return of the perishables sector dominates the return on capital, therefore \(V_T < 0\). This assumption is relaxed in Section 4.

We take \(V\) to be the jump variable because the share price in the relatively capital-intensive (non-perishable/manufacturing/North) sector adjusts more quickly than the relatively labour-intensive (perishable/service/South) sector. (5) and (6), therefore, capture the dynamics of the whole system, and, given in the discussion above, may be summarised in matrix form by

\[
\begin{bmatrix}
\dot{V} \\
\dot{P}
\end{bmatrix} = \begin{bmatrix}
V_{V^+} & V_{V^-} \\
V_{P^+} & V_{P^-}
\end{bmatrix}\begin{bmatrix}
V \\
P
\end{bmatrix} + \begin{bmatrix}
V_T \\
P_T
\end{bmatrix}[T]
\]

(7)

where the signs of the elements of the matrices are indicated according to the discussion above. The determinant of the principal matrix may be either positive or negative. If it is positive, then, since the trace is negative, then there is a cyclical adjustment to equilibrium. This is the scene depicted in Fig. 1. If, on the other hand, the determinant is negative, then there is a saddle-path adjustment to long run equilibrium. This is the scene depicted in Fig. 2. We now have all the tools in place necessary to proceed to the policy analysis conducted in the next section.
3. Policy analysis

The dynamics of the model developed in the previous section are illustrated in Fig. 1 and Fig. 2. The slopes of $\hat{P} = \hat{Q}$ and $\hat{V} = \hat{Q}$ loci are derived in Appendix B. Both are shown to be upwards sloping. However, their relative slopes will determine the dynamic behaviour of the system. If the slope of $\hat{P} = \hat{Q}$ locus exceeds that of $\hat{V} = \hat{Q}$ locus, then there is a cyclical adjustment to equilibrium (Fig. 1). Otherwise, there is a saddle-path adjustment to long run equilibrium (Fig. 2).

A technological advance (rise in $T$) shifts $\hat{V} = \hat{Q}$ locus downwards and $\hat{P} = \hat{Q}$ locus upwards (as shown in (B.2) and (B.3) in Appendix B). We illustrate the effects of such a technological advance in Fig. 1 and Fig. 2.

3.1. Cyclical dynamics

In the cyclical case, the results in long run fall in the stock market values of both the sectors ($V$ and $P$) (as shown in (B.5a) and (B.6a) in Appendix B). The intuition behind these results is as follows. Recall that the cyclical adjustment occurred when $\hat{V}/\hat{V} < \hat{F}/\hat{V}$ (graphically, $\hat{P} = \hat{Q}$ locus is steeper than $\hat{V} = \hat{Q}$ locus). This condition holds when $\hat{V}$ is small relative to $\hat{P}$, in other words, when the effect of the perishables sector stock market value is small relative to the effect of the non-perishables sector stock market value on the perishables sector stock market value. This occurs when, say, the perishables sector is small relative to the non-perishables sector. So, we can loosely say that this case mirrors the conditions in ‘the West’ following the industrial expansion of the late 18th century and up until shortly after the Second World War in the mid 20th century. It could be argued that during this period, despite huge technological advances, stock market indices remained constant (certainly compared with the huge rises in stock market indices witnessed in the last few decades of this century).
We now investigate the short run dynamics, i.e., the behaviour of the stock market values during the adjustment of the system. From Eq. (6), we note that $\hat{V}/V = R - D/V$. Since technical advances immediately raise the real return on capital, $R$, such that it exceeds the more slowly adjusting dividends, $D/V$, then $\hat{V}/V > 0$ during the adjustment phase. This implies the expectation of a fall in the commodity price level. The only way these expectations can be consistent with the long run equilibrium fall in the non-perishables stock market value is through the non-perishables stock market value initially rising and then adjusting, cyclically to long run equilibrium, respectively. In other words, there is commodity price overshooting. An alternative way of looking at this overshooting (and undershooting in Fig. 2) phenomena is in terms of the short run divergence between the returns on the different assets (which in the long run are all equal through arbitrage). In other words, we have provided a rationale for the long run behaviour of the stock markets and their short run volatility and potentially cyclical dynamics.

3.2. Saddle-path dynamics

In the saddle-path case, the results in long run rises in the stock market values of both the sectors ($V$ and $P$) (as shown in (B.5a) and (B.6a) in Appendix B). The intuition behind these results is the exact opposite of the analysis given in the previous paragraph. The saddle-path case arises when $\hat{V}_P/V_P > \hat{V}_P/P_P(V = 0 \text{ locus} \text{ is steeper than } \hat{P} = 0 \text{ locus})$. This occurs when $\hat{V}_P$ is large relative to $\hat{P}_P$, in other words, when the effect of the perishables sector stock market value is large relative to the effect of the non-perishables sector stock market value on the perishables sector stock market value. This in turn arises when, say, the perishables sector is large relative to the non-perishables sector. This scenario closely approximates to the experience of the post-industrialising countries of the west in the latter part of the 20th century. In these economies, the perishables sector has overtaken the traditional sectors in importance as the ‘information revolution’ has gathered pace. In turn, we have witnessed huge leaps in stock market indices of the perishables sector over this period.

We now investigate the short run dynamics, i.e., the behaviour of the stock market values during the adjustment of the system. From Eq. (6), we note that $\hat{V}/V = R - D/V$. Since technical advances immediately raise the real return on capital, $R$, such that it exceeds the more slowly adjusting dividends, $D/V$, then $\hat{V}/V > 0$ during the adjustment phase. This implies the expectation of a fall in the commodity price level. The only way these expectations can be consistent with the long run equilibrium rise in the non-perishables stock market value is through the non-perishables stock market value initially rising by more than the required long run rise and then adjusting monotonically downwards to long run equilibrium, respectively. In other words, there is commodity price overshooting. An alternative way of looking at this overshooting phenomenon in terms of the short run divergence between the returns on the different assets (which in the long run are all equal through arbitrage). In other words, we have provided a rationale for the long run behaviour of the stock markets and their short run volatility and potentially cyclical dynamics.

4. Hysteresis and irreversibility

Now, we explore the possibility of non-linearities in $\hat{V} = 0$ and $\hat{P} = 0$ loci, and show how this gives the possibility of multiple equilibria. The shapes of the loci we obtain are shown in Fig. 3 and explained as follows. From Eq. (5), $\hat{V}_P = R - D_V$, where $D_V > 0$. Hence in general, $\hat{V}_P$ can be positive or negative, depending on the relative magnitudes of $R$ and $D_V$, and using Eq.
(B.3) in Appendix B, this gives the non-linear form of \( \psi = \psi \) locus illustrated. The intuition behind the shape of this locus is that the stable regions of the locus (the upward sloping sections) correspond to where expectations of the return from dividends in the non-perishables sector exceed the return on capital, stimulating investment (and vice versa).

Similarly, from Eq. (6), \( \dot{p}_P = R - Q_P \), where \( Q_P > 0 \). Hence in general, \( \dot{p}_P \) can be positive or negative, depending on the relative magnitudes of \( R \) and \( Q_P \), and using Eq. (B.1) in Appendix B, this gives the non-linear form of \( \dot{p} = \dot{p} \) locus illustrated. We assume to start with that of \( R < Q_P \), that is the stock market return of the perishables sector dominates the return on capital, therefore \( \dot{p}_P < 0 \). Again, the intuition behind the shape of this locus is that the stable regions of the locus (the upward sloping sections) correspond to where expectations of the return from dividends in the perishables sector exceed the return on capital, stimulating investment (and vice versa).

The policy consequences can now be analysed. It is well known in the hysteresis literature that it is ‘large’ changes that may lead to policy irreversibility in non-linear models such as this one, where ‘large’ is defined to be a change beyond the critical value that triggers equilibrium loss. A ‘large’ relative technological advance compared with competitors (rise in \( T \)) may lead to a loss of the low stock market value equilibrium, and a structural shift to the high stock market equilibrium. This is represented by a shift from \( E_0 \) to \( E_1 \). As can be seen from Fig. 3, this leads to a long run rise in the perishables sector stock market value (from \( P_0 \) to \( P_1 \)), but possibly a fall in the non-perishables sector stock market value (from \( V_0 \) to \( V_1 \)). This may reflect the adjustment experiences of many western nations subsequent to the ‘industrial revolution’.

If the relative technological advantage is subsequently eroded (returning \( T \) to its former level), then this does not lead to the restoration of the initial equilibrium, but rather to the locally proximate equilibrium \( E_2 \), also characterised by high stock market values which represents growth of productive capacity. In other words, the advantage of the western nations of their late 18th century technological advances may not be eroded by, e.g., technology improvements in Eastern Europe or the Far East.

In other words, one-off relative technological advances may generate persistent effects giving the country a permanent ‘growth’ (as represented by stock market value, which represents the growth of physical capital) advantage. Conversely, if a trading competitor makes a relative technological advance, then the home country may find itself at a persistent disadvantage, widening the growth differential, which is reflected by the stock market value differential between trading partners. Hence, we have established an alternative mechanism for explaining
differential growth rates to that offered in the existing endogenous growth literature. This has important implications for the European Union wishing to secure continued technological advantage, particularly as regards the role of research and development policies.

5. Conclusions

This paper develops an intertemporal optimising model that models the distinction between stock market dynamics in the non-perishables and the perishables sectors. It shows that the technological advances have different effects on stock market values, depending on the relative importance of the non-perishables and perishables sectors. Furthermore, there is short run overshooting of the stock market value of the non-perishables sector. We identify the conditions leading to either monotonic or cyclical adjustment to long run equilibrium. This turns out to be that when the effect of the perishables sector stock market value is small relative to the effect of the non-perishables sector stock market value on the perishables sector stock market value. This occurs when the perishables sector is small relative to the non-perishables sector. Policy makers should be aware, if adjustment is cyclical, that short run counter-intuitive movements of these key indicators may be temporary and entirely consistent with the long run equilibrium.

Furthermore, we show that a temporary relative technological advance may give rise to a permanently higher stock market value. Hence, there are hysteresis effects in this model of exogenous growth. This shows that endogeneity of growth is not necessary to explain the widening disparity between growth levels.

Acknowledgements

The authors would like to thank Eric Levin for his useful comments on an earlier draft of this paper. The usual disclaimer applies.

References


Appendix A. The Euler equations

From (1) and (4), the appropriate current value Hamiltonian, $H$, is

$$H = U[A] + \lambda \left[ Y - A - I + RK + X \left( \frac{Y}{V} + \frac{D}{V} \right) + S \left( \frac{F}{P} + \frac{Q}{P} \right) \right] \quad (A.1)$$

The first-order conditions are:

$$\frac{\partial H}{\partial (A)} = 0 \rightarrow U'(A) = \lambda \quad (A.2)$$

$$\frac{\partial H}{\partial K} = \beta \lambda - \hat{A} \rightarrow \lambda R = \beta \lambda - \hat{A} \rightarrow R = \beta - \frac{\hat{A}}{\lambda} \quad (A.3)$$

$$\frac{\partial H}{\partial X} = \beta \lambda - \hat{A} \rightarrow \lambda \left( \frac{Y}{V} + \frac{D}{V} \right) = \beta \lambda - \hat{A} \rightarrow \frac{Y}{V} + \frac{D}{V} = \beta - \frac{\hat{A}}{\lambda} \quad (A.4)$$
\[
\frac{\partial \kappa}{\partial S} = \beta \lambda - \lambda - \lambda \left( \frac{\rho}{p} + \frac{Q}{p} \right) = \beta \lambda - \lambda - \frac{\rho}{p} + \frac{Q}{p} = \beta - \frac{\lambda}{\lambda}
\]  
(A.5)

Equating (A.3) with (A.4) and (A.5) yields the arbitrage conditions given in (5) and (6) in the main text. In addition, there is the usual transversality condition. A discussion of some of the advantages, and problems, associated with this and related approaches can be found in [Sen, 1994]. Finally, given a production of the form \( Y = Zq(K) \)

\[
\frac{\partial \kappa}{\partial K} = \beta \lambda - \lambda \Rightarrow \lambda Zq'_K(K) = \beta \lambda - \lambda \Rightarrow Zq(K) = \beta - \frac{\lambda}{\lambda} = R
\]  
(A.6)

Eq. (A.6) is simply the condition that the marginal product of capital is equal to the real return on capital.

**Appendix B. Comparative statics**

From the implicit function rule:

\[
V_F|_{\theta=0} = \frac{-\dot{p}_F^{(-)}}{\dot{p}_V} > 0 \quad (\text{slope } \dot{p} = 0)
\]  
(B.1)

\[
V_F|_{\theta=0} = \frac{-\dot{p}_T}{\dot{p}_V} > 0 \quad (T \text{-shift } \dot{p} = 0)
\]  
(B.2)

\[
V_F|_{\theta=0} = \frac{-\dot{V}_F}{\dot{V}_V} > 0 \quad (\text{slope } \dot{V} = 0)
\]  
(B.3)

\[
V_T|_{\theta=0} = \frac{-\dot{V}_T}{\dot{V}_V} < 0 \quad (T \text{-shift } \dot{V} = 0)
\]  
(B.4)

Thus,

\[
\dot{p}_T = \frac{\det y_{FT}}{\det y} = \frac{-\dot{p}_T^{-} \dot{V}_V^{-} + \dot{p}_T^{+} \dot{V}_V^{+}}{\dot{p}_F^{(-)} \dot{V}_V^{(-)} - \dot{p}_V^{+} \dot{V}_F^{+}} < 0 \quad (\text{cyc})
\]  
(B.5a)

\[
\dot{p}_T = \frac{\det y_{FT}}{\det y} = \frac{-\dot{p}_T^{-} \dot{V}_V^{-} + \dot{p}_T^{+} \dot{V}_V^{+}}{\dot{p}_F^{(-)} \dot{V}_V^{(-)} - \dot{p}_V^{+} \dot{V}_F^{+}} > 0 \quad (\text{sad})
\]  
(B.5b)

\[
\dot{p}_T = \frac{\det y_{FT}}{\det y} = \frac{-\dot{p}_T^{-} \dot{V}_V^{-} + \dot{p}_T^{+} \dot{V}_V^{+}}{\dot{p}_F^{(-)} \dot{V}_V^{(-)} - \dot{p}_V^{+} \dot{V}_F^{+}} < 0 \quad (\text{cyc})
\]  
(B.6a)
\[ \tilde{v}_T = \frac{\det y_T}{\det y} = \frac{-\tilde{p}_T^{(-)}\tilde{v}_T^{(-)} + \tilde{p}_T^{+}\tilde{v}_T^{+}}{\tilde{p}_T^{(-)}\tilde{v}_T^{(-)} - \tilde{p}_T^{+}\tilde{v}_T^{+}} > 0 \text{ (aad)} \] (B.6b)

Appendix C. Symbols list

Throughout the text, subscripts denote partial derivatives.

\[ \text{Corresponding author. Tel.: +44-1224-272-182/0; fax: +44-1224-272-181} \]

1 Of course, no civilisation lasts forever, whatever technological innovation has led to their initial dominance. The theory of hysteresis in fact states that only "non-dominated" extrema survive. Thus, our paper does not suggest that one country's advantage will last forever, only until another country makes an even bigger advance.

2 A full symbol list is provided in Appendix C.

3 See [Obstfeld and Rogoff, 1996] for a discrete time formulation.

4 So, the stock market value in this model represents the real (rather than financial) side of the economy.

5 The working is shown in Appendix A, and follows [Obstfeld and Rogoff, 1996 and Barro and Sala i Martin, 1995].

6 Internally generated physical capital augmentation is not assumed to be affected by changes in this stock market valuation.

7 By asset substitutability, we mean that \( D_P \) and \( Q_P \) have opposite signs (in this case, i.e., \( D_P < 0 \) and \( Q_P > 0 \)) and by association this implies that \( D_V \) and \( Q_V \) have opposite signs (in this case, i.e., \( D_V > 0 \) and \( Q_V < 0 \)).

8 By exogenous technical progress, we mean an exogenous improvement in the state of knowledge. This improvement in 'know-how' affects positively production and hence stocks market value in both the sectors instantaneously.

9 Although portfolio shares dynamically adjust to flow disequilibrium, they are, of course, constant in long-run equilibrium, hence \( X = S = 0 \).
Determinant positive is \( P_F^{(-)} V_V^{(-)} - P_V^{+} V_F^{+} > 0 \), implying \((-V_F/V_V) < (-P_F/P_V)\) \((-V_F/V_V) < (-P_F/P_V)\): from (B.1) and (B.3), graphically \( P = 0 \) locus is steeper than \( V = 0 \) locus.

And providing \((\text{tr } y)^2 < 4(\text{det } y)\).

Determinant negative is \( P_F^{(-)} V_V^{(-)} - P_V^{+} V_F^{+} < 0 \), implying \((-V_F/V_V) > (-P_F/P_V)\): from (B.1) and (B.3), graphically \( V = 0 \) locus is steeper than \( P = 0 \) locus.

In developing countries, although the proportion of economic activity accounted for by the perishables sector has increased, it has not yet overtaken the non-perishables sector, as in the developing world.

The authors have conducted simulations using plausible parameter values to confirm the shapes of these loci, i.e., the sign of \( V \) and \( P \) vary over the range of \( V \) and \( P \), respectively.

There are a large number of references on hysteresis and irreversibility, indeed the issues are covered today by most good advanced textbooks. [Varian, 1979] is an early example of the application of this technique of analysis. [Cross, 1993] gives an overview of the more methodological foundations of hysteresis together with a list of more recent applications. See [Roberts and McCausland, 1999] for an interesting application to international trade and debt.

Again, overshooting will take place.

Refer also to footnote 5.

There are two important things to note at this point. First, we are dealing here with the effect of very large technological shocks which give a permanent advantage in the long run (there is remanence). The most obvious such shock could be loosely termed as the ‘industrial revolution’ of the 18th and 19th centuries, which has arguably given the ‘West’ a long run lead that has persisted until today. This should not be confused with the more temporary high growth rates experienced recently by the eastern ‘tiger’ economies (at least until their favourable labour cost advantages are eroded). In these countries, the technology has been introduced by, and is largely still owned by, western interests. The recent erosion of the Asian markets since August 1997 is a good indication of the West’s advantages in controlling and determining the country of growth. Secondly, we should note that the growth in this model is represented by changes in the stock of effective physical capital as reflected by changes in the stock market value.

Hence, \( H = H e^{\beta t} \) and \( \lambda = \mu e^{\beta t} \).