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Abstract

A country's production possibility frontier or PPF is defined as the *boundary* of its economy's production set in the net output space for a given technology and fixed quantities of primary factors of production. In general equilibrium theory, exogenous changes in technology or primary-factor supplies alter equilibrium prices; however, government-policy induced domestic relative commodity price changes do *not* alter the shape of an economy's production set. We show that, under international capital mobility, which is empirically significant, the shape of a country's production set does, in fact, depend on market forces and this shape can be manipulated by government policy. (100 words)

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1. Introduction

A country's production possibility frontier, or PPF, is a foundational concept in economics. It is the *boundary* of its economy's production set in the net output space, consisting of feasible net output vectors, and is parametrically dependent on an exogenously given state of technology of transforming inputs into outputs, and on fixed factor supplies of primary factors of production.[1] The production set is invariant to changes in government policy that alter domestic relative commodity prices. However, theoretically there exist circumstances in which a country's production set is not only market dependent, but its shape can be manipulated by government policy. There is also mounting evidence that an underlying cause of such market dependence of the production set has, in fact, become empirically very significant. Therefore, the operational significance of a government-policy changeable production set must not be underestimated.

Some terminology pertaining to this distinction proves helpful. If changes in domestic relative equilibrium prices have no influence on the country's production set, we call its boundary a *Market-invariant PPF*. The classic treatment of such a case is Koopmans (1957), and the properties of a market-invariant PPF are well known. Specifically, it entails a *unidirectional* causal relationship between a PPF and markets: exogenous PPF changes affect a Walrasian competitive general equilibrium, but a change in government policy that causes relative market price changes does not affect the shape of the economy's production set.

However, if capital is internationally mobile, for which there is a growing body of empirical evidence, relative commodity price changes in a country can alter the value of marginal product of capital domestically, which would induce capital flows into or out of a country. This, in turn, would alter the shape of the country's production set. The production set of an economy

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[1] Among other restrictions imposed on this set are that it is (a) non-empty, (b) compact (closed and bounded) and (c) convex.

would then actually be influenced by relative commodity price changes. If so, we shall call it a *Market-dependent Production Set*. On theoretical grounds the concept of such a production set also needs to be investigated. The causal relationship in this case would be *bidirectional* insofar as relative market price changes *also* alter a country's feasible production possibilities, unlike the case of a market-invariant PPF.

While trade theorists have recently investigated the implications of the phenomenon of international capital mobility for trade policy *per se*, its implications for a market-dependent production set have not been spelled out sufficiently in the mainstream economics literature. A glance at any recent economics text such as Baumol and Blinder (2009) or Varian (2010) makes this abundantly clear. The purpose of this paper is to fill this gap.

At a substantive level, the reason this issue is important to understand is that the properties of an economy with a market-dependent production set are radically different from those of an economy with a market-invariant PPF. First, this is due to the fact that, in addition to the commodity flows into or out of a country, international capital flows back and forth constitute an *additional channel of quantity adjustments* for the attainment of a new equilibrium consequent upon a policy-induced commodity-price shock. Second, the consequent production set changes can magnify the consequences of relative commodity price changes, leading to *greater volatility in GDP and unemployment of labor*. Third, the production set changes induce *additional income and growth (or contraction) effects*, which are positive for countries that are net recipients of foreign direct investment, or FDI, and negative for countries that experience a net outflow of FDI. Clearly, an analysis that ignores such income effects is incomplete. The time has come, we argue, for economic theory and its teaching to embrace the concept of a market-dependent production set.

2

Perhaps the reason a market-dependent production set has not pervaded the mainstream theory is that a synthesis of the theoretical and empirical strands of the literature has not been undertaken to date. In this paper we combine the two strands of the literature, and that precipitates a market-dependent production set as an operationally significant foundational concept in economics.

At the methodological level, first, since our purpose is to demonstrate the theoretical existence a market-dependent production set, it is harmless for us to take a particular parameterization. The second part of our argument deals with the claim of empirical relevance of international capital mobility, which is justified on the basis of a number of studies pertaining to this matter.

Section 2 collects together and synthesizes the main theoretical and empirical arguments that lead to the conclusion of the existence of a market-dependent production set. Section 3 presents the Specific Factors model with international capital mobility, and contrasts market-invariant and market-dependent production sets. Section 4 contains some concluding remarks.

2. Synthesis of Theoretical Results and Empirical Evidence

In this section we bring together and synthesize the main theoretical and empirical arguments that lead to the conclusion of the existence of a market-dependent production set.

Arrow and Debreu (1954, p. 281) deal in Theorem 2 with the existence of a Walrasian competitive general equilibrium with one primary factor of production in an economy with exactly such a production set that is characterized by a market-invariant PPF.

However, a very significant feature of international capital mobility is that, if a country becomes part of an integrated world capital market, the quantity of capital that locates in that country, whether domestic or foreign capital, becomes free to be endogenously determined by

market forces, including being affected by the rental rate of capital that it takes as parametrically determined on the world capital market. Any economic policy that jostles the domestic rental rate of capital up above the world rate will induce an inflow, but if it pushes it below the world rate, an outflow of productive capital occurs. Therefore, the choice of economic policy by a government changes the shape of the economy's production set by altering the quantity of capital that locates in the country.

Since the pioneering work of Mundell (1957) on international capital mobility, this literature got the next shot in the arm from Neary (1985), from whose contribution a large theoretical literature on international capital mobility has emerged. Neary considers an economy with a finite number of commodities and primary factors of production. His is a general equilibrium model of a small open economy that admits of both intermediate goods and joint production. In such a framework, Neary shows that as factor-price rigidities are introduced, possibly due to international capital mobility, the responsiveness of general equilibrium output supplies to changes in commodity prices becomes more pronounced in terms of magnitude, and so is the case with the responsiveness of inverse factor-demand functions and thus of the magnitude of change in factor prices due to changes in supplies of those factors that are exogenously fixed.

Implications of these properties are, among others, that international capital mobility raises the cost of tariff protection, as shown by Neary and Ruane (1988). Neary (1988) extends this work to the case of quotas and voluntary export restraints (VERs). The large country case with international capital mobility is contained in Neary (1995). Chandra and Naqvi (1997) extend Neary's results for tariffs, quotas and VERs in a small open economy to an economy that exhibits external increasing returns to scale in some sectors. Franck (1999) considers tariff reform with pre-existing quotas and quota reform with pre-existing tariffs under international capital

4

mobility, and Bezmen (2006) extends Neary's (1995) work on the large country to external increasing returns to scale. Lal (1995) introduces international capital mobility in the Harris-Todaro model of the specific-factors type. Blanchard (2009) demonstrates that the well-known Lerner's symmetry result between import and export taxes is overturned by international capital mobility, but restored if a tax on remittances is also introduced.

While very valuable insights have emerged from this theoretical literature, including from contributions by many others, surprisingly none of these authors have made a case for embracing a market-dependent production set. This could be possibly because these results are interesting in themselves, whereas a distinct strand of the literature asses the empirical relevance of international capital mobility.

Another feature of international capital mobility, empirical in nature, is the magnitude of its flow per year. The greater the amount of capital that relocates, the larger is magnitude of the shift in the boundary of an economy's production set in any given period of time. Further, it is an empirical fact that the total magnitude of international capital mobility in the world is considerable, both in developed and in developing countries.

Azariadis and Pissarides (2007) conduct a very careful empirical analysis that bears out the theoretical conclusions of Neary (1985), and, in fact, extend this work to demonstrate that "as more international capital mobility takes place, unemployment responds faster and with more amplitude to shocks [to total factor productivity], so over long periods of time both unemployment and workers' incomes are more volatile than in an economy without international capital mobility (2007, 29)." They also argue (2007, p. 27) that "[o]ne of the most striking recent changes in the world economy is the speed with which the capital markets of industrial countries have become integrated."

Younas (2009) considers 24 OECD countries and 75 developing countries separately for the period 1970 to 2005, and finds that, in the context of the Feldstein-Harioka puzzle (Feldstein and Harioka 1980), "since investment by non-residents is not subject to inter-temporal budget constraint of the recipient country,…[i]n an open economy, domestic investment is financed by the pool of worldwide savings." (2009, 12). Further, Younas uses improved estimation techniques, to conclude that "capital is remarkably more mobile" both in developed and in developing countries, and that more recent economic openness and financial liberalization have also increased the magnitude of international capital mobility.

Such studies, among many others, suggest that there is little doubt that international capital mobility is high enough – both in developed and developing countries. Hence our theoretical assumption that capital is internationally mobile is justified on empirical grounds. However, as already noted, the reason a market-dependent production set has not pervaded economics is that a synthesis of the theoretical and empirical strands of the literature has not been undertaken to date, which is precisely the matter that we remedy in this paper.

3. Market-dependent Production Set

Consider the standard Specific Factors model, as in Jones (1971). Let all economic activity in an economy be divided into two parts: Manufactured goods, *M* and Services, *S*, produced by the technology embodied in the following production functions.

$$M = F(\bar{L}, K_m) \tag{1}$$

and

$$S = G(\bar{H}, K_s), \tag{2}$$

where $\bar{L}$ is the fixed quantity of unskilled labor and K_m the endogenously determined quantity of capital employed in the manufacturing sector of the economy, whereas $\bar{H}$ and K_s are the number of skilled workers and the amount of capital employed in service-sector production. Here $F(\bar{L}, K_m)$ and $G(\bar{H}, K_s)$ are *concave* production functions that are characterized by (i) the Inada conditions, including indispensible inputs, (ii) constant returns to scale, and (iii) the law of diminishing returns, which together imply that (iv) inputs are co-operative.[2]

Let this be a small open economy. Both commodities are internationally traded, insofar as services can be outsourced, and manufactures can also be traded. Further, let p_m and p_s be the exogenously specified *domestic* prices of the manufactured goods and of services, which in free trade are respectively equal to p_m^* and p_S^* that are taken to be the *world* prices of these commodities, which this economy takes as parametrically determined on the world markets of these commodities. Additional relationships that hold are

$$p_m F_K(\bar{L}, K_m) = r^* \tag{3}$$

and

$$p_S G_K(\bar{H}, K_s) = r^* \tag{4}$$

Equations (3) and (4) assert that the values of marginal product of capital equal the world rental rate of capital, r^*, in each sector. Since the country is also small in the world capital market, and is integrated in this market, it takes r^* as exogenously fixed. From (3) alone, the amount of capital employed in manufacturing is endogenously determined uniquely as $\hat{K}_m = K_m(\bar{L}, p_m, r^*)$, and from (4), capital employed in Services is determined as $\hat{K}_s = K_S(\bar{H}, p_S, r^*)$. Substituting for $\hat{K}_m$ and $\hat{K}_s$ in the production functions (1) and (2), we see that the equation of the PPF is

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[2] The cross partial derivatives of the two production functions are both positive. Intuitively this means that more capital increases the marginal productivity of unskilled labor in manufacturing, and conversely. Also, more capital employed in the service sector raises the marginal productivity of skilled labor, and conversely.

$$S = f(M; \bar{L}, \bar{H}, \; r^*, p_m, p_S). \qquad\qquad (5)$$

While the quantities of skilled and unskilled labor employed in the economy are constant in the initial general equilibrium, based on the argument contained in the previous paragraph, $\hat{K} = \hat{K}_m + \hat{K}_s = K(\bar{L}, \bar{H}, \; r^*, p_m, p_S)$ is the *endogenously* determined quantity of capital that is located and employed in the economy in general equilibrium in the presence of endogenous international capital mobility. The model is complete. The exogenous variable or parameters are: $\bar{L}, \bar{H}, p_m, p_S$ and r^*. The endogenous variables are: $K_m, \; K_s, M, S, w_L$ and w_H.[3]

The question arises: should (5) even be called the equation of the PPF? It is precisely because this PPF is not the same sort of relationship that is standardly called a PPF that necessitates the terminology of market-dependent production set, contrasted with the traditional PPF that is market invariant. The endogeniety of the quantity of capital located and thus employed in the economy under international capital mobility renders the relationship between the maximal output of one commodity for a given output of another commodity parametrically dependent on commodity prices and the world rental rate of capital. Hence, under international capital mobility, *a country's production set is not stationary in the net output space insofar as it is, in fact, not invariant to domestic commodity or factor price changes.*[4]

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[3] Once the values of $\hat{K}_m$ and $\hat{K}_s$ are determined (in terms of exogenous variables) from (3) and (4) respectively, substituting these values in the values of marginal product of unskilled and skilled labor also determine the general equilibrium values of the unskilled and skilled wage rates thus: $\hat{w}_L = p_m F_L(\bar{L}, \; K_m)$ and $\hat{w}_H = p_S G_H(\bar{H}, \; K_m)$. However, the general equilibrium values of these wage rates are not material to the argument we develop here.

[4] It is well known, as in Jones (1971), that for such an economy with exogenously determined supply of capital also, the PPF, defined as the maximal output of S for different feasible outputs of M, can be derived solely from the production functions (1) and (2), and the three factor-supply constraint, including $K_m + \; K_s = \bar{K}$, as $S = \varphi(M; \bar{L}, \bar{H}, \bar{K})$, with the property that $dS/dM < 0$ and $d^2S/dM^2 \leq 0$, so that given the technology and fixed factor supplies, *the location of the PPF is stationary in the output space insofar as it is invariant to changes in commodity or factor prices*, and a higher output of one sector is possible only with a lower output of the other sector. Clearly, $\varphi(.)$ is not the same sort of PPF as $f(.)$ in (5). We do not deal with the details of the exogenously fixed capital model here simply because its treatment is quite standard and available in most texts.

To see this, consider *Figure 1*, which is drawn under the price-normalization assumption that the domestic-price vector (p_m, p_S) belongs to the unit simplex, as in Debreu (1959), so that $p_m + p_S = 1$.
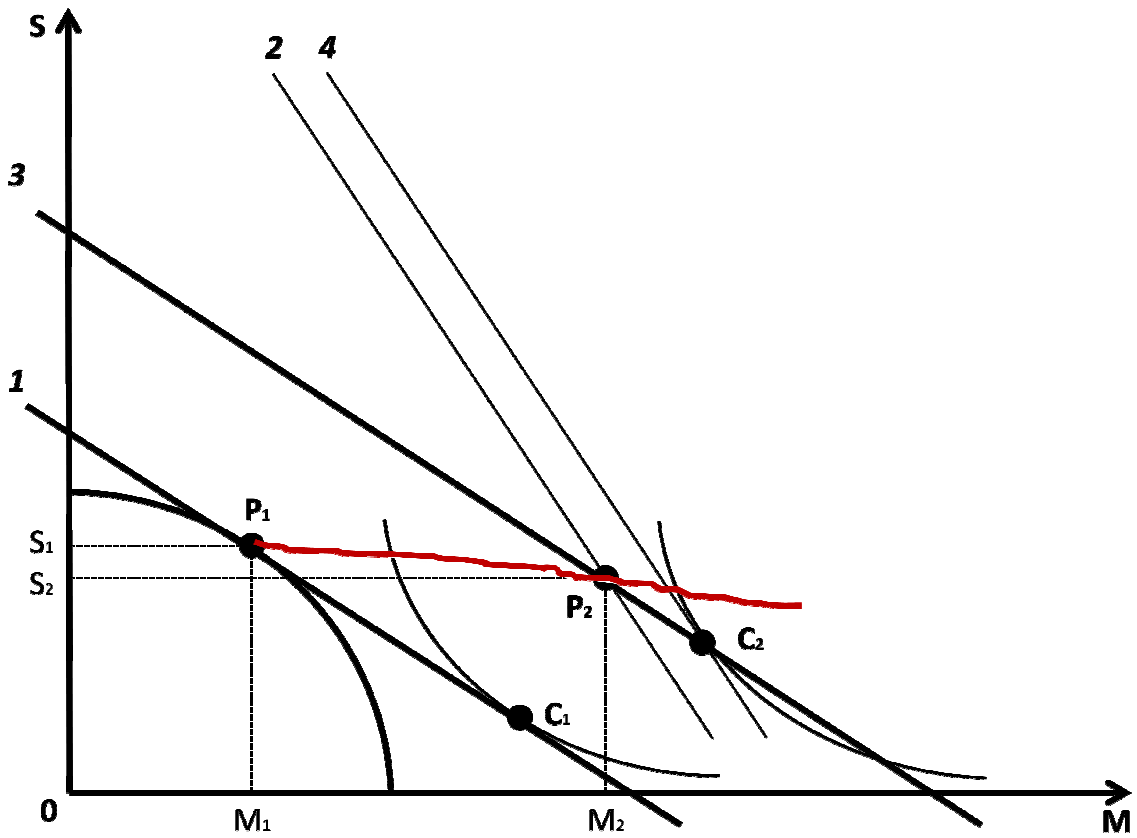

Figure 1

When life begins, the factor endowments are $\bar{L}$ and $\bar{H}$, the commodity prices are $p_m = p_m^*$ and $p_S = p_S^*$, and r^* is the world rental rate of capital. This is a small open economy both in commodity and capital markets, so that it takes p_m^*, p_S^* and r^* as exogenously determined on world markets.[5] These exogenous variables uniquely determine, in general equilibrium, $\hat{K}_m = K_m(\bar{L}, p_m, r^*)$ from (3) as capital employed in manufacturing and $\hat{K}_s = K_S(\bar{H}, p_S, r^*)$ from (4) as the capital employed in Services. Substituting for $\hat{K}_m$ and $\hat{K}_s$ in the production functions (1)

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[5] We do not entertain here the case of a large country simply because, aside from the issues arising from the Metzler paradox (a higher tariff may lead to a lower domestic relative price of the imported good), no additional insight is gained with regard to the matter of central interest here, which is the invariance or otherwise of the production set.

and (2), we obtain M_1 and S_1 in *Figure 1* as the output pattern corresponding to P_1 on the initial PPF, at which *Line 1*, with a slope of $-p = -(p_m/p_S)$ equals the slope of the strictly concave PPF, which, by definition, is the marginal rate of transformation of services into manufactured goods ($MRT_{SM} = \frac{dS}{dM} | Technology$).

Line 1 is also the country's consumption possibility frontier, or CPF, because foreigners are willing to trade with this country at the rate of exchange of *p* units of services per unit of the manufactured goods. Depending upon the preferences of the residents of this country, consumption pattern could be anywhere on *Line 1*, such as at C_1 , where a strictly convex community indifference curve is tangent to the CPF insofar as the marginal rate of indifferent substitution, MRS_{SM}, of services for manufactures, which is the consumers' psychological valuation of a unit of manufactures in terms of services, equals the same price ratio, $-p = -(p_m/p_S)$. Of course, no social welfare connotation is being ascribed to such an indifference curve.[6]

Suppose next that the government imposes an import tariff on the imports of manufactures (clearly, the society is consuming more manufactures than it produces, if one compares C_1 with P_1). Now, $p_m = p_m^* + t$, where *t > 0* is the import tariff, so that, given the normalization, the domestic price of manufactures is now higher than before, and the domestic price of services is lower than in the initial Walrasian general equilibrium, $p_S < p_S^*$. These new prices are reflected in the slope of the steeper *Line 2*. Given well-behaved, upward rising, general equilibrium supply curves (implied by the conditions imposed on the production functions), the output of *M* will be higher, and that of *S* lower, simply because, with a higher p_m, the LHS of (3) is higher, and equilibrium can only be restored by a lowering of the marginal product of capital in manufacturing, which, given the law of diminishing returns, can only be accomplished by an increase in K_m, so that the employment of capital in manufacturing must be higher. With a given employment of unskilled labor in manufacturing at $\bar{L}$, from (1) it is clear that manufacturing output will necessarily be higher at M_2 . Conversely, due to a lower domestic price of the service

[6] Group behavior of consumers may be *described* (representable) by that of a single (community) indifference map if personal preferences are identical and homothetic for all persons, but this constitutes no basis for declaring that such a representation should, or ought to, have any social welfare significance if interpersonal incomes are not also perfectly equal, except on the basis of a distributional value judgment that equal weights *ought* to be attached to persons' (poor and rich alike) consumption bundles despite non-identical incomes, which would be fine, if explicitly acknowledged as a value judgment. Otherwise, everyone in society would also have to have exactly the same income, in addition to identical and homothetic preferences, so that it would effectively be a Robinson Crusoe economy, without man Friday; an economy would, in such a case, be indistinguishable from a person. We make no such claim.

sector output, its capital employment will be lower, and with the fixed supply of skilled labor employment, its output will necessarily be lower, at S_2. Thus, $(M_2 , S_2) = P_2$ is the new production pattern in this economy, at a positive tariff. The new consumption pattern is C_2 on a different CPF given by *Line 3*, at which another community indifference curve is tangent to the tariff inclusive domestic price ratio, given by the absolute value of the slope of *Line 4*, which is parallel to *Line 2*.

Of course, at world prices, p_m^* and p_S^*, it is possible that $p_m^* (M_2 - M_1)$, which is the increase in the value of manufactured output at world prices, may be greater than, or less than, $p_S^* (S_1 - S_2)$, which happens to be the fall in the value of the service sector output. If $p_m^* (M_2 - M_1) > p_S^* (S_1 - S_2)$, at world prices the GDP of the country rises (which is the case presented in Figure 1); it falls otherwise, except in the unusual event that it remains constant.

However, does P_2 lie on a different PPF? The answer happens to be no. The crucial point is that, under endogenous international capital mobility, which in the post-crisis world is a statistically significant phenomenon in most countries (both developed and developing), the production pattern gets endogenously shifted from P_1 to P_2 , by the choice of government policy, which is here a positive import tariff, so that the consumption pattern can be anywhere on *Line 3* through P_2. However, P_2 does *not* lie on any PPF. Instead, the bold red *curve connecting P_1 and P_2 that is monotonically decreasing constitutes the endogenous, market-dependent or policy-dependent production pattern path of this economy that is predicated parametrically on the value of the tariff that lies between zero and the prohibitive level.* Extending the curve above or below P_2 to force it to lie on another PPF would be an error because these additional points will never be realizable by the country. While the boundary of the new production set still exists, it does not constitute a PPF simply because any output pattern other than P_2 on this boundary is simply not producible by this economy, and thus does not constitute a production possibility. This is due to the fact that market forces, in response to a different value of the tariff, will alter the boundary of the production set yet again, and the new production patter, P_3 say, will lie on the boundary of yet another production set, but not lie anywhere else on the boundary of the production set through P_2. Such is the nature of dependency of the production set on market forces.

Both Shiller (2010) and Stiglitz (2011), among others have called for endogenizing some variables that were in the pre-crisis world taken to be exogenously specified in economic models. Our work presented here is in the spirit of the direction suggested by Shiller and Stiglitz with

respect to endogenizing the PPF so as to convert the unidirectional relationship, from exogenous PPF changes influencing market equilibrium prices, but not vice versa, to a bidirectional relationship, in which market price changes affect the production pattern of the economy *by altering its production set*. Thus the size and shape of the economy's production set actually shrinks or expands, certainly its shape changes, in response to market price changes, which in turn may be policy induced. This possibility is entirely precluded in the traditional literature in economics and in general equilibrium theory, all the way from Haberler (1930), to Arrow and Debreu (1954), Koopmans (1957), and Debreu (1959), right up to the present time, as in Baumol and Blinder (2009), and Varian (2010), among others.

4. Concluding Remarks

The conclusions we have reached have very substantial consequences for economic theory, general equilibrium theory and for macroeconomics. For, policy-induced or external-shock-provoked changes in domestic relative prices do not merely change the points of tangency of the price hyper-planes with the PPF, but they also alter that shape of the production set, and thereby change the production pattern, both due to (1) resource reallocation effects and (2) production-set change effects. With rapid international capital mobility, a single-minded obsession with the consequent *movements along a pre-existing* PPF due to commodity price changes will fail to capture the full effect, since such movements completely ignore the effects of induced production set changes. With the consideration of a market-invariant PPF, attention gets unduly focused exclusively on resource reallocation among industries, which is a consequence solely of substitution effects (the matrix of factor-price derivatives of factor-demand functions is negative definite, see Neary (1985)), while the actual income effects that arise due to changes in the quantity of capital that locates in the country are utterly disregarded.

We do not claim that trade-offs in the production of alternative commodity combinations are irrelevant. Indeed they remain perfectly relevant. We merely point out that these substitution effects are only part of the story, and that *there exist circumstances* under which they may well be much less significant, particularly if they are overwhelmed by the magnitude of endogenous production set changes stimulated by international capital mobility, in turn provoked by changes in domestic relative market prices that are engineered by government policy. Indeed, based on empirical work, Azariadis and Pissarides (2007, p. 30) argue that in the case of a country with a

given capital stock, "[w]hen its economy is hit by a negative … shock, it reduces its demand for labour, but the capital stock initially remains at … [a] high level. Its demand for labour does not fall very much initially because the high level of the capital stock cushions it. But … if the shock persists long enough, the capital stock falls to a new low level and the demand for labour gradually falls with it." Of course, exactly the opposite happens if the country is the recipient of FDI.

An implication is that, with regard to the effects of market price changes on an economy's production set, the traditional separation in general equilibrium theory as well as in macroeconomics between technology and factor supplies on the one hand, and market-determined prices of commodities and factors, on the other hand, is no longer a valid assumption to make. Technology of production and supplies of factors of production, and the markets in which they connect with other markets, including of final goods, are all inextricably connected. This is one salient feature of economies that is captured by a market-dependent production set, though disregarded by a standard market-invariant PPF in the extant literature. Just as general equilibrium market prices are not invariant to exogenous changes in the production set, so the shape and size of an economy's production set is not invariant to changes in market prices.

There are also significant implications for the pedagogical approach to the teaching of economic theory. The market-dependent production set does not appear to have reached the texts in economics. There is never a hint in the undergraduate (or graduate) microeconomics texts that a change in government policy, for example in tariffs or import quotas, can actually induce capital flows in to or out of a country, and thus change the shape of the economy's production set. The time has come to purge our textbooks of the market-invariant PPF.

Others have also had something to say about how economics should be taught in the post-2007-2009 world. Blinder (2010), in addition to asking for a complete overhaul of the macroeconomics curriculum, has recently talked about planning to drop the assumption of a single-interest-rate economy from macroeconomic models in the next, 12th Edition, of his joint text with Baumol.[7] Perhaps the neglect of a market-dependent production set in the literature is due to a lack of a synthesis of the theoretical and empirical strands of the literature, which we have remedied to obtain the market-dependent production set.

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[7] See Baumol and Blinder (2009).

While in this paper we have paid attention to the empirically significant fact pertaining to international capital mobility, which precipitates a market-dependent production set, our position should not be construed as any suggestion that this is the sole cause of market dependency of a production set of an economy. In fact, it can be shown that even if capital is internationally immobile, *variable labor supply* in the form of an upward-sloping aggregate supply curve of labor as a function of the real wage rate – regardless of whether it is skilled labor, $H = H(w_S)$, or unskilled labor, $L = L(w_L)$ – would also precipitate a market-dependent production set, because it would render the quantity of a resource in the economy a function of the resource price. Another case of a market-dependent production set would arise if the *efficiency-wage hypothesis* holds in either sector of the economy: $M = F(e(w_L)L,\ K_m)$ or $S = G(e(w_H)H,\ K_S)$, with $e'(.) > 0$ and $e''(.) < 0$, where $e(.)$ is the number of efficiency units delivered by a worker. Work on such other underlying causes of a market-dependent production set is underway.

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