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CONCEPTUALLY BASED MEASURES OF STRUCTURAL ADAPTABILITY

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ABSTRACT

This paper provides definitions and measures of the extent of adaptability of an economy to exogenous changes in product prices, factor availability and technological change. It is argued that flexibility can in general only be defined relative to the exogenous changes that occur. Using a dual approach, measures of flexibility in response to the particular exogenous shock are developed. In addition, a decomposition of the total change in National Income into its component parts including gains due to flexibility or losses due to inflexibility is developed.

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1. Introduction

The objective of this paper is to provide conceptually based and, we hope, empirically implementable measures of structural adaptability.[1] Our work on adaptation can be broken down into two parts. The first part is to define adaptation in terms of a primitive concept and imbed this definition in a suitably general model. The second is to use the model to derive the empirical counterpart of the definition and to construct the relevant measures for a number of countries over time. This paper deals with the first part of the project. The second part is the subject of ongoing research.

By "conceptually based," we mean a number of things. First, the measure should be based upon a primitive concept. For example, the primitive concept associated with adaptability is "flexibility", i.e. the ability to adjust in response to exogenous changes.[2]

The exogenous changes studied here are price, factor endowment, and technology changes.

In order to be "empirically implementable," a measure should be implemented by way of a technique which is relatively general. For example, our definition of structural flexibility can be implemented using the revenue function. This model of production is quite general, although it does make a number of restrictive assumptions about technology and market structure. Finally, the measure should be estimable given existing data and estimation techniques. With structural flexibility, implementation involves estimating the revenue function, a difficult but not hopeless task.

A natural conceptual definition of structural flexibility is the ability of an economy to respond to changes in exogenous parameters. A larger response would be associated with greater "flexibility". Since on the production side of an economy the basic endogenous variable is the allocation of factors of production across sectors, flexibility will be associated with the rate at which physical marginal products diminish as factors are reallocated in response to exogenous parameter changes. The definition of structural flexibility will depend on the parameters that are changing. An economy may be flexible in adjusting to price changes but not in adjusting to endowment or technology changes. Thus, definitions of flexibility can only be relative to given shocks.

It is important to define structural flexibility for at least two reasons. Firstly, different economies are thought of as being more or less flexible on a priori grounds. However, there is no hard evidence to support this in the absence of empirically implementable definitions that are conceptually based. Secondly, flexibility has been closely associated with the economic performance of high growth economies, such as the NICs. A major reason to develop measures of structural adjustment, therefore, is to look at the relationship between performance and flexibility.

At this juncture, we would like to stress that our main objective is simply to develop a rigorous and empirically implementable measures of adaptability; we are not suggesting that our proposed definitions are the only valid ones. Instead, our definition is developed in the spirit that it captures some important aspects of the term in question and is what we call "conceptually based". Our measures of adaptation are both appealing, as they capture the intuitive idea that a more flexible economy adjusts more to exogenous changes, and empirically implementable. In contrast to the large literature that exists on macroeconomic structural adjustment,[3] our approach is micro-based.

In what follows we shall rely on the dual approach to a large extent and make considerable use of the revenue function,[4] $R(p,v)$. With p and v denoting exogenously given vectors of prices and endowments, respectively, the revenue function is defined to be:

$$R(p,v) = \max_{x} p'x \text{ subject to } (x,v) \text{ being in the feasible set.}$$

The reader is reminded that, given constant returns to scale, the revenue function is homogeneous of degree one in both prices and endowments. Its derivative with respect to prices equals the vector of equilibrium outputs, $R_p(p,v) = x(p,v)$, while its derivative with respect to endowments equals the shadow prices (i.e., equilibrium returns) of the factors of production, $R_v(p,v) = w(p,v)$. The revenue function can also be defined as the value function for the program that minimizes factor payments subject to the constraint that price weakly falls short of costs:

$$R(p,v) = \min_{w} w'v \text{ such that } p \leq c(w).$$

As will become apparent, our definition of flexibility is related to the second order derivatives of the revenue function.[5] In sections 2, 3 and 4 below we develop indices of adaptation with respect to changes in prices, endowments and technology, dealing with each change in isolation. In each case, our index measures the percentage gain or loss of national income attributable to the economy's ability (or inability) to respond to exogenous changes. Consequently, it is possible for us to decompose, the growth of national income between any two periods, during which prices, endowments and technology all simultaneously change, into gains and losses attributable to the economy's adaptability, or lack therof. This is the subject of Section 5. Section 6 concludes.

2. Adaptation to Price Changes

Our definition of price flexibility is a very natural one. Essentially, flexibility is defined in terms of the curvature of the production possibilities frontier, or PPF. The PPF for a two-good economy is depicted diagrammatically in Figure 1. At any instant in time, with factor allocations given, the PPF is depicted by the curve FBG. Over the medium and long run, however, factors of production can be reallocated between sectors, which yields the smoother curve DBE. Initially prices are such that production is at point B and national income, in units of good 1, is given by OV. As prices change from P to P', the production point moves from B to A, and national income falls to OT. If production had not adjusted, however, income would have fallen to OS. Thus, by adjusting its production structure the economy enjoys a gain of ST. It is the benefit of this adaptation that our measure of adaptation is designed to capture.

Consequently, our index of structural adjustment is given by:

$$
\begin{aligned}
I(p^1) &= \frac{R(p^1,v) - R(p^0,v) - (p^1 - p^0)' R_p(p^0,v)}{R(p^1,v)} \\
&= \frac{R(p^1,v) - p^{1\prime} R_p(p^0,v)}{R(p^1,v)} \qquad (1)\\
&= \frac{p^{1\prime}[x(p^1,v) - x(p^0,v)]}{R(p^1,v)} \\
&\geq 0.
\end{aligned}
$$

The index is defined, in the first line of the equation, to be the actual change in nominal national income less the change in income that would have occurred if the economy had kept on producing base period outputs (that is, if it had been totally inflexible), divided by first period income. The second and third lines show that this is equal to the growth rate of the value of output at *current or period 1 prices*.[6] This is why we use the notation $I(p^1)$. With endowments given, the index captures the gain from adjusting production in response to exogenous price changes. Dividing by period one income ensures that this index is homogeneous of degree zero in both p^0 and p^1.[7] The last line simply points out that the properties of the revenue function ensure that the index is non-negative.

Alternatively, we could define an analogous index taking period 1 as the initial period and period 0 as the new period. This would give us:

$$
\begin{aligned}
I(p^0) &= \frac{R(p^0,v) - R(p^1,v) - (p^0-p^1)' R_p(p^1,v)}{R(p^0,v)} \\[2ex]
&= \frac{R(p^0,v) - p^{0\prime} R_p(p^1,v)}{R(p^0,v)} \qquad (2) \\[2ex]
&= \frac{p^{0\prime}[x(p^0,v) - x(p^1,v)]}{R(p^0,v)} \\[2ex]
&\geq 0.
\end{aligned}
$$

which is the change in income between period 1 and period 0 less the change that would have occurred had the economy been totally inflexible and not adjusted its production, divided by period 0 income. In other words, it is the change in the value of output evaluated at period 0 prices, relative to period 0 income.[8] Dividing by period 0 income ensures that the measure is homogeneous of degree zero in both p^0 and p^1.

It is easily seen from the first equality in the above equations that the numerator of our price flexibility indices can be interpreted as the error from a first order approximation of the revenue function. By the mean value theorem then, the numerator of this index is also equal to the second order terms evaluated at some point between the two prices:

$$I(p^1) = \frac{(p^1-p^0)'R_{pp}(p^*,v)(p^1-p^0)}{2R(p^1,v)}$$

$$I(p^0) = \frac{(p^0-p^1)'R_{pp}(p^{**},v)(p^0-p^1)}{2R(p^0,v)} \tag{3}$$

$$p^*,p^{**}\epsilon(p^0,p^1)$$

Thus our measure of adaptation is fully defined by the price changes and the matrix of second order derivatives with respect to price of the revenue function at some point between the two prices.[9] Note that our analysis focuses on discrete changes since one cannot think of adaptation with infinitesimal changes. As we know from the envelope theorem, the gain from adapting optimal behavior to changes in exogenous parameters is, at the optimum, nil. For infinitesimally small changes in prices, the index is automatically zero.

3. Adaptation to Changes in Endowments

We can define flexibility with respect to endowment changes in a manner analogous to our index of price flexibility. Here it is convenient to use the dual of the Lerner-Pearce diagram, illustrated in figure 2. For illustrative purposes, consider an economy with two factors and one good. The curve, p = c(w), depicts the price equals cost condition. If factors of production are perfectly substitutable then the price equals cost curve is given by the L shaped curve ABC.[10] Imperfect substitutability is reflected in the flattening of the curve, as in the case of DBE in figure 2.[11]. Consider a change in the endowment of labor, with capital fixed. This makes the factor payments line steeper. If the economy is perfectly flexible, wages do not change, and income (per unit of capital) rises from OF to OG. With imperfect substitutability, the return to labor falls, while the return to capital rises, with the net effect being that income only rises to OH. The distance GH measures the loss due to imperfect factor substitutability. It is this loss which is the basis for our measure of flexibility.

Consider the function:

$$
\begin{aligned}
I(v^1) &= \frac{-[R(p,v^1) - R(p,v^0) - (v^1 - v^0)' R_v(p,v^0)]}{R(p,v^1)} \\
&= \frac{-[R(p,v^1) - v^{1\prime} R_v(p,v^0)]}{R(p,v^1)} \qquad (4) \\
&= \frac{v^{1\prime}[w(p,v^0) - w(p,v^1)]}{R(p,v^1)} \\
&\geq 0.
\end{aligned}
$$

The first line of the equation above shows that the function, $I(v^1)$ can be interpreted as the difference in the response of an economy which is perfectly flexible (that is, which can absorb factors at given wages so that the change in national income is the change in endowments times original wages), and that of an economy which can only fully absorb factors of production if wages change.[12] Rearranging terms to get the last line shows that $I(v^1)$ equals the change in the value of period 1 endowments as v changes from v^0 to v^1. Note that $I(v^1)$ falls as the economy becomes *more* flexible, thus it is not an index of the gain from adaptation, but rather of the loss due to imperfect flexibility. By the definition of the revenue function, this index is always non-negative.

An analogous measure based upon period 0 endowments, $I(v^0)$, is easily constructed.[13]

As in the case of price flexibility, our measure of endowment flexibility is related to the properties of the second order derivatives of the revenue function. Examining the first line of the equation earlier above, it is easily seen that it is the error from a first order expansion of the revenue function, i.e. it equals the negative of the second order terms evaluated at some endowment, v^*, between v^1 and v^0 and hence corresponds to a positive definite quadratic form:

$$I(v^1) = -[\frac{1}{2}\frac{(v^1 - v^0)' R_{vv}(p, v^*)(v^1 - v^0)}{R(p, v^1)}] \tag{5}$$

$$\geq 0.$$

The index thus measures the curvature of the revenue function with respect to v. Note that $I(\cdot)$ is zero for a perfectly flexible economy by this definition and that as $I(\cdot)$ rises, the economy becomes less flexible. We should note that an economy which is not flexible with respect to price shocks could be very flexible in response to endowment changes.[14]

4. Adaptation to Changes in Technology

The third parameter change we can deal with is a change in technology with prices and endowments constant. Consider first the simplest such change, which is a Hicks-neutral change in technology which varies across industries. Now notice that this can be represented by $x^i = a^{it}F^i(v^i)$ in the ith sector, where x^i represents output, a^{it} total factor productivity and v^i the factor input vector used in the ith sector. The revenue function is then:

$$\max_{x^1,\ldots,x^n} \quad \Sigma_i\, p^i x^i \qquad \text{subject to} \quad x^i = a^{it}F^i(v^i)$$

$$\text{for} \quad i=1,\ldots,n, \quad \Sigma_i\, v^i = v.$$

Alternatively, we can write this problem as:

$$\max_{F^1,\ldots,F^n} \quad \Sigma_i\, p^i a^{it} F^i \quad \text{subject to } F^i = F^i(v^i),$$

$$\text{for} \quad i=1,\ldots,n, \quad \Sigma_i\, v^i = v.$$

Notice that in this case, technological change can be thought of as a change in effective prices. Thus, $R(p,v,A_d^{\,t}) \equiv R(A_d^{\,t}p,v,I)$ where $A_d^{\,t}$ is the diagonalization of the Hicks-neutral technology vector which has a^{it} as its ith element, and I is the identity matrix.

Consequently, the gains from adapting to Hicks-neutral technical change can be measured in a manner analogous to that used in our measure of price flexibility:

$$I(A_d^1) = \frac{R(A_d^1p,v) - R(A_d^0p,v) - (p'A_d^1 - p'A_d^0)R_{A_d p}(A_d^0p,v)}{R(A_d^1p,v)}$$

$$= \frac{R(A_d^1p,v) - p'A_d^1R_{A_d p}(A_d^0p,v)}{R(A_d^1p,v)} \tag{6}$$

$$= \frac{p'A_d^1[x(A_d^1p,v) - x(A_d^0p,v)]}{R(A_d^1p,v)}$$

$$\geq 0.$$

where we use $x(A_dp,v)$ to denote the derivative of the revenue function with respect to the effective price, that is it equals the vector of optimal F^i's. Thus, the index is defined as the growth in national income less the growth that would have accrued to the economy if it had not changed its factor allocations. The difference is the percentage increase in national income attributable to adjusting factor allocations in response to the change in effective prices. It is easily confirmed that this measure is homogeneous of degree zero in A_d^1 and A_d^0.

Figure 3 provides a diagrammatic exposition of our index of flexibility in response to Hicks-neutral changes in technology. Initially, the economy is at point E, which represents $A_d^0x(A_d^0p,v)$. Now suppose technology changes from A_d^0 to A_d^1, and suppose the technological change is faster in good 1 than in good 2. If factor allocations remain constant in the two sectors at base period levels, output would be $A_d^1x(A_d^0p,v)$ in the second period, which is depicted by point D in Figure 3.[15] The movement from E to D corresponds to $(p'A_d^1 - p'A_d^0)x(A_d^0p,v)$. This gives AB as the increase in income due to technological change in the absence of flexibility. As factor allocations change, the economy moves from D to F, so BC represents the gain from adaptation. Our index, using period 1 technologies as the base, equals BC/OC.[16]

Factor-augmenting technical change is equally easily handled, in this case, in a manner analogous to that used to analyze endowment flexibility. We consider the case of factor augmenting technical change which is uniform across all industries. Thus, the effective endowment of each factor i, regardless of the industry in which it is used, be given by $a^{it}v^i$. With A_F^t denoting the vector of factor augmentation coefficients, and A_d^t now denoting the diagonalization of A_F^t, the supply of effective factors is now given by A_d^tv. Thus, for given prices, the wages per factor can be higher and keep price equal to cost. Hence, the revenue function can be written as:

$$R(p,v,A_d') = \min_{w} w'v \text{ such that } p \leq c((A_d')^{-1}w).$$

where w is the vector of factor returns. Alternatively, this revenue function can also be formulated as:

$$R(p,A_d'v,I) = \min_{w} w'A_d'v \text{ such that } p \leq c(w).$$

where w must now be interpreted as the return per effective factor. Consequently, the appropriate index of flexibility in response to changes to effective factor endowments would seem to be:

$$\begin{aligned} I(A_d^1) &= \frac{-[R(p,A_d^1v,I) - R(p,A_d^0v,I) - (v'A_d^1 - v'A_d^0)R_{A_d v}(p,A_d^0v,I)]}{R(p,A_d^1v,I)} \\ &= \frac{-[R(p,A_d^1v,I) - v'A_d^1R_{A_d v}(p,A_d^0v,I)]}{R(p,A_d^1v,I)} \\ &= \frac{v'A_d^1[w(p,A_d^0v) - w(p,A_d^1v)]}{R(p,A_d^1v,I)} \\ &\geq 0. \end{aligned} \tag{7}$$

where $w(p,A_d'v)$ denotes the derivative of the revenue function with respect to effective factor endowments, i.e. the equilibrium return per effective factor. The first line of the equation above is the difference between the change in national income in an economy which is perfectly flexible (that is, can absorb the change in effective factor endowments at given wages), and that of the sample economy. This difference is the loss due to imperfect factor substitutability. This index is always non-negative and is homogeneous of degree zero in both A_d^1 and A_d^0. An analogous measure based upon effective endowments in period 0 is easily constructed.[17] Thus, the effects of any combination of Hicks-neutral or uniformly-factor augmenting technical change can easily be interpreted using our indices of price or endowment flexibility. The interpretation of more general forms of technical change will be explored in subsequent work.

5. Decomposing the Growth of National Income

Clearly, the above measures allow for an easy interpretation of the sources of growth in an economy in which each exogenous variable (price, endowment or technology) changes one at a time. Our measures also allow for a straightforward interpretation of changes in national income in an economy in which all three parameters vary simultaneously during the period of analysis. We illustrate the technique with the analysis of an economy in which both prices and endowments change during the comparison period, with technology held constant.

The total change in income between the two periods can be decomposed into:

$$
\begin{aligned}
R(p^1,v^1) - R(p^0,v^0) &= [R(p^0,v^1) - R(p^0,v^0)] + [R(p^1,v^1) - R(p^0,v^1)] \\
&= [\ [v^1-v^0]'w(p^0,v^1) + v^{0\prime}[w(p^0,v^1)-w(p^0,v^0)]\ ] \\
&\quad + [\ [p^1-p^0]'x(p^0,v^1) + p^{1\prime}[x(p^1,v^1)-x(p^0,v^1)]\ ]
\end{aligned} \tag{8}
$$

Alternatively:

$$R(p^1,v^1) - R(p^0,v^0) = [R(p^1,v^0) - R(p^0,v^0)] + [R(p^1,v^1) - R(p^1,v^0)]$$

$$= [\ [p^1-p^0]' x(p^0,v^0) + p^{1\prime}[x(p^1,v^0)-x(p^0,v^0)]\ ]$$

$$+ [\ [v^1-v^0]' w(p^1,v^1) + v^{0\prime}[w(p^1,v^1)-w(p^1,v^0)]\ ] \tag{9}$$

Looking at the algebra above, one can decompose the change in national income by first changing endowments, and then prices (VP) or by first changing prices and then endowments (PV). Figure 4 illustrates these two alternative paths. We assume that endowments increase between the two periods, so that the period 1 PPF lies economy produces at point B, while at period 1 prices and endowments, it produces at point A. If faced with period 1 prices, but period 0 endowments it would have produced at point D, while if it had been faced with period 1 endowments and period 0 prices it would have been at point C. Thus, the VP path corresponds to moving from B to C as endowments change, and then from C to A as prices change. Similarly, the PV path involves moving from B to D as prices change, and then from D to A as endowments change. Each price change can in turn be decomposed into a pure price effect and the gain due to flexibility, while each endowment change can be decomposed into a pure endowment effect and the loss due to imperfect flexibility, as illustrated in the above equations. Using the techniques presented earlier, one can easily extend the technique to allow for Hicks-neutral and factor-augmenting technical change as well.

A problem with the approach presented above is that although the total change in national income is independent of the path, the quantities attributable to the various effects do depend upon the path chosen for the decomposition. The usual index number problems apply as the indices are affected by the choice of the evaluation point. This is a problem common to all empirical work and cannot be avoided in this analysis either.

6. Conclusions

On the theoretical side, at least three issues need to be worked on. First, the measure of adaptation in response to changes in technology needs to be extended to allow for other kinds of changes in technology. If technological changes can be thought of as a combination of factor augmenting and Hicks neutral changes in technology, we can deal with it in our existing framework. We are as yet unsure of how to deal with other kinds of technical change. In particular, we cannot deal with factor augmenting technical change where the rate of technical change varies across industries. However, we are not terribly concerned about this, as this is not likely to be a constraint in practice since most cross-national estimates of technical change focus on the Hicks neutral case.

A second, more substantial, issue is dealing with the dependence of our measures of adaptation on the choice of the evaluation point. This is, of course, the standard index number problem. Most problematic is the dependence of our decomposition of the change in income on the choice of the path. In both cases, we hope to be able to better deal with the issues on the basis of further theoretical work.

A third issue is extending the analysis to study the flexibility of particular sectors rather than the whole economy, and to extend our analysis to cases where endowments are not exogenous, for example, when capital is mobile internationally or where there are migrant workers. The two are clearly related. If we wish to study the flexibility of a sector, it is inappropriate to take endowments of factors as given; rather, we should let endowments be endogenous and take factor prices as given. However, this simply involves treating factor prices as product prices and inputs as negative outputs in the revenue function. We can use the same approach if factors are mobile internationally and the economy can be thought of as a small open economy.

This final point suggests that our work may shed light on the capital mobility debate spawned by the work of Feldstein and Horioka (1980). This work argues that a close positive correlation between savings and investment for an open economy is indicative of an absence of international capital mobility. This is important as it implies that policies that increasing savings will also raise investment domestically. However, as pointed out by Obstfeld (1986), this depends on the particular pattern of shocks. It is quite possible to construct a pattern of shocks such that, despite capital being perfectly mobile, a close positive relation exists between savings and investment nationally both in time series and cross sectional data.[18] The policy implications of observed correlations between savings and investment could therefore be very different from those of Feldstein and Horioka (1980). Mobility of capital is related to flexibility in response to changes in the "price" vector of different sources of capital in the above framework. An application of interest is to directly look for estimates of flexibility in response to changes in the price of capital in order to shed light on this debate. The approach outlined above also appears promising in getting estimates of the extent of mobility of other factors.

In terms of the empirical work we hope to do, computing our indices requires estimating revenue functions. Moreover, these revenue functions should be capable of allowing different degrees of substitutability in inputs and transformation between outputs. The appropriate starting point here is work on particular functional forms for the revenue function that already exist in the literature. These functional forms have been used extensively in the past in developing CGE (computable general equilibrium) models such as the ORANI model of the Australian economy.[19] In addition, much work has been done on estimating revenue functions. In international trade, this literature has focused on estimating import and export demand functions as in Kohli (1978) and Lawrence (1989).

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Notes

1. This paper is related to a larger project by Krishna dealing with conceptually based definitions of a number of terms such as "openness", b: the "terms of trade", and "trade diversification".

2. Young (1983, 1989) defined "structural flexibility" as the ability to change the relative shares of factors of production accounted for by the different sectors of an economy. Arguing that this ability explains the remarkable economic performance of the East Asian NICs, Young measured rates of factor reallocation in a large sample of economies, showing that the NICs had indeed experienced some of the most rapid rates of structural change in the world. This paper defines flexibility more broadly as the ability to respond to exogenous changes. Further, while Young argued that cross-national differences in flexibility were due to incomplete markets, labor market barriers, and political intervention in the market place, the approach of this paper emphasizes cross-national differences in technologies, within a framework of perfect competition.

3. For some recent work on macroeconomic adjustment see Taylor (1991).

4. A good reference source for those unfamiliar with the general approach is Dixit and Norman (1980). Our convention will be to define vectors as column vectors, and denote their transposes by "'"s as row vectors. There are m factors and n goods so that v is m x 1 and p is n x 1.

5. The standard way to decompose the effects of price, technology, and endowment changes on national income would be to do the following. Let r(P, v, A) denote the revenue function capturing the production side of the economy, where P denotes price, v denotes the endowment vector and A denotes the technology level. Then assuming that P, v, and A change over

time but the function r(•) does not, differentiating the revenue function and using the fact that the derivative with respect to P is output and with respect to v is wages, gives:

$$\frac{dr}{dt}\frac{1}{r} = \sum_{i=1}^{n} \theta^{i}\frac{dP^{i}}{dt}\frac{1}{P^{i}} + \sum_{j=1}^{m} \lambda^{j}\frac{dv^{j}}{dt}\frac{1}{v^{j}} + \sum_{i=1}^{n} \alpha^{i}\frac{dA^{i}}{dt}\frac{1}{A^{i}}$$

The percentage change in income is decomposed into the appropriately weighted sum of percentage price changes, percentage factor endowment changes and percentage technology changes. The weights on prices and endowments are the production value shares and the factor value shares in income respectively. The weight on technology is the same as the weight on prices if technological change is Hicks neutral. The weight on technology is the same as the weight on the factors if technological change is factor augumenting. Note that flexibility does not even enter here.

6. In terms of figure 1, the index is (OT-OS)/OT = ST/OT.

7. Since, in this section, we are examining price changes in isolation, we ignore the issue of homogeneity in endowments. As will be seen further below, when accounting for all types of changes our flexibility measures are homogeneous of degree zero in prices, factors and factor productivity.

8. In terms of figure 1, this is UV/OV.

9. Note that we are assuming the revenue function is differentiable and hence, there are at least as many factors as goods. This is easy to motivate in terms of the specific factors model.

10. For example, if the production function is given by x = AK + BL, then one unit of the good can be made with either 1/A units of capital, or 1/B units or labor. Thus, the unit cost is given by min [w_L/B,w_K/A] so that the price equals cost line is L shaped.

11. In the extreme, if there are fixed coefficients in production, the

production function is given by $x = \min[K/a_K, L/a_L]$, so that the cost of making a unit of the good equals $w_L a_L + w_K a_K$, which is a straight line.

12. Note that if there are as many produced goods as factors, w is independent of v as the minimization would occur at the intersection of the price equals cost conditions for the two sectors, that is, at a kink. In this case, output changes are sufficient to ensure full flexibility. This independence of w from v is the key factor in multi-good and multi-factor generalizations of the Rybczynski theorem.

13.

$$I(v^0) = \frac{-[R(p,v^0) - R(p,v^1) - (v^0-v^1)'R_v(p,v^1)]}{R(p,v^0)}$$

$$= \frac{-[R(p,v^0) - v^{0\prime}R_v(p,v^1)]}{R(p,v^0)}$$

$$= \frac{v^{0\prime}[w(p,v^1) - w(p,v^0)]}{R(p,v^0)}$$

$$\geq 0,$$

14. An obvious example is the standard HOS model in trade with the same number of goods as factors and no specialization. It is well known that in this model, factor prices remain fixed as endowments change so that there is complete flexibility in response to factor changes. However, the response to price changes can be large or small depending on technology.

15. One finds point D by multiplying the outputs at E by the percentage increase in total factor productivity in each industry. The reason that the scaling up of outputs by the technological change parameters lies on the PPF is due to the specification of technological change chosen. The initial allocation of factors remains efficient as it remains on the contract curve; only the labels on the isoquants change in this case.

16. The measure, evaluated at period 0 endowments, is:

$$I(A_d^0) = \frac{R(A_d^0 p,v) - R(A_d^1 p,v) - (p'A_d^0 - p'A_d^1)R_{A_d p}(A_d^1 p,v)}{R(A_d^0 p,v)}$$

$$= \frac{R(A_d^0 p,v) - p'A_d^0 R_{A_d p}(A_d^1 p,v)}{R(A_d^0 p,v)}$$

$$= \frac{p'A_d^0 [x(A_d^0 p,v) - x(A_d^1 p,v)]}{R(A_d^0 p,v)}$$

$$\geq 0.$$

17.

$$I(A_d^0) = \frac{-[R(p,A_d^0 v,I) - R(p,A_d^1 v,I) - (v'A_d^0 - v'A_d^1)R_{A_d v}(p,A_d^1 v,I)]}{R(p,A_d^0 v,I)}$$

$$= \frac{-[R(p,A_d^0 v,I) - v'A_d^0 R_{A_d v}(p,A_d^1 v,I)]}{R(p,A_d^0 v,I)}$$

$$= \frac{v'A_d^0[w(p,A_d^1 v) - w(p,A_d^0 v)]}{R(p,A_d^0 v,I)}$$

$$\geq 0,$$

18. In more recent work Feldstein and Bacchetta (1991) update the work of Feldstein and Horioka (1980) and examine ways of incorporating alternative explanations of their findings. Frenkel (1991) also deals with such issues.

19. See Dixon et al. (1982).

Figure 1

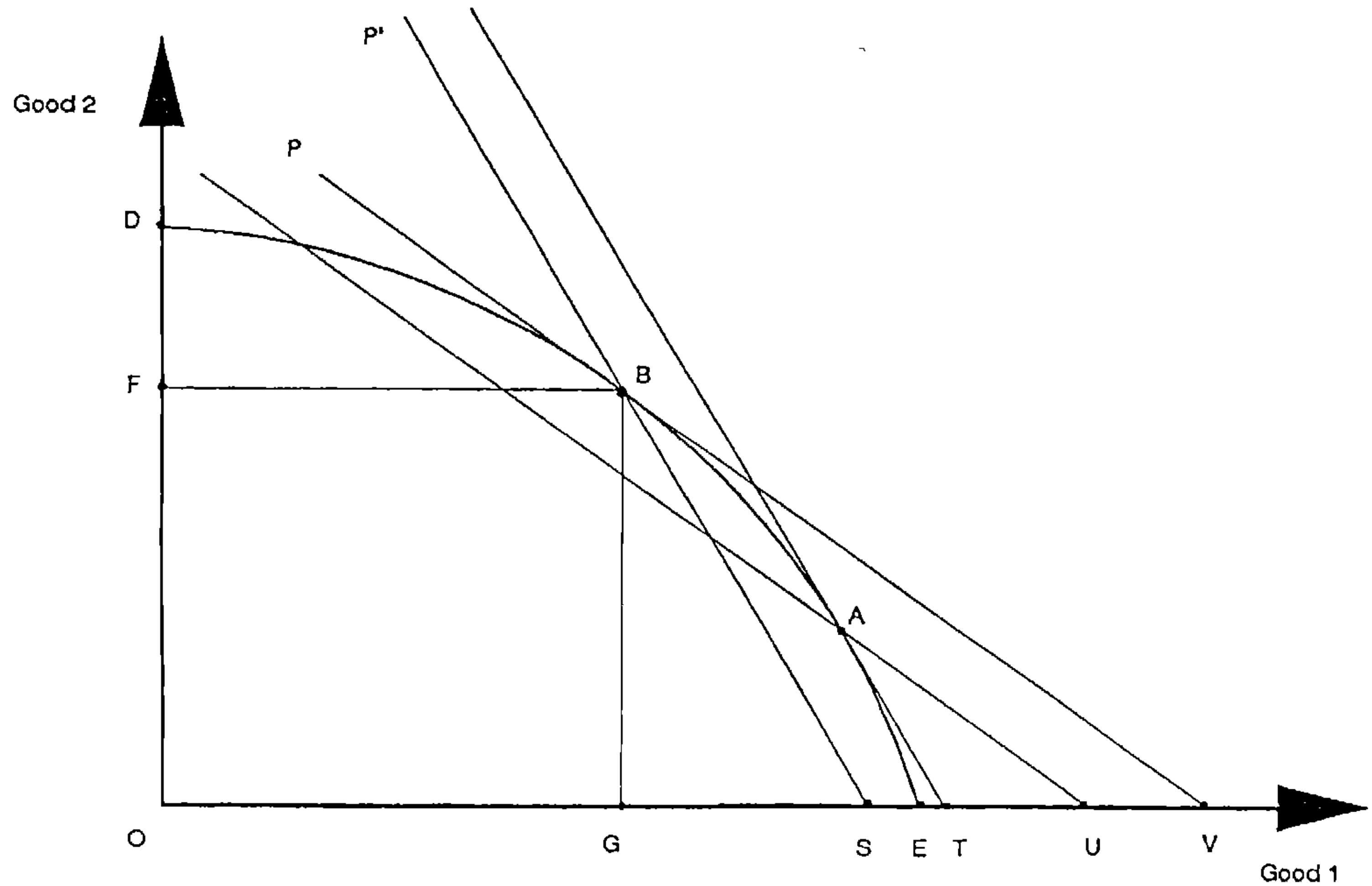


Figure 2

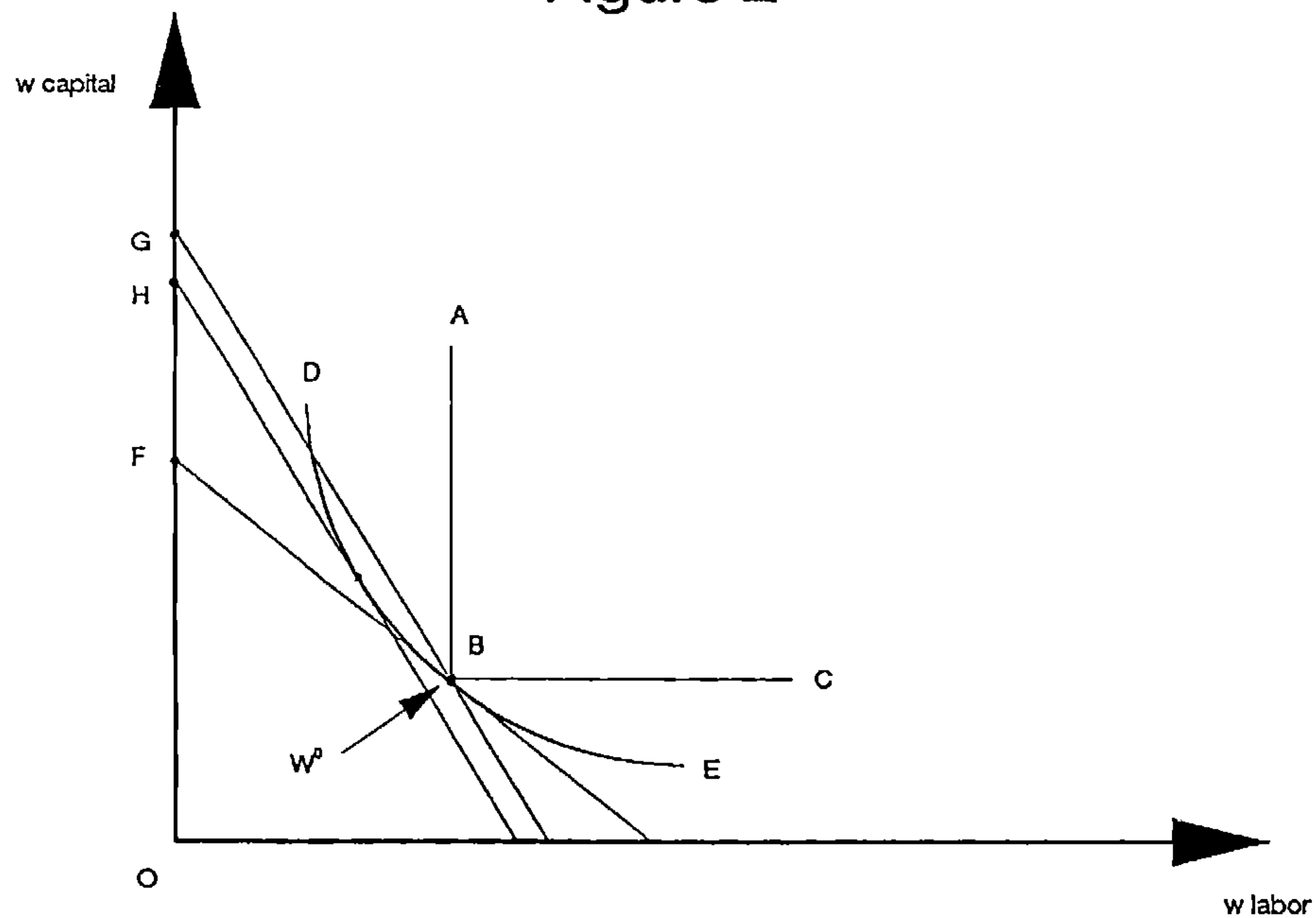


Figure 3

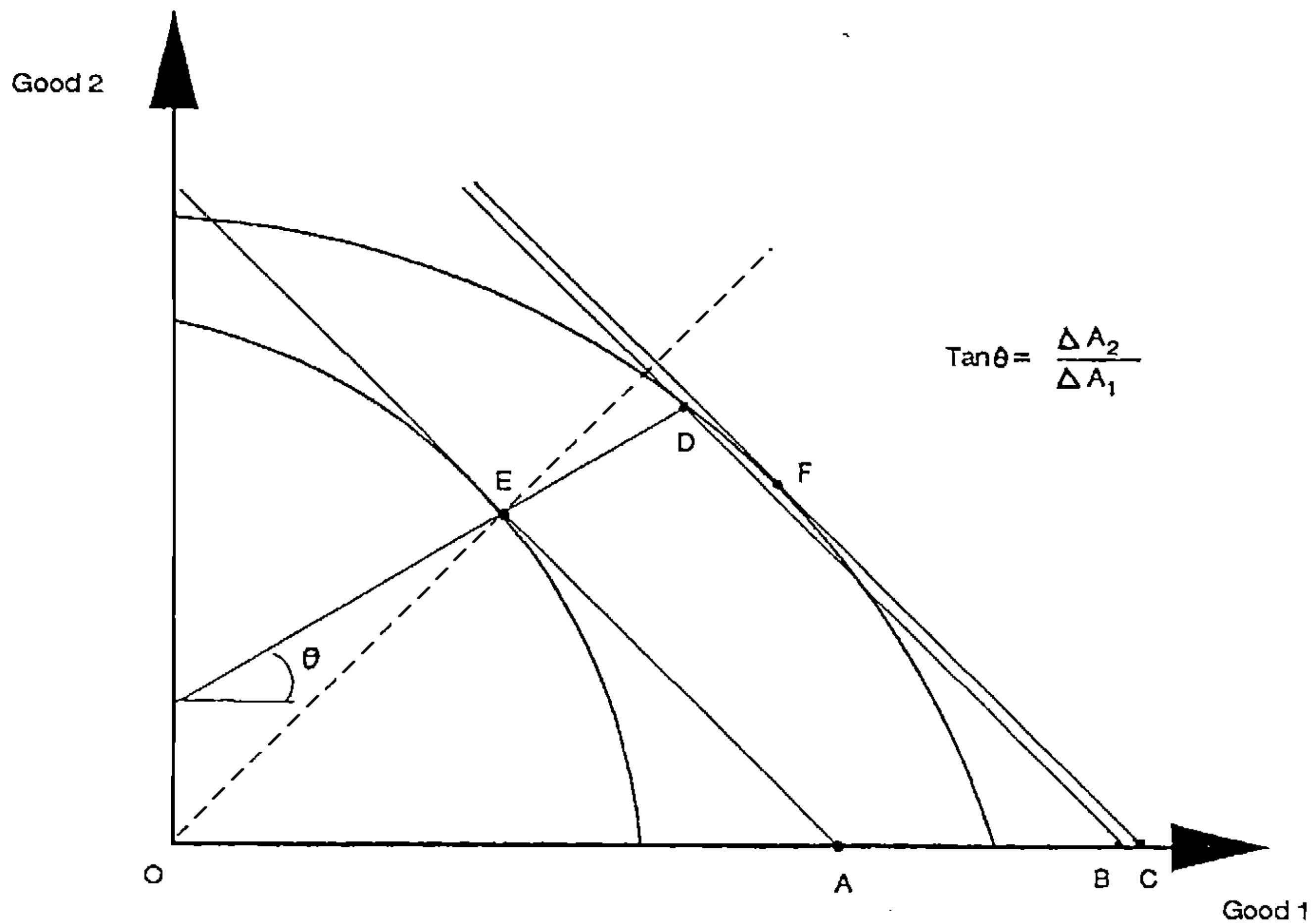
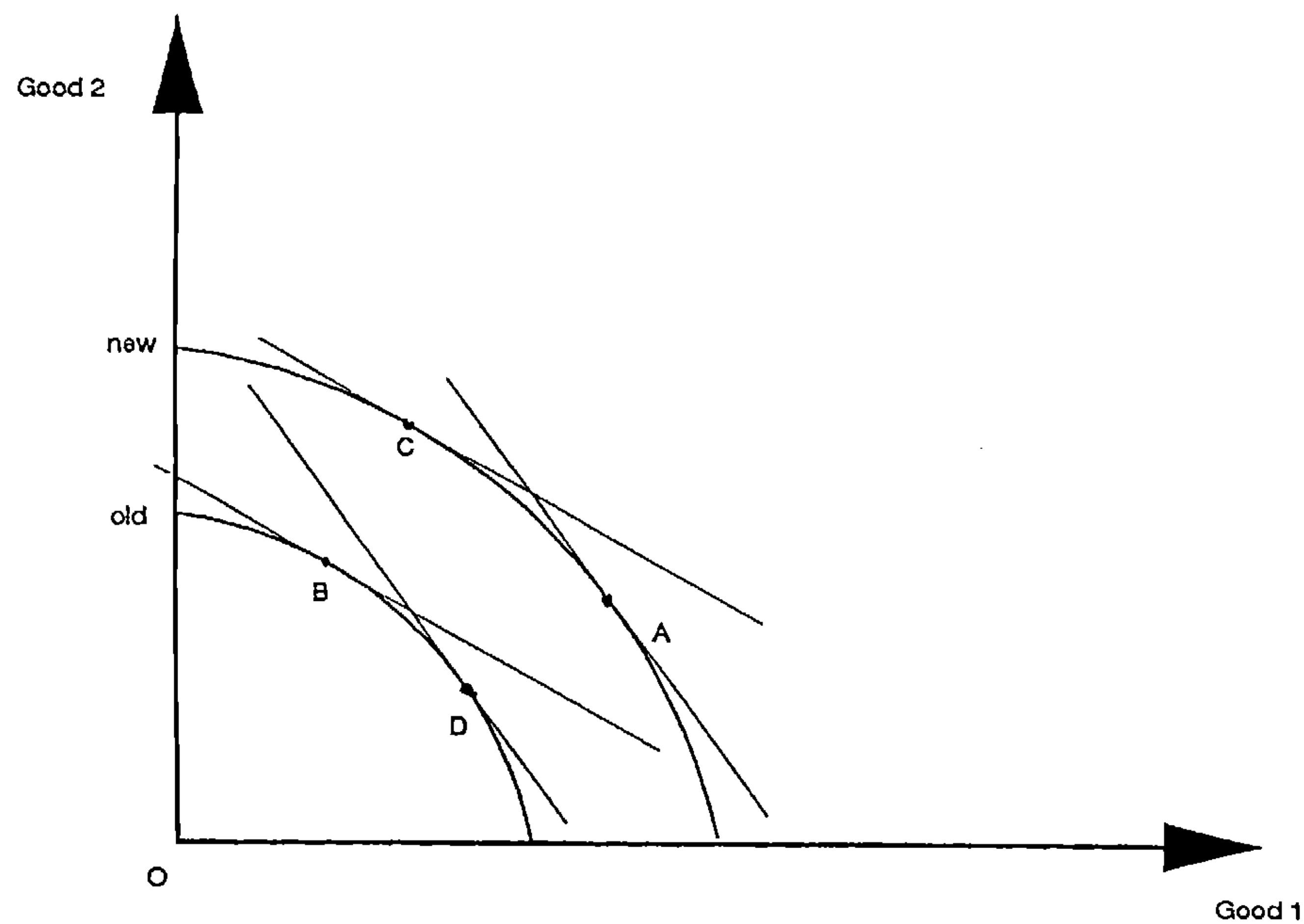


Figure 4



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