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Dynamic Factor Price Equalization & International Income Convergence

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Abstract

The paper develops a tractable way to incorporate the micro structure of dual models of international trade into a standard class of dynamic open-economy macro models. In the process, it develops the concept of a dynamic factor price equalization set and an integrated intertemporal equilibrium. A number of results are obtained concerning trade, growth, and income convergence. Countries with higher capital/labor ratios may stay wealthier over time, both in the transition and in the new steady state. Real shocks in one country will be transmitted to the other country through the factor markets and traded goods prices.

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I. Introduction

The integration of international trade theory using duality into dynamic macroeconomic models is relatively unexplored. In this paper we follow the pioneering contribution by Manning and Markusen (1991) as well as more recent contributions by Bajona and Kehoe (2006a, 2006b). We offer a duality-based methodology for incorporating multi-sector effects of international trade into open economy macroeconomic models, introducing the concept of the dynamic factor price equalization (FPE) set. For the macro audience, this approach offers a tractable way to integrate trade based upon differences in factor endowments into dynamic, multi-country macro models. Multi-country dynamic stochastic general equilibrium models have often included trade arising from scale economies and imperfect competition but have (to the best of our knowledge) not emphasized trade based on differences in factor endowments. For the trade audience, it provides a framework for integrating the insights from trade models into mainstream open economy macro models. Trade economists have often assumed fixed savings rates in their attempts to embed trade models in a dynamic setting, although this approach is not generally followed in the macro literature. For a general economics audience, the paper offers insights into the nature of income convergence across countries and links this with the evolution of relative factor abundance over time.

In the model, aggregate production in each country is derived from revenue and expenditure functions using duality techniques developed in Dixit and Norman (1980) and Woodland (1982). This aggregate production function depends on output prices and factor endowment stocks. It preserves all of the structure of a standard GDP function from the trade theory literature. The model also specifies that there is a representative infinitely-lived Ramsey consumer that maximizes the sum of present value utility subject to a budget constraint and a no Ponzi game condition. This gives rise to a familiar Euler equation that describes the evolution of consumption over time, as well as a savings-investment equation that describes the evolution of the capital stock. In a two-country version of the model considered below, we examine the properties of the dynamic FPE set. If the global economy is initially outside of this set, the equations of motion will pull the economy back into this set. Once in the dynamic FPE set, the equations of motion will keep the economy in the set.

Inside the dynamic FPE set, factor prices will be equalized internationally, and with identical tastes and technology, the economy can be regarded as a fully integrated world equilibrium in a dynamic sense. We refer to this as the two-country integrated intertemporal equilibrium. In this equilibrium, all of the standard properties of a closed economy one-sector neoclassical growth model hold, ruling out cycles and chaos, and allowing us to characterize the evolution of international inequality and the persistence of productivity and endowment shocks. In particular, we are able to apply results from Caselli and Ventura (2000) to analyze international differences by noting the formal equivalence of our two-country open economy neoclassical growth model and Caselli and Ventura's closed economy neoclassical growth model with heterogeneous households. This allows us to derive a number of results. Outside the steady state, but inside the dynamic FPE set, we will have absolute divergence of capital holdings but there may be periods of relative convergence or divergence, while the relative consumption ranking will remain unchanged. Once in the global steady state, any remaining relative cross-country inequalities in asset positions and consumption will remain unchanged over time. These results provide yet another reason why we might observe lack of income convergence internationally.

The model also allows us to analyze the effects of real shocks. A distinctive feature of the explicit micro foundations for the aggregete production function is that a real shock in one country is immediately transmitted to the other country through the factor markets and traded goods prices. For instance, following a real shock to capital or labor stocks in one country, the resulting changes in income and consumption rankings will persist until the new global steady state is reached and possibly even in the new steady state. This provides a micro-founded explanation for the persistent effects of output shocks found in Cerra and Saxena (2008). Changes in the pattern of trade resulting from a factor endowment shock will also persist until the new steady state is reached and may also persist even in the new steady state.

The remainder of the paper is organized as follows. The basic two-sector, one country model is described in Section II, including the micro foundations of the aggregate production function. Section III considers the Ramsey growth framework and the properties of the single country equilibrium, the two-country integrated intertemporal equilibrium, and the results described briefly above. Section IV considers what happens outside the dynamic FPE set. Some conclusions are offered in Section V.

II. Basic Two-Sector Model

We start with the properties of a single, integrated economy with fully mobile capital K and labor L, two intermediate goods X_1 and X_2 produced using K and L, and a set of consumers with identical homothetic preferences defined over a composite Q of intermediate goods X_1 and X_2.

A. Intermediate Demand

We define an aggregate good Q that is consumed or invested. It serves as the numeraire.

(1) $$Q = f(X)$$

where $f(\cdot)$ is a strictly increasing, strictly concave, twice continuously differentiable, linear homogeneous aggregator function. Producers choose the mix of X_1 and X_2 that minimizes the cost of intermediate goods needed to produce final output level Q. This yields the expenditure function $e(P,Q)$:

(2) $$e(P,Q)=\min_{X}\{P\cdot X \mid f(X)\geq Q\}$$

Given the linear homogeneity of $f(\cdot)$, the expenditure function can be expressed as a function of price aggregator $I(P)$:

(3) $$e(P,Q)=I(P)Q$$

From the envelope theorem, the vector of demand quantities X can be recovered from the expenditure function.

(4) $$X=\frac{\partial e(P,Q)}{\partial P}=Q\cdot\frac{\partial I(P)}{\partial P}$$

B. Production and Equilibrium

Firms are competitive and produce goods X_j with strictly increasing, strictly concave, continuously differentiable, linear homogeneous technologies $h^j(\cdot)$ defined over K and L. Given our technology set, this means we can define the minimized unit cost of production β_j as a function of the vector of factor prices ω:

(5) $$\beta_j(\omega)=\min_{v^j}\{\omega\cdot v^j \mid h^j(v^j)=1\}$$

where $j=1,2$ and $v^j\in(K_j,L_j)$. From the envelope theorem we can also then derive the vector of cost-minimizing unit input coefficients a with elements $a_{j,i}$ from ω:

(6) $$a_{j,i}=\frac{\partial\beta_j}{\partial\omega_i}\geq 0$$

where $j=1,2$ and $i=K,L$. At the same time, from the dual relationship of profit maximization and cost minimization, we can combine relative factor prices with unit input coefficients to obtain an expression involving relative goods prices.

(7) $$\frac{\sum\omega_i a_{j,i}}{\sum\omega_i a_{k,i}}=\frac{\beta_j}{\beta_k}=\frac{p_j}{p_k}$$

This gives us the dual underpinnings of the Lerner-Pierce diagram (Figure 1). In the figure, the relative price of X_1 and X_2 equals relative costs, so that the factor price ratio

$-\omega_L / \omega_K = -w / r$ is tangent to the unit value isoquants for any price vector P consistent with production of both goods under zero profit conditions. Starting from an endowment vector like point V in Figure 1 (which also shows the range of capital/labor ratios within which both countries produce each good, known as the diversification cone), we can recover the value of production (GDP) for any price vector P by multiplying the endowment vector V by factor prices ω. This is the revenue function g.

(8) $$Q = g(P,V) = \min_{\omega}\{\omega \cdot V \mid \beta(\omega) \geq P\}$$

The revenue function may equivalently be derived as the maximum value of output of the intermediate goods X at prices P subject to the resource constraints:

(9) $$Q = g(P,V) = \max_{X}\{P \cdot X \mid a \cdot X \leq V\}$$

From the envelope theorem, we can recover the supply vector X from goods prices P and endowments V. Factor prices can also be recovered for any set of (feasible) goods price and endowment vectors.

(10) $$X = \frac{\partial g(P,V)}{\partial P}$$

(11) $$\omega = \frac{\partial g(P,V)}{\partial V}$$

Equilibrium GDP $\hat{Q}$ and prices $\hat{P}$ are defined by the equality of income and expenditure and market clearing conditions.

(12) $$e(\hat{P},\hat{Q}) - g(\hat{P},V) = 0$$

(13) $$\frac{\partial e(\hat{P},\hat{Q})}{\partial P} - \frac{\partial g(\hat{P},V)}{\partial P} = 0$$

We can, in turn, derive the equilibrium factor income vector $\hat{\omega}$ from equilibrium goods prices.

(14) $$\hat{\omega} = \frac{\partial g(\hat{P},V)}{\partial V}$$

From equations (5)–(14), equilibrium GDP $\hat{Q}$, returns to labor $\hat{w}$ and capital $\hat{r}$, and relative factor intensities $\hat{a}$ are all defined, in reduced form, by relative endowments and the technology set.

(15) $\hat{Q} = G(V)$
(16) $\hat{w} = W(V)$
(17) $\hat{r} = R(V)$
(18) $\hat{a} = A(V)$

III. Integrated Intertemporal Equilibrium

A. Single Country Properties

The previous section defined the static production structure. This section specifies the dynamic structure of the model. Time subscripts will generally be suppressed to simplify the notation, except where necessary. Infinitely lived consumers maximize a standard intertemporal utility function with discount rate ρ and inverse elasticity of substitution θ:

(19) $$U(t) = \int_t^\infty u[c(v)]e^{-\rho v} dv$$

(20) $$u(c) = \frac{c^{1-\theta} - 1}{1-\theta}$$

where $\theta > 0$, per capita consumption c is measured in units of Q, and population size is assumed constant and equal to the labor stock L for simplicity. Households maximize intertemporal utility subject to the budget constraint, expressed in per capita terms:

(21) $$\dot{a} = w + ra - c$$

where a is household assets in per capita terms, $\dot{a}$ is the time derivative of a, and w and r are factor returns defined by equations (16) and (17), all measured in units of Q. We impose the usual no Ponzi game condition to rule out explosive borrowing by households.

(22) $$\lim_{t\to\infty}[a(t)e^{-\overline{r}(t)t}] \geq 0$$

(23) $$\overline{r}(t) = (1/t)\int_0^t r(v)dv$$

We have the familiar Euler equation for the evolution of consumption:

(24) $$\dot{c}/c = (1/\theta)(r - \rho)$$

(25) $$c(t) = c(0)e^{(1/\theta)[\overline{r}(t)-\rho]t}$$

We have a similar standard result for the evolution of the capital stock ($k = K/L$):

(26) $\dot{k} = G(k) - c - \delta k$

where δ is the depreciation rate.

Proposition 1: *Outside the steady state, the country's capital stock* k *and the capital intensity of both sectors will rise (fall) over time when we are below (above) steady-state values, with a consequent rise (fall) in the wage-rental ratio.*

Discussion: Together, equations (24) and (26) define the evolution of per-capita consumption and the capital stock outside the steady state, as well as the steady-state values themselves. In aggregate, we have the standard result that capital stocks and consumption will grow over time on a per-capita basis in an economy below steady-state values, while the opposite happens above these levels. Given equation (26) we can derive the evolution of the composition of production by differentiating equations (12) and (13) with respect to changes in the capital stock. Because k rises in the aggregate GDP function, we know that wages w will rise relative to the return to capital r. Moreover, w will rise and r will fall measured in units of either intermediate good and, given the price aggregator function $I(P)$, also in units of the composite good Q. Finally, there are three effects driving output mix. From the Rybczynski theorem, holding prices constant production of the capital-intensive intermediate good will expand and that of the labor-intensive good will contract. However, relative goods prices are endogenous, and depending on substitution effects the relative outputs of the capital and labor intensive sectors may rise or fall. If we assume services are labor intensive, we will have a rising price for services with rising income—a version of the Balassa-Samuelson effect. We summarize this as the following corollary.

Corollary 1: *Outside the steady state, the price of (labor-intensive) services will rise over time when we are below (above) steady-state values—a version of the Balassa-Samuelson effect.*

B. Two Countries

We next focus on the two-country case, where trade leads to equalization of relative factor prices in the integrated equilibirum. From the recent literature on representative agent models, this means we can also characterize the evolution of relative incomes, capital stocks, and output in the transition to steady state (Caselli and Ventura), once trade has equalized prices.

Global properties of the integrated intertemporal equilibrium

We now turn to the description of the two-country integrated intertemporal equilibrium, where the two countries have the structure outlined above. We assume both countries have identical technologies and tastes. Intermediate goods are freely traded internationally, which equalizes their prices across countries. Factors are perfectly mobile domestically but are immobile internationally. International borrowing is precluded, implying that household assets equal the capital stock in each country. We start by returning to the input coefficient ratios in Figure 1 and equation (7). We can define the global endowment vector $V = \sum_i V_i$. This is point O^2 in Figure 2. As long as the individual country endowments V_i $(i = 1,2)$ lie within the diversification cone shown in Figure 1, then trade alone will equalize factor prices. In terms of Figure 2, this means that as long as endowments are inside the box constructed using the equilibrium input vectors, trade equalizes factor prices in an equilibrium with trade in goods (Woodland, Dixit and Norman). This allows us to characterize the properties of the two-country global economy in the integrated intertemporal equilibrium from the properties of a comparable single-country representative consumer model.

Proposition 2: *Outside the steady state, and in the integrated intertemporal equilibrium, the global capital stock and output of the capital-intensive sector rise (fall) over time when we are below (above) steady-state values.*

Proposition 3: *Globally, the economy will remain inside the range of factor price equalization sets (the dynamic FPE set), defined by the range of factor-intensity ratios consistent with diversified production in equilibrium (diversification cone), along the single country growth path.*

Discussion: Note that, as long as we are inside the FPE set, w and r are equalized across countries. Within the FPE set, representative households in each region will have the same wage income but their capital income will differ. Denoting per-capita holdings of assets in region i as κ_i, and the global level as κ,

(27) $$\kappa_i = K_i / L_i$$

(28) $$\kappa = \left(\sum_{i=1,2} \frac{L_i}{\sum_{j=1,2} L_j} \kappa_i \right)$$

the propensity to consume will be identical across households, as will the relationship of the change in relative consumption to the interest rate in equation (24) above (Caselli and Ventura, Barro and Sala-i-Martin). This means that, in aggregate, the path of average consumption per capita c and average capital per worker k, and also average assets $\kappa = k$, will be identical to the values defined for a global representative household economy using equation (24).

Regarding Proposition 3, we will show in Section IV below that, if the endowment vector initially lies outside the dynamic FPE set, then differences in rates of return to capital will provide incentives for capital accumulation or decumulation that will move the endowment vector back inside the box over time. Once inside the dynamic FPE set, production will be diversified and the results obtained for an integrated intertemporal equilibrium apply.

International inequality

We will now analyze the relative and absolute convergence properties of transition in the two-country model described above. Consistent with Caselli and Ventura, a variety of dynamics are possible regarding the relative convergence or divergence of capital/labor ratios inside the dynamic FPE set. Nevertheless, the rich country stays richer in absolute terms if the global capital stock is initially below its steady-state level.

To see this, begin by noting that for households from country j $(j=1,2)$, the evolution of assets is determined by savings (income net of consumption) while consumption itself depends on the propensity to consume μ:

(29) $\dot{\kappa}_j = w + r\kappa_j - c_j$

(30) $c_j = \mu(\kappa_j + \tilde{w})$

Here $\tilde{w}$ is the present value of future wage income

(31) $\tilde{w}(t) = \int_t^\infty w(v)e^{-\bar{r}(v)v}dv$

and μ is the propensity to consume defined implicitly by equation (30). We can combine these equations to obtain the (absolute) evolution of assets.

(32) $\dot{\kappa}_j = (w - \mu\tilde{w}) + (r - \mu)\kappa_j$

From equation (32), we can derive expressions that permit consideration of absolute and relative convergence:

(33) $\dot{\kappa}_j - \dot{\kappa} = (r - \mu)(\kappa_j - \kappa)$

(34) $\dfrac{\dot{\kappa}_j}{\kappa_j} - \dfrac{\dot{\kappa}}{\kappa} = (w - \mu\tilde{w})(\kappa_j^{-1} - \kappa^{-1})$

Concerning absolute convergence, if the global capital stock is below its steady state level, then we will show below that $r > \mu$ and a country with a higher capital/labor ratio than the global capital/labor ratio will accumulate capital more quickly in absolute terms than the global level of capital accumulation. In turn, a country with a lower capital/labor ratio than the global ratio will accumulate capital more slowly than the global level. In this situation, the rich will stay richer in the transition to a new steady state.

Conversely, if the global capital stock is above its steady state level, then $r < \mu$ and the richer country will decumulate capital more quickly than the global rate, which in turn will fall more quickly in absolute terms than the capital stock in the poorer country. In this situation, the richer country once again takes a disproportionate share of the absolute adjustment in the capital stock.

The fact that $r > \mu$ if the global capital stock is initially below its steady state level can be shown to hold for all $\theta > 0$ as follows:

$$(35) \qquad r(0)/\mu(0) = r(0)\int_0^\infty e^{[\bar{r}(t)(1-\theta)/\theta - \rho/\theta]t}dt > r(0)\int_0^\infty e^{-\bar{r}(t)t}dt > r(0)\int_0^\infty e^{-r(0)t}dt = 1$$

where the first inequality follows from the fact that $r > \rho$, and the second inequality holds because r is falling, in transition when the capital stock is initially below its steady-state value. Similarly, it can be shown that $r < \mu$ if the global capital stock is above its steady state level.

From equation (34) and taking the case where the global capital stock is initially below its steady state level, whether or not there is relative convergence depends on the sign of $w - \mu\tilde{w}$. If $w - \mu\tilde{w} > 0$, the richer country's capital stock will grow at a slower rate than the global capital stock, and in turn the poorer country's capital stock will at a faster rate than the global capital stock, and there will be relative convergence. Conversely, if $w - \mu\tilde{w} < 0$, there will be relative divergence. On the one hand, unfortunately this term depends in a complex way on the time paths of wages and returns to capital and theory does not provide clear preditions regarding its sign. It may indeed change sign any number of times during the transition period. On the other hand, this implies that the model allows for a rich set of possible dynamics in relative income—a global version of the issues emphasized by Caselli and Ventura. In steady state, it can be shown that $w = \mu\tilde{w}$, implying that capital grows at the same rate in all countries (zero in our simplified setup, though it could easily be generalized to allow for positive growth in steady state).

The following propositions summarize the results of our discussion:

Proposition 4: *If the global capital stock is initially below the steady state, but inside the dynamic FPE set, there will be absolute divergence of capital holdings although in relative terms countries may either converge or diverge. Factor price equalization will hold even though capital formation is funded domestically, consistent with Feldstein and Horioka (1980).*

Proposition 5: *Outside the steady state, but inside the dynamic FPE set, the relative consumption ranking will remain unchanged.*

Proposition 6: *Once in global steady state, any remaining relative cross-country inequalities in asset positions and consumption will remain unchanged.*

Discussion: We have already demonstrated the first proposition. The second of these propositions follows directly from the equalization of returns to capital in equation (24) inside the dynamic factor price equalization set. The third also follows from equation (24) because returns are equalized in the integrated intertemporal equilibrium and (unequal) consumption patterns remain unchanged. Similarly, in steady state asset positions are by definition unchanged.[2]

Endowment shocks

The last two propositions above also lead to the following corollaries:

Corollary 2: *Following a real shock to capital or labor stocks, resulting changes in relative income and consumption rankings persist in transition to the steady state, and will persist in the steady state.*

Corollary 3: *Following a real shock to capital or labor stocks, resulting changes in the composition of trade persist in transition to the steady state, and will persist in the steady state.*

Discussion: Assume we start with identical countries in steady state (i.e., along the diagonal in Figure 2) and then experience a demographic shock, where the population drops in one country. We now have one capital-rich and one capital-poor country. The capital-abundant country will export the capital-intensive good, while the labor-abundant country will export the labor-intensive good. Essentially, trade will reallocate the consumption of factor services, equalizing factor returns across countries (measured in units of numeraire Q). We now have too much capital in the global economy, so the capital stock will fall over time. Moreover, the rich country's capital/labor ratio will fall by more than the poor country's in absolute terms because r is rising and μ is falling in transition with $r < \mu$. This follows from the discussion of equation (33). As we move to the new steady state, the newly capital-rich

[2] See Caselli and Ventura (2000) for a discussion in a more general case. From their paper, if government consumption is introduced with exogenous price growth and if households have a heterogeneous endowment of productivities, then relative rankings may reverse in the path to steady state.

region will remain relatively capital rich, but its capital stock will adjust more quickly in absolute terms, and in the new steady state trade will reflect the initial demographic shock.[3]

Productivity shocks

We next consider productivity shocks and two countries that differ initially in their capital/labor ratios. In particular, consider a symmetric, positive productivity shock to both sectors in the rich country only. This will effectively increase the economic size of the rich country while leaving its factor intensity unchanged in effective physical units. The real shock in the rich country will therefore be transmitted to the poor country through international trade in intermediate goods, which in turn will affect factor returns. The shock will reduce the return to capital and increase the wage rate in the integrated intertemporal equilibrium. Following the discussion of endowment shocks, surprisingly, the effects of a productivity shock in one country will be transmitted to the other country in perpetuity.

Proposition 7: *A productivity shock to the rich country will be transmitted to the poor country through factor markets and traded goods prices. The effects of the productivity shock to the rich country on the poor country will be permanent.*

IV. OUTSIDE THE DYNAMIC FPE SET

The remaining question is whether the world economy with free trade in intermediate goods but internationally immobile factors will move back into the dynamic FPE set if a shock takes it out of the set. Consider starting from an integrated intertemporal equilibrium with two identical countries in steady state and then reallocating enough capital from one country to the other so that the endowment vector moves out of the dynamic FPE set. For the world as a whole, if it were fully integrated, there would be no need for a change in the aggregate capital stock because it was previously in steady state. The question is whether the now poor country will accumulate capital and the now rich country will decumulate capital in transition to a new steady state.

If these were two closed economies, standard results for the Ramsey-Cass-Koopmans model could be used to show that the poor country would indeed accumulate capital and the rich country would decumulate capital. This follows from the Euler equation (24) in steady state, which serves to pin down the (common) steady state capital/labor ratio by requiring that the marginal product of capital is equal to the discount rate. The discount rate is unchanged and common to the two countries, which implies that each country would adjust its capital/labor ratio over time to return to the (unchanged) steady state capital/labor ratio.

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[3] Bajona and Kehoe (2006b) provide an alternative proof, based on monotonicity, that the initial ranking of countries' capital/labor ratios persists.

Being outside the dynamic FPE set implies that at least one country is completely specialized in the production of one of the intermediate goods so that we cannot appeal to results in the integrated intertemporal equilibrium. In theory, standard results based upon a closed economy growth model do not necessarily hold when there is free trade in intermediate goods but internationally immobile factors, as discussed in Bajona and Kehoe (2006a, 2006b). However, with competitive behavior we can in fact characterize both the dynamics of capital accumulation outside the steady state, and the properties of the steady state itself. Consider first the latter. In the steady state, rates of return must be equalized, as determined by the rate of time discount: $r = \rho$ in both countries. Since at least one country must be diversified in the steady state, there is also a unique steady-state capital/labor ratio for each sector consistent with this rate of return r. (See our earlier discussion of the Lerner-Pearce diagram.) This means that if one of the countries remains specialized, it must be on the border of the steady-state FPE set. Otherwise, both countries must be strictly inside the dynamic FPE set in steady state. In terms of the evolution of the capital stock, the rate of return is higher for the capital-poor country when we are outside the dynamic FPE set, while prices of the intermediate goods and final good are equalized by trade. As such, rates of capital accumulation will be higher in the poor country.[4] We summarize these points in the following propositions:

Proposition 8: *If we are outside the dynamic FPE set, the mechanisms driving capital accumulation will drive the global economy toward the dynamic FPE set.*

Proposition 9: *The existence of a steady state implies factor price equalizaton. The global economy is either on the border or inside the steady-state FPE set.*

V. CONCLUSIONS

In this paper we have developed a tractable way to incorporate the micro structure of dual models of international trade into a standard class of dynamic open-economy macro models. In the process, we have introduced the concept of a dynamic FPE set and an integrated intertemporal equilibrium. These analytical tools should be useful in a variety of different applications, including the trade structure underlying open-economy macro models, as well as the macro structure of dynamic trade models.

Aside from the methodological contributions of the paper, we have derived a number of results concerning trade, growth, and income covergence. We show that wealthier countries, in the sense of having higher capital/labor ratios, may stay absolutely wealthier over time, both in the transition and in the new steady state. The pattern of trade will reflect a higher

[4] We assume here that individual agents do not incorporate the evolution of terms of trade effects into their optimization problem. This does imply opportunities for public policy beyond the scope of this paper. It is also consistent with competitive behavior on the part of agents.

capital intensity and this will also persist over time. Real shocks in one country will be transmitted to the other country through the factor markets and traded goods prices. Surprisingly, the effects of real shocks will be permanent in this model. Some logical extensions include considering nontraded goods and the real exchange rate, dynamic behavior of specific factors models, and the effects of demographic shocks in multi-country overlapping generations models.

Figure 1. Lerner-Pierce Diagram

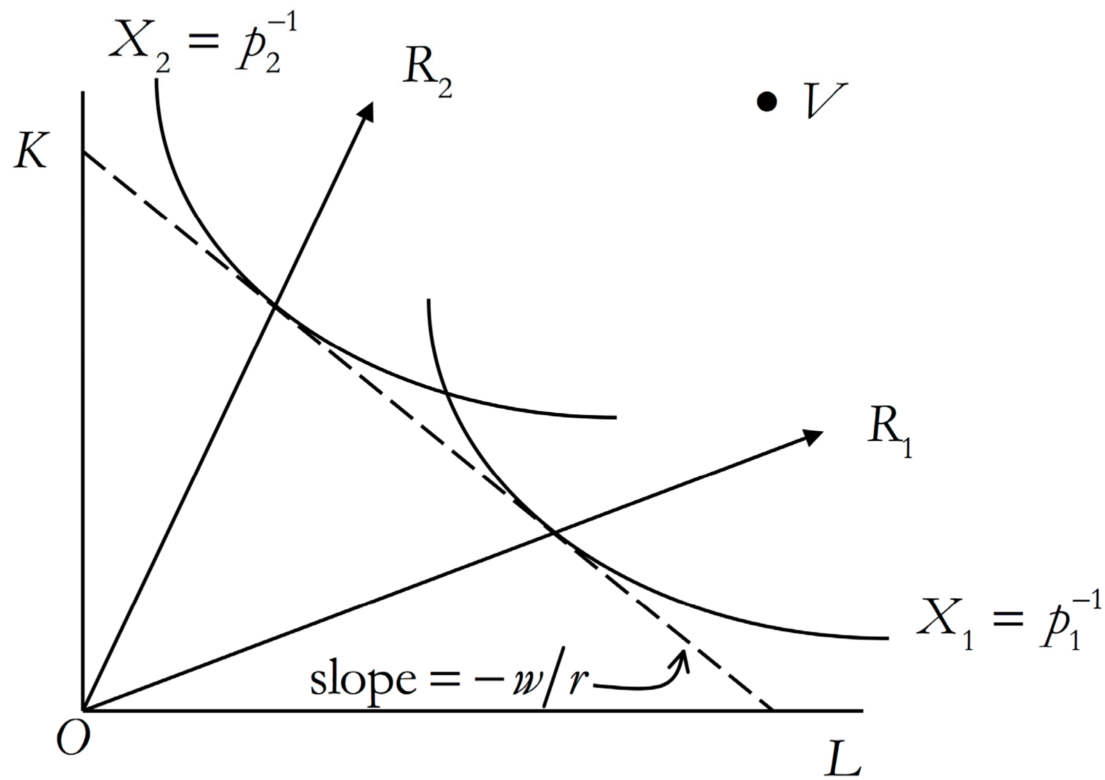
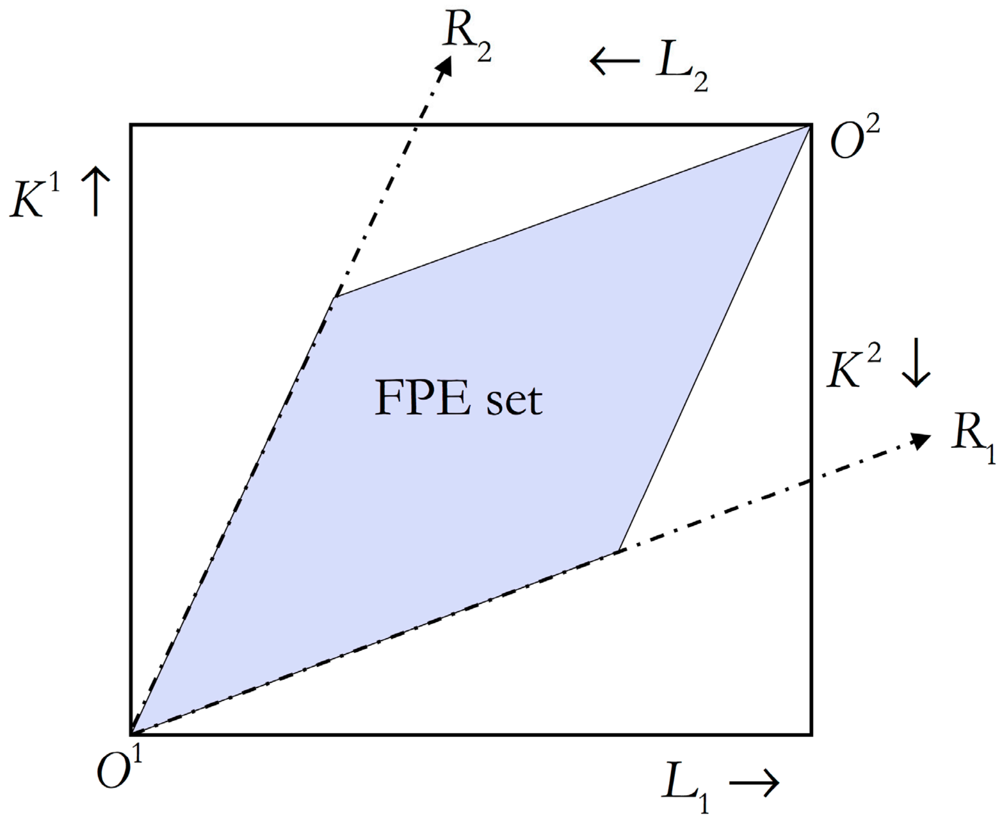


Figure 2. Factor Price Equalization Set



REFERENCES

Bajona, Claustre, and Timothy J. Kehoe (2006a), "Trade, Growth, and Convergence in a Dynamic Heckscher-Ohlin Model," Research Department Staff Report 378, Federal Reserve Bank of Minneapolis, September 2006.

Bajona, Claustre, and Timothy J. Kehoe (2006b), "Demographics in Dynamic Heckscher-Ohlin Models: Overlapping Generations versus Infinitely Lived Consumers," Research Department Staff Report 377, Federal Reserve Bank of Minneapolis, October 2006.

Barro, Robert J., and Xavier Sala-i-Martin (2004), *Economic Growth*, Second Edition, Cambridge: MIT Press.

Caselli, Francesco, and Jaume Ventura (2000), "A Representative Consumer Theory of Distribution," *American Economic Review* 90, pp. 909–926.

Cerra, Valerie, and Sweta Chaman Saxena (2008), "Growth Dynamics: The Myth of Economic Recovery," *American Economic Review* 98, pp. 439–457, forthcoming.

Dixit, Avinash K., and Victor Norman (1980), *Theory of International Trade: A Dual, General Equilibrium Approach*, Cambridge: MIT Press.

Feldstein, Martin, and Charles Horioka (1980), "Domestic Savings and International Capital Flows," *Economic Journal* 90, pp. 314–329.

Manning, Richard, and James R. Markusen (1991), "National Product Functions in Comparative Steady-State Analysis," *International Economic Review* 32, pp. 613–624.

Woodland, Alan D. (1982), *International Trade and Resource Allocation*, Amsterdam and New York: North-Holland Elsevier Science Publishers.