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FLOWENLA Discussion Paper

The economic impact of East-West migration in an enlarged European Union

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ABSTRACT

This paper provides a theoretical framework for a study of the economic impact of East-West European migration that will follow the pending enlargement of the European Union. We set out a calibrated general equilibrium two-bloc model of the European economy that incorporates the growing integration of labour, capital and goods markets. The model is of the `new-growth, new-trade' genre where long-term growth is endogenous and is driven by innovation in the production of new industries. The East is characterised by a lower total factor productivity in all industries, a relatively lower endownment of skilled labour and a lower initial capital stock. We examine the impact of East-West European migration of different skill compositions. East-West migration induces two effects: an *efficiency effect* from the more efficient use of labour in the West and a *sectoral reallocation effect* arising from the change in the skilled-unskilled wage rates. The first effect is studied by examining migration with no skill bias and the second by examining migration of exclusively skilled labour. Both types of migration result in a increase in world growth in the steady state. Skilled-labour migration results in a shift out of the high-tech sector in the Prepared for the third Workshop of the Fifth Framework Programme project \ European Enlargement: The Impact of East-West Migration on Growth and Employment", Brussels, September, 2003. This paper is preliminary and should not be quoted without permission from the authors.

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1 Introduction

This paper provides a theoretical framework for a study of the economic impact of East-West European migration that will follow the pending enlargement of the European Union. Specifically, we set out a calibrated general equilibrium two-bloc model of the European economy that incorporates the growing integration of labour, capital and goods markets.

The model draws upon previous work by two of the authors that examines trade liberalization issues in a North-South context[1] and on work by one of the authors on migration.[2] An important feature of the North-South modelling was the possibility that the South could copy innovative goods invented in the North leading to 'product cycles'. In the East-West European context of the current study we assume that IPRs are respected ruling out behaviour of this type. Capital flows will play an important role in the study so unlike most previous trade-growth models which focus on specialism in production (e.g., Grossman and Helpman, 1992), we incorporate intertemporal aspects of lending and borrowing usually associated with macro-growth models (e.g., Barro and Sala-i-Martin, 1995).

Our model is of the 'new-growth, new-trade' genre where long-term growth is endogenous and affected by a range of policy interventions, and imperfect competition and economies of scale feature in goods markets. Long-term endogenous growth is driven by innovation in the production of new industries. This Schumpeterian view of growth has had its critics. Two critiques of this literature in particular need addressing: first, the usual formulation of the models gives rise to a *scale effect*, namely that the long-term growth rate rises with population. Second, closed-economy models of endogenous growth suggest different long-term growth rates reflecting policy and structural differences between countries. Both of this predictions conflict with empirical evidence. Our brief therefore is to construct a model without scale effects and with a common long-term growth.

The rest of the paper is organised as follows. Section 2 sets out the 'core' model without labour mobility. Section 3 sets out the balanced-growth steady state of the dynamic model. Section 4 provides the welfare calculation for migrants, remaining residents in the East

[1] Currie, Levine, Pearlman and Chui (1999), Chui, Levine and Pearlman (2001), and Chui, Levine, Mansoob and Pearlman (2002).

[2] Levine (1999), Ghatak et al (1996), Krichel and Levine (2001).

and indigenous households in the West taking into account ownership of assets. Each of these groups is divided into skilled and unskilled households giving six groups in total. In the last part of this section we develop a migration equilibrium. Section 5 describes the calibration of the model. Section 6 sets out the numerical results and section 7 provides conclusions and some suggestions for future developments of the model.

2 The Model

In each bloc East (E) and West (W), in the absence of specialization there are four sectors: a high-technology manufacturing sector, m, produces an expanding variety of differentiated goods; a traditional traded sector, y, produces a single traded homogeneous good (e.g., food, steel); a traditional non-traded sector, z, produces another homogeneous good (e.g., construction, services) and an R&D innovative sector, i, produces blueprints for new manufactured goods. Sectors m, y and z use four factor inputs consisting of skilled labour H^b, and unskilled labour L^b, $b = E, W$ in the aggregate, and physical capital consisting of inputs from the two traditional sectors. The ranking of unskilled-skilled labour intensiveness is: z, y, m and i. The assumed market structures for outputs are competitive for the traditional and R&D sectors and monopolistic for manufacturing. Labour markets are assumed to clear and there are no free public services. In the basic model there is no labour mobility between East an West. Migration between these blocs is then considered in a subsequent section of the paper.

Asymmetries between East and West are a central aspect of this study. On the demand side in our analysis allow for the possibility that parameters (such as the discount rate) defining consumer preferences differ between the two regions. Following Parente and Prescott (2000) we assume that both East and West have access to the same common technologies, but the ability of firms to avail themselves of the best technology differ in the two blocs, leading to different total factor productivities. Estimates from Hall and Jones (1999) of total factor productivities for the US and some typical East and West European economies are given in table 1 below. Since our focus is on *long-run* growth, the question arises as to whether such large TFP differences will persist for long in the transitional economies. Estimates of TFP growth and labour productivity for Eastern and Western Germany in the 1990s from Burda and Hunt (2001) show that in the first half of the decade convergence was rapid, but in the second half it slowed down considerably leaving Eastern labour productivity almost frozen at around two-thirds of that in the West. This suggests that in the transitional economies we may expect some rapid convergence at first, but that some significant East-West TFP productivity difference will persist for some considerable time. This is what we assume in our simulations. The remaining differences between East and West are the factor endowments of skilled and unskilled labour and initial capital stocks.[3]

Country	$\frac{Y}{L}$	TFP
USA	1.00	1.00
Italy	0.834	1.14
W.Germany	1.118	0.94
France	0.818	1.09
UK	0.727	1.01
Cyprus	0.446	0.737
Malta	0.463	0.812
Hungary	0.307	0.424
Czech	0.211	0.369
Poland	0.238	0.363

Table 1. Labour Productivity and TFP Differences between Countries (Hall and Jones, 1999)

2.1 Consumers and Aggregate Demand

In blocs $b = E, W$, consumers consist of two representative households. Types $l = L, H$, supply fixed quantities of labour to the labour market and maximises an intertemporal utility function,

$$U_l^b(t) = \int_0^\infty e^{-\rho^b(\tau-t)} \left\{ \frac{[(C_{ml}^b)^{\theta_m^b}(C_{yl}^b)^{\theta_y^b}(C_{zl}^b)^{\theta_z^b}]^{1-1/\sigma} - 1}{1-1/\sigma^b} \right\} d\tau; \qquad \sum_{i=m,y,z} \theta_i^b = 1, \sigma^b \neq 1; \tag{1}$$

[3]The latter however are irrelevant for the steady state results.

where ρ^b is the subjective discount rate, $\sigma < 1$ is the intertemporal elasticity of substitution, C^b_{yl} and C^b_{zl} are total consumption of the traditional traded and non-traded goods respectively by type l; and C^b_{ml}, an index of consumed manufacturing goods by households of type l, takes the form

$$C^b_{ml} = \left[\int_0^n (x^b_{lj})^\alpha dj\right]^{1/\alpha}; \qquad \alpha \in (0,1), \tag{2}$$

due to Dixit-Stiglitz, where n is the total number of varieties available, α is a taste parameter and x^b_{jl} is consumption of variety j by type l in bloc b.[4]

The consumers' optimization problem consists of two stages. Let p_{mj} be the price of manufactured variety j and p_y, p^b_z, $b = E, W$ be the prices of the traded and non-traded traditional goods. Then the first stage is the current period maximization of $(C^b_{ml})^{\theta_m}(C^b_{yl})^{\theta_y}(C^b_{zl})^{\theta_z}$ over the varieties given total nominal household expenditure for each group of workers, $C^b_l = \int_0^n [p_{mj}x^b_{jl}]dj + p_y C^b_{yl} + p^b_z C^b_{zl}$. This is a standard problem which yields demands

$$C^b_{yl} = \theta^b_y \frac{C^b_l}{p_y}; \qquad C^b_{zl} = \theta^b_z \frac{C^b_l}{p^b_z}; \qquad x^b_{jl} = \frac{\theta^b_m C^b_l p^{-\varepsilon}_{mj}}{\int_0^n p^{1-\varepsilon}_{mj'} dj'}; \qquad l = L,\ H,\ ;\ b = E, W \tag{3}$$

where $\varepsilon = 1/(1-\alpha) > 1$ is the elasticity of substitution. Hence the total nominal consumption of manufactured goods in bloc b by households of type l is given by

$$\int_0^n p_{mj} x^b_{jl} dj = \theta^b_m C^b_l = P_m C^b_{ml} \tag{4}$$

where C^b_{ml} is real consumption and

$$P_m = \left[\int_0^n p^{1-\epsilon}_{mj}\right]^{\frac{1}{1-\epsilon}} \tag{5}$$

is the price index for manufacturing. Finally the profit-maximizing choice of output by the firm producing variety j requires the total world demand for the variety j given by

$$x_j = \sum_{b=E,W} (x^b_{Lj} + x^b_{Hj}) = \frac{\left[\sum_{b=E,W} \theta^b_m C^b\right] p_j^{-\varepsilon}}{\int_0^n p^{1-\varepsilon}_{j'} dj'} \tag{6}$$

where $C^b = C^b_L + C^b_H$ is total households' nominal expenditure in bloc b.

[4] Notice the elasticity $\epsilon = 1/(1-\alpha)$ is assumed to be equal across all varieties wherever they are produced.

The second stage of the consumers' problem is intertemporal. Net assets, A_l^b, held by households of type l consist of an equity stake in new blueprints, domestic physical capital in all sectors and claims on domestic and foreign residents. Arbitrage in capital markets within each bloc ensures equality on the return r^b from these assets. This implies budget constraints for the groups $l = L, H$ of the form:

$$\dot{A}_L^b = r^b A_L^b + w_L^b L^b - T_L^b - C_L^b; \quad \dot{A}_H^b = r^b A_H^b + w_H^b H^b - T_H^b - C_H^b, \tag{7}$$

where $\mathbf{w^b} = [w_L^b, w_H^b]$ are the wage rates and $[T_L^b, T_H^b]$ are non-distortionary taxes paid by the two groups. Maximizing (1) subject to (2), (3) and (7) gives another standard result:

$$\dot{C}_l^b / C_l^b - \dot{P}^b / P^b = \sigma^b (r^b - \dot{P}^b / P^b - \rho^b)\, ;\, l = L, H \tag{8}$$

where

$$P^b = (P_m)^{\theta_m^b} p_y^{\theta_y^b} (p_z^b)^{\theta_z^b} \tag{9}$$

is the price index for total consumption in bloc b. Hence aggregating over the two types of household we have

$$\dot{C}^b / C^b - \dot{P}^b / P^b = \sigma^b (r^b - \dot{P}^b / P^b - \rho^b) \tag{10}$$

The budget constraint for aggregate net assets wealth is,

$$\dot{A}^b = r^b A^b + w_L^b L^b + w_H^b H^b - C^b, \tag{11}$$

In each region manufacturing firms have identical costs and all firms, East or West, face an identical demand given by (6). Hence $p_j = p^W$, $j = 1, 2, \cdots, n^W$ and $p_j = p^E$, $j = n^W + 1, n^W + 2, \cdots, n$ where $n = n^W + n^E$. Then from (5) we now have that $P_m = \left[n^W (p^W)^{1-\epsilon} + n^E (p^E)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}}$. We can now write aggregate assets in region b as:

$$A^b = A_L^b + A_H^b = n^b v^b + p_y K_y^b + p_z^b K_z^b + F^b \tag{12}$$

where n^b varieties with stock market value v^b are produced in bloc b and K_y^b and K_z^b and K_m^b are aggregate levels of physical capital created from the two traditional sectors and F^b are net claims of bloc b on residents in the other bloc (a negative value implies a liability).

2.2 Accounting Identities and Eastern Debt

Let $B_j^b; j = y, m$ denote the trade balance in traded sector j. Then the accounting identities are:

$$p_y Y^b = p_y(C_y^b + \dot{K}_y^b + \delta_y K_y^b) + B_y^b \tag{13}$$

$$Z^b = C_z^b + \dot{K}_z^b + \delta_z K_z^b \tag{14}$$

$$p_m^b n^b x^b = P_m C_m^b + B_m^b \tag{15}$$

where $\delta_y, \delta_z, \delta_m$ are the depreciation rates for the three types of capital. If financial capital is mobile, $r^E = r^W = r$, say, and foreign assets held by each bloc accumulate according to:

$$\dot{F^b} = rF^b + B_y^b + B_m^b \tag{16}$$

and $F^W = -F^E$, in this two-bloc world. From (16) this is equivalent to the world trade balance condition

$$B_y^W + B_m^W + B_y^E + B_m^E = 0 \tag{17}$$

However open-economy models with capital mobility of this genre have some implausible properties, discussed in Barro and Sala-i-Martin, chapter 3. One way of resolving this difficulty is to assume that the bloc that borrows is *credit-constrained* and can only borrow up to its holdings of other assets; i.e., if it is the East that borrows then liabilities F^W are constrained by $A^E \geq 0$. With credit constraints interest rates r^W and r^W can diverge.

In the complete absence of capital mobility, interest rates can diverge and the trade must balance implying

$$B_y^b + B_m^b = 0 \tag{18}$$

We can set up the model to incorporate capital immobility as a special case of constrained mobility as follows. The credit constraint takes the form:

$$F^W \leq \phi(n^E v^E + p_y K_y^E + p_z K_z^E) = \phi a^E \tag{19}$$

say, where $\phi \in [0, 1]$ is the maximum proportion of Eastern assets, a^E, owned by Western households. Then (16) applies and $r^W = r^E = r$ iff $F^W < \phi a^E$. Otherwise the credit constraint binds, $r^W \neq r^E$ necessarily and (16) is replaced with

$$\phi \dot{a}^E = r^W \phi a^E + B_y^W + B_m^W \tag{20}$$

2.3 The Traditional Sectors

Turning to the supply side, since the traditional sectors are perfectly competitive, the price is equal to the marginal cost. If both regions produce the traded traditional good, global price equalization then gives the following equality

$$p_y = \Gamma_y^E(\mathbf{w^E}, \mathbf{R^E}) = \Gamma_y^w(\mathbf{w^W}, \mathbf{R^W}). \tag{21}$$

where $\Gamma_y^b(\cdot)$ is a cost function and $\mathbf{R^b} = [\mathbf{R_y^b}, \mathbf{R_z^b}]$ are the net costs (rental prices) of the two types of physical capital. Equating the returns on capital to r^b we have

$$R_j^b = p_j^b[r^b + \delta_j - \frac{\dot{p}_j^b}{p_j^b}]\,;\; j = y, z \tag{22}$$

In (21), unit cost functions $\Gamma_y^b(\mathbf{w^b}, \mathbf{R^b}), b = E, W$, for the traded traditional sector and the corresponding unit factor requirements are given in Appendix A, and are derived from the following, CES production function

$$Y^b = T_y^b\left[[\gamma_{1y}L_y^{\mu_y} + \gamma_{2y}H_y^{\mu_y}]^{\frac{\eta_y}{\mu_y}} + [\gamma_{3y}K_{yy}^{\xi_y} + \gamma_{4y}K_{zy}^{\xi_y}]^{\frac{\eta_y}{\xi_y}}\right]^{\frac{1}{\eta_y}}\;;\; \sum_{j=1}^{4}\gamma_{jy} = 1 \tag{23}$$

for factor inputs $[L_y, H_y, K_{yy}, K_{zy}]$ into the y-sector. In (23), $\sigma_{\mu_y} = 1/(1-\mu_y)$ is the elasticity of substitution between skilled and unskilled labour, $\sigma_{\xi_y} = 1/(1-\xi_y)$ is the elasticity of substitution between the two types of physical capital and $\sigma_{\eta_y} = 1/(1-\eta_y)$ is the elasticity of substitution between labour of either type with physical capital of either type.[5]

We assume identical technology is available in both blocs apart from the total factor productivity, T_y^b, which can differ. We assume that the East is inefficient relative to the West in all sectors. If this inefficiency is uniform across sectors, with our constant returns to scale production functions this can be interpreted the quality of skilled, unskilled labour and physical capital in the West being uniformly higher than in the South (in addition to the proportion of skilled workers being higher). Alternatively (or in addition) the inefficiency could be caused by barriers to innovation as in Parente and Prescott(2000) in which case it need not be uniform across sectors.

[5]An alternative specification for the CES production function assumes a common rate of substitution between unskilled labour on the one hand, and skilled labour and all types of physical capital on the other; i.e., $Y^b = T_y^b\left[[\gamma_{1y}L_y^{\eta_y} + [\gamma_{2y}H_y^{\xi_y} + \gamma_{3y}K_{yy}^{\xi_y} + \gamma_{4y}K_{zy}^{\xi_y}]^{\frac{\eta_y}{\xi_y}}]\right]^{\frac{1}{\eta_y}}$. Then $\eta_y > 0$ and $\xi_y < 0$ captures the empirical possibility that skilled labour and physical capital are complements (Hammermesh (1993)).

For the non-traded traditional sectors prices in each bloc can differ and (21) becomes

$$p_z^b = \Gamma_z^b(\mathbf{w^b}, \mathbf{R^b})\,;\; b = E, W \tag{24}$$

where unit cost functions $\Gamma_z^b(\mathbf{w^b}, \mathbf{R^b}), b = E, W$ are derived from an analogous CES production function

$$Z^b = T_z^b \left[[\gamma_{1z} L_z^{\mu_z} + \gamma_{2z} H_z^{\mu_z}]^{\frac{\eta_z}{\mu_z}} + [\gamma_{3z} K_{yz}^{\xi_z} + \gamma_{4z} K_{zz}^{\xi_z}]^{\frac{\eta_z}{\xi_z}} \right]^{\frac{1}{\eta_z}} \;;\; \sum_{j=1}^{4} \gamma_{jz} = 1 \tag{25}$$

for factor inputs $[L_z, H_z, K_{yz}, K_{zz}, K_{mz}]$ into the z-sector.

2.4 Manufacturing firms

Given factor inputs $[L_m, H_m, K_{ym}, K_{zm}]$, production in the manufacturing sector producing variety j is given by a CES production function analogous to (23)

$$x_j^b = T_m^b \left[[\gamma_{1m} L_m^{\mu_m} + \gamma_{2m} H_m^{\mu_m}]^{\frac{\eta_m}{\mu_m}} + [\gamma_{3m} K_{ym}^{\xi_m} + \gamma_{4m} K_{zm}^{\xi_m}]^{\frac{\eta_m}{\xi_m}} \right]^{\frac{1}{\eta_m}} \;;\; \sum_{j=1}^{4} \gamma_{jm} = 1 \tag{26}$$

from which the cost functions $\Gamma_m^b(\mathbf{w^b}, \mathbf{R^b})$ are derived as before.

The manufacturing firm in either bloc producing variety j at price p_j where $j \in [0, n]$ maximises profits, $\pi_j = (p_j^b - \Gamma_m^b) x_j^b$ with x_j^b given by (6). For identical firms in each bloc, this yields equilibrium price, output, profits and manufacturing price index:

$$\begin{aligned} p^b &= \frac{\Gamma_m^b}{\alpha} && (27) \\ x^b &= \frac{\theta_m C (p^b)^{-\epsilon}}{P_m^{1-\epsilon}} && (28) \\ \pi^b &= (1-\alpha) p^b x^b && (29) \\ P_m &= \left[n^E (p^E)^{1-\epsilon} + n^W (p^W)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} && (30) \end{aligned}$$

Notice that since $\epsilon > 1$, P_m is a *decreasing* function of the number of varieties, $n = n^E + n^W$.

2.5 The Innovative Sector and Knowledge Capital

The innovative R&D sector employs only labour and the rate of production of new goods invented in this sector is given by the production function

$$\dot{n}^b = T_i^b \Lambda \left[[\gamma_{1i} L_i^{\mu_i} + \gamma_{2i} H_i^{\mu_i}]^{\frac{\eta_i}{\mu_i}} + [\gamma_{3i} K_{yi}^{\xi_i} + \gamma_{4i} K_{zi}^{\xi_i}] \right]^{\frac{1}{\eta_i}} \;;\; \sum_{j=1}^{4} \gamma_{ji} = 1 \tag{31}$$

where Λ is knowledge capital. Our treatment of knowledge capital differs from much of the literature in that we adopt a formulation that does not lead to the empirically troublesome conclusion that growth increases with population size. The basic idea is that a new blueprint emerging in the R&D sector contains new ideas and information useful to future generations of innovations but these diffuse gradually in time and *through the population*.

Let $L^E + H^E + L^W + H^W = N$ say, be the total world's working population. In fact, later we normalise $N = 1$. Let $n = n^E + n^W$ be the total number of varieties in the world. Then knowledge capital Λ is defined by

$$\Lambda = \frac{n}{N} \tag{32}$$

i.e., knowledge capital depends on the *density* of varieties in the population and not on the absolute number. This small change in the usual formulation (for example adopted in G&H) removes the world population size effect on growth. Notice also that knowledge capital is independent of the distribution of populations between East and West and is therefore unaffected by migration.

2.6 The Financial Sector

Let the stock market value of the typical R&D firm in bloc b be denoted by v^b. A new blueprint costs $\Gamma_i(\mathbf{w^b}, \mathbf{R^b})/\Lambda$, and the NPV rule requires this to be equated with v^b, giving

$$v^b = \frac{\Gamma_i(\mathbf{w^b}, \mathbf{R^b})(1 - s^b)}{\Lambda}. \tag{33}$$

where $s^b \in (0, 1)$ is the proportion of R&D costs met by a subsidy in bloc b. The no-arbitrage condition is

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} = r^b \tag{34}$$

the left hand side is the total rate of return to equity holders (dividend plus capital gains) and r^b denotes the interest rate on riskless loans between households. If

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} < r^b \tag{35}$$

then no innovative goods are created in bloc b.

2.7 Factor Equilibrium Conditions

If all labour markets clear labour market equilibrium condition for each type of labour are

$$\frac{a^b_{Li}}{\Lambda}\dot{n}^b + a^b_{Lm}n^b x^b + a^b_{Ly}Y^b + a^b_{Lz}Z^b = L^b \tag{36}$$

$$\frac{a_{Hi}}{\Lambda}\dot{n}^b + a^b_{Hm}n^b x^b + a^b_{Hy}Y^b + a^b_{Hz}Z^b = H^b \tag{37}$$

The model is closed with the equilibrium conditions for the remaining factors, K_y and K_z.

$$\frac{a^b_{K_y i}}{\Lambda}\dot{n}^b + a^b_{K_y m}n^b x^b + a^b_{K_y y}Y^b + a^b_{K_y z}Z^b = {K_y}^b \tag{38}$$

$$\frac{a_{K_z i}}{\Lambda}\dot{n}^b + a^b_{K_z m}n^b x^b + a^b_{K_z y}Y^b + a^b_{K_z z}Z^b = {K_z}^b \tag{39}$$

The model is closed with a balanced budget condition for government spending on subsidies and tax receipts.

$$T^b = T^b_L + T^b_H = \frac{n^b \Gamma^b_i s^b}{\Lambda} \tag{40}$$

which completes the specification of the core model for given L^b, H^b.

2.8 Summary of Model

Consumption Demand

$$C^b_z = \frac{\theta^b_z C^b}{p^b_z} \tag{i}$$

$$C^b_y = \frac{\theta^b_y C^b}{p_y} \tag{ii}$$

$$C^b_m = \frac{\theta^b_m C^b}{P_m} \tag{iii}$$

$$x^b = \frac{(\theta^E_m C^E + \theta^W_m C^W)(p^b_m)^{-\epsilon}}{P^{1-\epsilon}_m} \tag{iv}$$

$$\frac{\dot{C}^b}{C^b} = (1-\sigma^b)\frac{\dot{P}^b}{P^b} + \sigma^b(r^b - \rho^b) \tag{v}$$

Aggregate Demand

$$p_y Y^b = p_y(C^b_y + \dot{K}^b_y + \delta_y K^b_y) + B^b_y \tag{vi}$$

$$Z^b = C^b_z + \dot{K}^b_z + \delta_z K^b_z + G^b \tag{vii}$$

$$p^b_m n^b x^b = P_m C^b_m + B^b_m \tag{viii}$$

Assets

$$A^b = n^b v^b + p_y K_y^b + p_z^b K_z^b + F^b = a^b + F^b \quad \text{(ix)}$$

$$\dot{A}^b = r^b A^b + w_L^b L^b + w_H^b H^b - \frac{n^b \Gamma_i^b s^b}{\Lambda} - C^b \quad \text{(x)}$$

Eastern Debt and World Balanced Trade Condition

$$\begin{aligned} \text{if } F^W < \phi a^e \text{ then } r^W &= r^E = r \text{ and } \dot{F}^W = r^W F^W + B_y^W + B_m^W \\ \text{otherwise } r^W &\neq r^E \text{ and } \phi \dot{a}^E = r^W \phi a^E + B_y^W + B_m^W \end{aligned} \quad \text{(xi)}$$

$$B_y^E + B_m^E + B_y^W + B_m^W = 0 \quad \text{(xii)}$$

Capital Returns

$$R_y^b = p_y[r^b + \delta_y - \frac{\dot{p}_y}{p_y}] \quad \text{(xiii)}$$

$$R_z^b = p_z^b[r^b + \delta_z - \frac{\dot{p}_z^b}{p_z^b}] \quad \text{(xiv)}$$

Traditional Sectors

$$p_z^b = \Gamma_z^b(\mathbf{w^b}, \mathbf{R^b}) \quad \text{(xv)}$$

$$p_y = \Gamma_y^b(\mathbf{w^b}, \mathbf{R^b}) \quad \text{(xvi)}$$

Manufacturing Sector

$$p_m^b = \frac{\Gamma_m(\mathbf{w^b}, \mathbf{R^b})}{\alpha} \quad \text{(xvii)}$$

$$\pi^b = (1-\alpha) p_m^b x^b \quad \text{(xviii)}$$

Aggregate Price Indices

$$P_m = \left[n^E (p_m^E)^{1-\epsilon} + n^W (p_m^W)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \quad \text{(xix)}$$

$$P^b = P_m^{\theta_m^b} p_y^{\theta_y^b} (p_z^b)^{\theta_z^b} \quad \text{(xx)}$$

Financial Sector

$$v^b = \frac{\Gamma_i(\mathbf{w^b}, \mathbf{R^b})(1-s^b)}{\Lambda} \quad \text{(xxi)}$$

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} \geq r^b \quad \text{(xxii)}$$

World Knowledge Capital

$$\Lambda = \frac{n^E + n^W}{N} \tag{xxiii}$$

Factor Equilibrium

$$\frac{a^b_{Li}}{\Lambda}\dot{n}^b + a^b_{Lm}n^b x^b + a^b_{Ly}Y^b + a^b_{Lz}Z^b = L^b \tag{xxiv}$$

$$\frac{a_{Hi}}{\Lambda}\dot{n}^b + a^b_{Hm}n^b x^b + a^b_{Hy}Y^b + a^b_{Hz}Z^b = H^b \tag{xxv}$$

$$\frac{a^b_{K_y i}}{\Lambda}\dot{n}^b + a^b_{K_y m}n^b x^b + a^b_{K_y y}Y^b + a^b_{K_y z}Z^b = {K_y}^b \tag{xxvi}$$

$$\frac{a_{K_z i}}{\Lambda}\dot{n}^b + a^b_{K_z m}n^b x^b + a^b_{K_z y}Y^b + a^b_{K_z z}Z^b = {K_z}^b \tag{xxvii}$$

Assume (xxii) holds with equality so innovation occurs in both blocs. Four of these equations, (xi), (xii), (B.10) and (xxiii) refer to the world, the remaining 23 to each bloc. For the case where the credit constraint binds, this gives us $4 + 2 \times 23 = 50$ equations in total in endogenous variables C^b_z, C^b_y, C^b_m, C^b, x^b, Y^b, Z^b, K^b_y, K^b_z, B^b_y, B^b_m, n^b, p^b_m, π^b, p^b_z, W^b, v^b, r^b, P^b, w^b_L, w^b_H, R^b_y, R^b_z, $b = E, W$ and p_y, P_m, Λ which total $23 \times 2 + 3 = 49$ variables. Where the credit constraint does not bind $r^W = r^E$ but we have one more endogenous variable F^W.

There appears to be too many equations. However our general equilibrium model describes an equilibrium in world traded output, and in non-traded output, the financial sector and labour markets in each bloc. By Walras' law we know one of the latter equilibrium conditions is in each bloc superfluous. If we eliminate one financial market relationship describing A^b then we can dispense with equation (ix) reducing the equations by 4 and the variables by 2. In fact, for the case of capital immobility with $B^b = 0$ from (ix) and (x) and (xxii), a little algebra gives

$$C^b + v^b\dot{n^b} + p_y\dot{K}^b_y + p^b_z\dot{K}^b_z = w^b_L L^b + w^b_H H^b + n^b\pi^b + (r^b + \delta)(p_y K^b_y + p^b_z K^b_z) \tag{41}$$

which is a national income identity equating expenditure (C^b) and investment in shares issued to finance new blue prints ($v^b\dot{n^b}$) plus investment in physical capital with labour income plus profits. Therefore, we can dispense with (ix) and (x). This leaves us with 46 equations in 47 endogenous variables – one equation short. However, there is nothing to pin down the price level in our model and we are free to choose any nominal variable as the numeraire.

3 The Steady State

Assume consumer preferences are identical in East and West. We also confine ourselves to the case of capital immobility (i.e, $\phi = 0$ in (xi). We seek a balanced-growth steady state in which shares of manufacturing varieties $\xi^b = \frac{n^b}{n}$ are constant, the growth of varieties in the world produced by each bloc are equal and constant; i.e., $\dot{n}/n = \dot{n^E}/n^E = \dot{n^W}/n^W = g$, all prices, wage rates, nominal consumption, nominal output and total nominal financial wealth (nv) are all constant. Then we have $\dot{v^b}/v^b = -g\,; b = E, W$, $\dot{P}/P = \theta_m g/(1-\epsilon) = -\theta_m g(1-\alpha)/\alpha < 0$ and $\Lambda = n/N$. Let $X^b = n^b x^b$ be manufacturing output. Then the steady state takes the form

$$
\begin{aligned}
r &= \rho + \frac{1-\alpha}{\alpha}\theta_m g\left(\frac{1}{\sigma} - 1\right) && (42)\\
A^b &= n^b v^b + p_y K^b + p_z^b K_z = N\xi^b\Gamma_i(\mathbf{w}^b, \mathbf{R}^b)(1-s^b) + p_y K_y^b + p_z^b K_z^b && (43)\\
p_y &= \Gamma_y^E(\mathbf{w}^E, \mathbf{R}^E) = \Gamma_y^W(\mathbf{w}^W, \mathbf{R}^W) && (44)\\
p_m^b &= \frac{1}{\alpha}\Gamma_m^b(\mathbf{w}^b, \mathbf{R}^b) && (45)\\
p_y Y^b &= \theta_y C^b + \delta p_y K_y^b + B_y^b && (46)\\
p_z^b Z^b &= \theta_z C^b + \delta p_z^b K_z^b && (47)\\
p_m^b X^b &= \theta_m C^b + B_m^b && (48)\\
B_y^b + B_m^b &= 0 && (49)\\
R_y^E = R_y^W &= p_y(r+\delta) && (50)\\
R_z^b &= p_z^b(r+\delta) && (51)\\
r + g &= \frac{1-\alpha}{\alpha}\frac{\Gamma_m^b(\mathbf{w}^b, \mathbf{R}^b)}{\Gamma_i^b(\mathbf{w}^b, \mathbf{R}^b)(1-s^b)}X^b && (52)\\
L^b &= N\xi^b a_{Li}^b(\mathbf{w}^b, \mathbf{R}^b)g + a_{Lm}^b(\mathbf{w}^b, \mathbf{R}^b)X + a_{Ly}^b(\mathbf{w}^b, \mathbf{R}^b)Y^b && (53)\\
H^b &= N\xi^b a_{Hi}^b(\mathbf{w}^b, \mathbf{R}^b)g + a_{Hm}^b(\mathbf{w}^b, \mathbf{R}^b)X^b + a_{Hy}^b(\mathbf{w}^b, \mathbf{R}^b)Y^b && (54)\\
K_y^b &= N\xi^b a_{K_y i}^b(\mathbf{w}^b, \mathbf{R}^b)g + a_{K_y m}^b(\mathbf{w}^b, \mathbf{R}^b)X^b + a_{K_y y}^b(\mathbf{w}^b, \mathbf{R}^b)Y^b && (55)\\
K_z^b &= N\xi^b a_{K_z i}^b(\mathbf{w}^b, \mathbf{R}^b)g + a_{K_z m}^b(\mathbf{w}^b, \mathbf{R}^b)X^b + a_{K_z y}^b(\mathbf{w}^b, \mathbf{R}^b)Y^b && (56)\\
\xi_E + \xi^W &= 1 && (57)
\end{aligned}
$$

giving 30 equations in 30 variables g, r, R_y, p_y and A^b, p_m^b, X^b, Y^b, K_y^b, K_z^b, B_m^b, B_y^b, ξ^b, C^b, R_z^b, $\mathbf{w}^b = [w_L^b, w_H]^b$, $b = E, W$. We choose nominal GDP as the numeraire. Exogenous parameters driving the equilibrium are ρ, α, σ, θ_m, θ_y (describing the preferences of consumers), the depreciation rates δ, technology parameters T_j^b, γ_{kj}, η_j, ξ_j; $k = 1, 2, \cdots, 3$, $j = y, z, m, i$, for the four sectors of the traditional good, manufacturing and R&D and exogenous endowment proportions L^b and H^b.

The additional relationship which is rendered superfluous by Walras' Law is

$$C^b = r^b A^b + w_L^b L^b + w_H^b H^b - \xi^b \Gamma_i^b(\mathbf{w}^b, \mathbf{R}^b) s^b \tag{58}$$

GDP is defined as value added in the R&D sector ($\dot{n}^b v^b$), plus that in the m, y and z sectors: i.e., by

$$\mathrm{GDP}^b = \xi^b \Gamma_i^b g + p_m^b X^b + p_y Y^b + p_z^b Z^b \tag{59}$$

in the steady state. Define as proportions of nominal GDP $m^b = p_m^b X^b / GDP^b$ and similarly define y^b and z^b for bloc $b = E, W$. Define the R&D and consumption shares as $rd^b = 1 - x^b - y^b - z^b = \Gamma_i^b \xi^b g / GDP^b$ and $c^b = C^b / GDP^b$ respectively. Define relative GDP as $rel^E = GDP^E / GDP^W$. Then the steady state becomes:

$$\begin{aligned}
\frac{w_L^b a_{Li}^b}{\Gamma_i^b} rd^b + \frac{w_L^b a_{Lm}^b}{p_m^b} m^b + \frac{w_L^b a_{Ly}^b}{p_y} y^b + \frac{w_L^b a_{Lz}^b}{p_z^b} z^b &= \frac{w_L^b L^b}{GDP^b} \equiv wageL^b \\
\frac{w_H^b a_{Hi}^b}{\Gamma_i^b} rd^b + \frac{w_H^b a_{Hm}^b}{p_m^b} m^b + \frac{w_H^b a_{Hy}^b}{p_y} y^b + \frac{w_H^b a_{Hz}^b}{p_z^b} z^b &= \frac{w_H^b H^b}{GDP^b} \equiv wageH^b \\
\frac{a_{K_y i}^b}{\Gamma_i^b} rd^b + \frac{a_{K_y m}^b}{p_m^b} m^b + \frac{a_{K_y y}^b}{p_y} y^b + \frac{a_{K_y z}^b}{p_z^b} z^b &= \frac{1}{\delta p_y}(y^b + m^b - (\theta_m + \theta_y) c^b) \\
\frac{a_{K_z i}^b}{\Gamma_i^b} rd^b + \frac{a_{K_z m}^b}{p_m^b} m^b + \frac{a_{K_z y}^b}{p_y} y^b + \frac{a_{K_z z}^b}{p_z^b} z^b &= \frac{1}{\delta p_y}(z^b - \theta_z c^b) \\
\frac{rel^E rd^E}{\Gamma_i^E} + \frac{rd^W}{\Gamma_i^W} &= g
\end{aligned}$$

$$
\begin{aligned}
r &= \rho + \left(\frac{1}{\sigma} - 1\right)\frac{\theta_m g}{\epsilon - 1} \\
R_y &= p_y^W(r+\delta) \\
R_z^W &= p_z^W(r+\delta) \\
R_z^E &= p_z^E(r+\delta) \\
\Gamma_y^W &= \Gamma_y^E \\
(r+g)rd^W &= (1-\alpha)m^W g \\
(r+g)rd^E &= (1-\alpha)m^E g \\
m^W + rel^E m^E &= \theta_m(c^W + rel^E c^E) \\
\frac{m^W}{m^E} &= \frac{\Gamma_i^E rd^W}{\Gamma_i^W rd^E}\left(\frac{p_m^W}{p_m^E}\right)^{1-\epsilon}
\end{aligned}
$$

Noting that $p_m^b = \frac{\Gamma_m^b}{\alpha}$, $p_y = \Gamma_y^b$ and $p_z^b = \Gamma_z^b$, this gives us 18 equations in endogenous variables x^b, y^b, z^b, c^b, $wageL^b$, $wageH^b$, R_z^b $(b = E, W)$, R_y, r, rel^E and g. When there is no R&D in the East then $rd^E = x^E = 0$. Nominal Western GDP is chosen as our numeraire.

4 Immigration and Welfare

We now turn to the balanced growth steady state of the full model as set above. Our calculations of the immigration surplus are based on pre- and post-migration equilibria and require distinguishing between the asset accumulation of migrants and the host country workers.

4.1 Asset Accumulation following Migration

At time t let $M_l(t)$, $l = L, H$ be the numbers of Eastern households of type l who have migrated in the post-migration state. Let $\bar{L}^b$ and $\bar{H}^b$ be the pre-migration levels of post-migration steady states of the two skill types. Then the working populations of the two skill types are given by

$$
\begin{aligned}
L^E &= \bar{L}^E - M_L\,;\; L^W = \bar{L}^W + M_L \\
H^E &= \bar{H}^E - M_H\,;\; H^W = \bar{H}^W + M_H \qquad (60)
\end{aligned}
$$

We make no distinction between the worker of the same skill type in the two blocs. Nor do we allow for discrimination against immigrants in the Western labour market. As a consequence the only change on the supply side arises from the numbers of workers of each type. However the consumption/savings decisions of the migrants must be considered separately.

Following migration starts we need consider three *residential* groups of workers: migrants who have settled in the West; the remaining residents in the East and non-migrants in the West. We use a superscript $q = M, N, E$ to refer to these these groups. Thus Western assets can now be divided into those held by the M and N groups; i.e., $A_l^W = A_l^M + A_l^N$ for each skill type $l = L, H$. Similarly consumption in the West by the l-type can be written $C_l^W = C_l^M + C_l^N$. Assume that migrants accumulate their assets in the West. Aggregating over skill types as before and writing $A^q = A_L^q + A_H^q$, $q = M, N, E$ and $A^b = A_L^b + A_H^b$, and similarly for consumption, the household budget constraints for migrants, non-migrants in the West and remaining workers in the East are then given by

$$\dot{A}^M = r^W A^M + w_L^W M_L + w_H^W M_H - T^M - C^M \tag{61}$$

$$\dot{A}^N = r^W A^N + w_L^W (L^W - M_L) + w_H^W (H^W - M_H) - T^N - C^N \tag{62}$$

$$\dot{A}^E = r^E A^E + w_L^E L^E + w_H^E H^E - T^E - C^E \tag{63}$$

Aggregating (61) and (62) gives

$$\dot{A}^W = r^W A^W + w_L^W L^W + w_H^W H^W - C^W \tag{64}$$

where T^q are taxes paid by group q. Thus, with our three assumptions – homogeneous labour of the same skill type between blocs, no discrimination against immigrants and migrants invest their assets with in the West – the budget constraints, consumption and savings decisions aggregate in a straightforward manner. The only economic effect on the aggregate economies arises from the change in working populations given by (60). However the welfare of our six groups need to be calculated separately and this requires that the assets of each group are carefully identified following migration from East to West.

Total assets in the West of which groups $q = N, M$ have some share are given by $\bar{A}^W = \bar{\xi}^W \bar{\Gamma}_i + \bar{p}_y \bar{K_y}^W + \bar{p}_z^W \bar{K_z}^W$ in the pre-migration state owned by the total pre-migration population) and $A^W = \xi^W \Gamma_i + p_y K_y^W + p_z^W K_z^W$ after migration that increases the total Western population to $N^W = (1 + M)\bar{N}^W$ where $M = \frac{M_L + M_H}{\bar{N}^W}$ is the total migration rate. First consider the accumulation of the physical capital component of these assets. For the y-sector, after migration, in the new steady state $K_y^W - \bar{K}_y^W$ of capital accumulates which now has value $p_y(K_y^W - \bar{K}_y^W)$. Migrants don't bring capital with them, but do save and share in the newly accumulated capital and acquire $\frac{M}{1+M}p_y(K_y^W - \bar{K}^W)$ leaving non-migrants with their initial holding, now valued at p_y and their share of the new capital, $\frac{1}{1+M}p_y(K^W - \bar{K}^W)$. Treating capital in the z-sector and equity similarly we arrive at the total assets of Western non-migrants and migrants as

$$A^N = \frac{\Gamma_i(M\bar{\xi}^W + \xi^W)}{1+M} + \frac{p_y(M\bar{K}_y^W + K_y^W)}{1+M} + \frac{p_z^W(M\bar{K}_z^W + K_z^W)}{1+M} \quad (65)$$

$$A^M = \frac{M\Gamma_i(\xi^W - \bar{\xi}^W)}{1+M} + \frac{Mp_y(K_y^W - \bar{K}_y^W)}{1+M} + \frac{Mp_z^W(K_z^W - \bar{K}_z^W)}{1+M} \quad (66)$$

In the East remaining households own all the assets $A^E = \xi^E\Gamma_i^E + p_yK_y^E + p_z^EK_z^E$.

Finally we need to divide assets between skilled and non-skilled households within categories $q = N, M.E$. We assume this division corresponds their labour income; i.e.,

$$\bar{A}_L^N = \frac{\bar{w}_L^W\bar{L}^W}{\bar{w}_L^W\bar{L}^W + \bar{w}_H^W\bar{H}^W}\bar{A}^N\,;\ \bar{A}_H^N = \frac{\bar{w}_H^W\bar{H}^W}{\bar{w}_L^W\bar{L}^W + \bar{w}_H^W\bar{H}^W}\bar{A}^N$$

in the pre-migration state with an analogous division in the post-migration state. We have now determined holdings of assets for skilled and unskilled non-migrants in the West, migrants and non-migrants remaining in the East before and after migration. We now turn to the calculations of welfare for these six groups.

4.2 Welfare Calculations

Given steady state assets and labour income we can now determine total consumption of unskilled non-migrants from (62) in the pre-migration state as

$$\bar{C}_L^N = \bar{r}\bar{A}_L^N + \bar{w}\bar{L} - T_L^N$$

with obvious analogous expressions for the post-migration state, for skilled non-migrants and for the other four group, $q = M, E$ $l = L, H$. We are now in a position to calculate the immigration surplus based on the change in utility following migration

The utility of non-migrants group of skill type $l = L, H$ is given by

$$U_l^N(t) = \int_t^\infty e^{-\rho(\tau-t)}\left\{\frac{[(C_{ml}^N)^{\theta_m}(C_{yl}^N)^{\theta_y}]^{1-1/\sigma} - 1}{1-1/\sigma}\right\}d\tau; \quad \sum_{i=m,y}\theta_i = 1, \sigma \neq 1;$$

Consider T periods after migration and assume T is large enough for the model to have reached its new balanced-growth steady state. Then $\dot{n}/n = g$, its steady state value, or $n(t) = n(T)e^{g(t-T)}$ for $t > T$. Then the steady-state welfare is calculated as:

$$\begin{aligned} U_l^N &= \frac{1}{1-1/\sigma}\left[\frac{(C_l^N/\tilde{P})^{1-1/\sigma}n(T)^{\theta_m(1-1/\sigma)/(\varepsilon-1)}}{\rho-\theta(1-1/\sigma)g/(\varepsilon-1)} - \frac{1}{\rho}\right];\ l = L, H \\ &= U_l^N(C_l^N, n(T), g) \end{aligned} \tag{67}$$

say, where $\tilde{P} = \left(\frac{p_m}{\theta_m}\right)^{\theta_m}\left(\frac{p_y}{\theta_y}\right)^{\theta_y}$.

To calculate the *welfare based immigration surplus* we compare the utility before and after migration at the same pre-migration level of varieties, $n(T) = \bar{n}$, say. We measure this change in utility in terms of an *equivalent permanent consumption change* as follows. Let ΔU_l^q be change in utility coming about from a 1% permanent change in consumption at the pre-migration steady state at $n(T) = \bar{n}$ calculated by perturbing consumption in (67). Then using the notation indicated in the latter equation, the immigration surplus for the two types of worker, in terms of an equivalent % change in utility, is obtained as

$$\text{Immigration Surplus} = \frac{U_l^N(C_l^N, \bar{n}, g) - U_l^N(\bar{C}_l^N, \bar{n}, \bar{g})}{\Delta U_l^N};\ l = L, H \tag{68}$$

Note that this expression is independent of our choice of $\bar{n}$. Similarly we define the welfare gain in terms of equivalent permanent changes in consumption for the migrants and the remaining Eastern residents as

$$\text{Migration Surplus} = \frac{U_l^M(C_l^M, \bar{n}, g) - U_l^M(\bar{C}_l^M, \bar{n}, \bar{g})}{\Delta U_l^M};\ l = L, H \tag{69}$$

$$\text{Emigration Surplus} = \frac{U_l^E(C_l^N, \bar{n}, g) - U_l^E(\bar{C}_l^E, \bar{n}, \bar{g})}{\Delta U_l^E};\ l = L, H \tag{70}$$

4.3 The Migration Equilibrium

An incentive to migrate exists for skill type $l = L, H$ only if the intertemporal utility following migration exceeds that if the household remains in the East. Let $u_l^M = \frac{U_l^M}{M_l^M}; l = L, H$ be the utility per migrant and $u_L^E = \frac{U_L^E}{L_E}$ and $u_H^E = \frac{U_H^E}{H_E}$ be the utility of remaining households of skill types L and H respectively. Then an incentive to migrate exists for each skill type only if the economic benefit from migration $u_l^M - u_l^E > 0\ l = L, H$. The necessary and sufficient condition for migration is that the benefit must exceed the cost. These costs are the actual cost of migration and those associated with the preference for consumption in one's home country arising from cultural differences between the blocs, links with family and friends etc. We assume that these costs are some fixed proportion of the no-migration utility, i.e., $m_l u_l\,; l = L, H$, where the fixed proportion, m_l, can differ between the skill types. Then equating the cost of migration with the benefits gives the condition for a migration equilibrium in a *laissez-faire* migration regime as

$$u_l^M = (1 + m_l)u_l^E \; l = L, H \tag{71}$$

5 Calibration

To relate the model to the European economies, the first requirement of the exercise is to identify which types of labour relate to the categories of 'skilled' and unskilled' and which sectors constitute traditional, high-tech manufacturing and R&D. We will assume identical consumer preferences for migrants and non-migrants.

To carry out the simulations the following parameter values are required:

Utility Weights, Elasticities and Discount Rates: θ_m, θ_y, σ, α and ρ.

Capital Depreciation Rate: δ.

Production Function Weights, Elasticities and Total Factor Productivities: γ_{kj}, $k = 1, 3$; $j = m, y, i$, $\quad \eta_j$, $\xi_j, j = m, y, i$, $\quad T_j$, $j = m, y, i$.

Pre-Migration unskilled and skilled labour proportions: $(\bar{L}, \bar{H})$

The procedure commonly referred to as the 'microeconomic approach' to calibration (see, for example the discussion in Shoven and Whalley (1992)) chooses values for weights in utility and production functions to be consistent with observations of data in the form of averages of sector shares, factor shares within each sector, the real interest rate and the growth rate over a number of years. Elasticities in production are selected using econometric estimates. Our baseline calibration assumes Cobb-Douglas production technology, but in order to investigate the case where skilled labour and capital are complements rather than substitutes we also present simulations with a generalized CES production function of the form

$$Y_j = T_j \left[\gamma_{1j} L_j^{\eta} + (1 - \gamma_{1j})[\gamma_{2j} H_j^{\xi} + (1 - \gamma_{2j}) K_j^{\xi}]^{\eta/\xi} \right]^{\frac{1}{\eta}}$$

in sector $j = y, m, i$ where Y_j denotes output in sectors $j = y, m$ and $\dot{n}/\Lambda$ in the innovative sector. Then all the parameters are re-calibrated so that the steady state of the model is consistent with the original data. Notice we assume μ and η are the same in all three sectors.

We use econometric estimates for σ and depreciation rates, and various sources on price mark-ups for α. From Appendix C the following are chosen: $\sigma = 0.4$, $\delta = 0.1$ and $\alpha = 0.7$. In the pre-migration equilibrium this leaves parameters $[T_i, \rho, \theta_m, \{\gamma_{kj}\}, k = 1, 2;\ j = y, m, i] = \Theta$, say, to calibrate. Then $\theta_y = 1 - \theta_m$ completes the calibration.

On the production side, units of output and factor inputs can be chosen such that $T_m = T_y = 1$.[6] Let s_{Lj}, s_{Hj} be the factor shares of unskilled and skilled workers respectively in sector $j = i, m, y$ as evaluated in the balanced growth steady state of our model. Denote data for these shares by $\hat{s}_{Lj}$, $\hat{s}_{Hj}$. Let $\widehat{\frac{p_m X}{p_y Y}}$ be data for the relative nominal outputs in the manufacturing and traditional sectors respectively. Similarly let data on the real interest rate, the long-term growth rate be denoted by $\hat{r}$ and $\hat{g}$ respectively. Given parameters Θ, we can then solve for the balanced growth steady state with values $g(\Theta)$, $r(\Theta)$, $p_m(\Theta)X(\Theta)$, $p_y(\Theta)Y(\Theta)$, $s_{Lj}(\Theta)$, $s_{Hj}(\Theta)$, $j = i, m, y$. Given data for these variables we can then solve

$$\begin{aligned} g(\Theta) &= \hat{g} \\ r(\Theta) &= \hat{r} \\ s_{Lj}(\Theta) &= \hat{s}_{Lj}\,;\ j = i, m, y \\ s_{Hj}(\Theta) &= \hat{s}_{Hj}\,;\ j = i, m, y \\ \frac{p_m(\Theta)X(\Theta)}{p_y(\Theta)Y(\Theta)} &= \frac{\widehat{p_m X}}{p_y Y} \end{aligned}$$

To calibrate m_l we use estimates of migration flows provided by a number of sources. Then we solve the model with M_L and M_H fixed at these estimates, say $\hat{M}_L$ and $\hat{M}_H$ to give utilities $u_l^M(\hat{M}_L,\hat{M}_H)$ and $u_l^E(\hat{M}_L,\hat{M}_H)$. Then from (71) we calibrate m_l as

$$m_l = \frac{u_l^M(\hat{M}_L, \hat{M}_H) - u_l^E(\hat{M}_L, \hat{M}_H)}{u_l^E(\hat{M}_L, \hat{M}_H} \quad l = L, H \tag{72}$$

[6] We choose units of output, skilled and unskilled labour and capital such that $L_j = H_j = K_j = 1$ results in one unit of output in sector $j = y, m$. Then in our constant returns to scale CES production function we have that $T_j = 1$.

Data	Value	Source
$\hat{r}$	0.03	stylized
$\hat{g}$	0.07	stylized
$p_m X$	0.36	Burda and Hunt (2001)
$p_y Y$	0.64	Burda and Hunt (2001)
s_{Ly}	0.27	Keuschnigg and Kohler (1999a, 1999b)
s_{Hy}	0.43	Keuschnigg and Kohler (1999a, 1999b)
s_{Lm}	0.17	Keuschnigg and Kohler (1999a, 1999b)
s_{Hm}	0.50	Keuschnigg and Kohler (1999a, 1999b)
s_{Li}	0.076	Keuschnigg and Kohler (1999a, 1999b)
s_{Hi}	0.882	Keuschnigg and Kohler (1999a, 1999b)

Table 1. Data used in Calibration

For data, we choose $\hat{r} = 0.03$ and $\hat{g} = 0.07$. Since all growth in our model is concentrated in the manufacturing sector of size θ_m, this gives long-term GDP growth as $\theta_m \hat{g} = 2.4\%$ in our calibration. The remaining data on factor and sector shares are discussed in the Appendix and summarized in Table 1. Table 2 summarizes the baseline calibration.

In our results the size of the R&D sector is around 5%. In Appendix C we review estimates of the size of the R&D which suggest a value around only 2%. However some R&D must be contained within unobserved 'intangible' investment which Parente and Prescott (2000) suggest may be as high as 40% of GDP. The size of actual as opposed to observed R&D in our model is therefore not implausible. Note also that our simulations show a skilled/unskilled wage ratio of 2:1 which is reasonable, given the broad definition of 'skilled' labour that makes it half the working population.

Parameter	Value	Source
$\bar{H}$	0.5	Keuschnigg and Kohler (1999a, 1999b)
$\bar{L}$	0.5	ditto
σ	0.4	Ogaki and Reinhart (1998)
α	0.7	Keuschnigg and Kohler (1999a, 1999b)
δ	0.1	Canova et al (1994, 1996, 2000)
μ_j, η_j, $j = m, y, i$	0.0 (i.e., Cobb-Douglas)	Hammermesh (1993), GTAP
T_i	1.18	Calibrated
ρ	0.01	Calibrated
θ_m	0.46	Calibrated
γ_{ky} ; $k = 1, 2$	$\gamma_{1y} = 0.27$, $\gamma_{2y} = 0.59$	Calibrated
γ_{km} ; $k = 1, 2$	$\gamma_{1m} = 0.17$, $\gamma_{2m} = 0.60$	Calibrated
γ_{ki} ; $k = 1, 2$	$\gamma_{1i} = 0.076$, $\gamma_{2i} = 0.95$	Calibrated

Table 2. Summary of Baseline Calibration

6 Results

We now turn to numerical solutions of the steady state using the calibrated parameter values set out in table 1. We begin with two identical blocs where factor endowments of the two types of labour and total factor productivity (TFP) are the same. Then in the first subsection we allow the TFP in all Eastern sectors to fall below that of the West. For a particular choice of TFP in the East we next examine changes in the pattern of trade as Eastern skill composition changes. In the subsequent two subsections we then examine the effect of East-West migration with different skill compositions.

6.1 Changes in Eastern Total Factor Productivity

Figures 1 to 6 show various endogenous variables of interest as the TFP in the East fall to one third of that in the West in the case where labour endowments are equal East and West; i.e., $H^E = L^E = H^W = L^W$. The most striking result of Eastern inefficiency is that the rate at which new varieties are produced in its R&D sector falls. Furthermore the West must produce more of the traditional good itself. Consequently, as a result of these two effects, world growth falls substantially, as seen in figure 1. This change is accompanied by sector shifts shown in figures 2 to 4 and wage changes (relative to Western nominal GDP) in figure 5. There are two effects on the Western share of innovative goods. First the East produces less of everything including its traded good and the West must divert resources towards this sector. The Western share of innovative goods then falls. But as Eastern TFP falls further total productions in all sectors falls to a point where the Western share starts to rise. Eventually as TFP in the East gets smaller and smaller it must in effect disappear as a trading partner and the Western share will approach unity. Figure 6 measures the 'migratory' pressure' as the relative West-East wage rates for the two types of labour. Clearly from this figure as TFP in the East falls then the pressure for unskilled labour grows more quickly than unskilled labour.

6.2 Changes in the Eastern Skill Composition

Figures 7 to 12 fixes the West-East TFP ratio at $TFP^W/TFP^E = 1.75$ and examines the effect of the skill composition in the East falling from $H^E = 0.25$ to $H^E = 0.20$. Now the West has a comparative advantage for skill-intensive innovative activity. The R&D and high-tech sectors in the East now diminishes in size and production shifts to its traditional sector. The opposite happens in the West and its share of innovative goods rises. In the integrated two-country world the fall in the world's share of skilled labour sees the relative skilled-unskilled wage rates rising in both countries equally and therefore no change in the migratory pressure occurs. The incentives to engage in skill-intensive R&D diminish and therefore the growth rate falls.

6.3 East-West Migration

In the next two sections we consider the second case where the East is relatively less endowed with skilled labour with $L^W = H^W = 0.25$, whereas $L^E = 0.3$ and $H^E = 0.2$. In addition TFP is less in the East and we put $TFP^W = 1.75TFP^E$.

6.3.1 Migration with no Skill Bias

Figures 13 to 21 shows the effect of a 10% increase in the Western population from immigration with no skill bias in its composition. An increase in growth now occurs of 0.25%

which is almost entirely the result of a movement of workers from a country with a low TFP to one with a high TFP. All sectors in the West grow as they absorb the immigrant workers. The transfer of workers from a less to a more efficient R%D sector sees the Western share of new products rise and world growth rises. The consequent increase in demand for high skill labour causes the relative skill-unskilled wage in both blocs to rise. There is a small rise in the Western R&D share rd^W and a small decrease'in rd^W.

The effect of these changes on welfare is summarised in figures 14 to 17. Figure 17 shows the world surplus worked out as the equivalent % permanent change in consumption for a representative household consisting of skilled and unskilled workers, East and West at weighted according to post-migration proportions. The maximum world surplus is around 9% when migration reaches 10% of the Western workforce. This breaks down into 1% for Western skilled workers, about 0.5% for native unskilled workers, giving an *immigration surplus* of around 0.85% for the representative Western native household (figure 14). For those remaining in the East skilled workers gain by over 0.75%, unskilled workers lose by -1.35% giving an *emigration deficit* for the representative Eastern non-migrant of about -1.2% (figure 15). Finally figure 16 shows that the representative migrant gains by a substantial 200%.

6.3.2 Skilled Migration with Remittances

Our next set of simulations in figures 22-30 look at the effect of a 10% increase in the Western population consisting of skilled workers. Now there are additional reallocation effects in both blocs arising from the changes in the proportions of skilled to unskilled workers. Taken together with the efficiency effect of a movement from a less to a more efficient economy, growth now rises by over 0.5% (figure 22). The world surplus now rises to 11% (figure 26). The immigration surplus is almost 12% for unskilled natives, -2.5% for skilled natives averaging at almost 6 % (figure 23). The emigration surplus is 17% for skilled, -50% for unskilled averaging at -10% (figure 24), but both skilled and unskilled migrants gain substantially again (figure 25).

The main result that is emerging is that migration of all types of workers from a low to a high TFP region of the world can increase growth, but in the absence of some distribution mechanism there are winners and losers, with remaining non-migrants in the latter category. The reason is that the East sees a reduction in its share of high tech goods which involve a price mark-up over marginal cost, and the relative wage of the unskilled workers fall. Indeed from figure 28 skilled migration of over 5% of the West workforce sees the R&D and high-tech sectors disappear altogether in the East.

One possible distribution mechanism is through remittance between migrants and their families remaining in the East. Figures 31 and 32 show the effects of skilled migrants remitting a given percentage of their income ranging between 0% and 50%. Assuming that families are either entirely skilled or unskilled, these remittances will end up in the pocket of skilled households in the East. This group were winners in the absence of remittances (see figure 24) so remittances in themselves do not mitigate the distributional effects of migration. However if we assume that intra-country distributional mechanisms exist, or that households are of mixed skilled type, then we can focus on the representative household in both blocs. Then from figures 31 we see that for any remittance rate above around 35%, migrants remain substantial winners, and the Eastern representative household begins to emerge as a winner. These welfare effects with remittances are summarized in table 3.

Type of Migration	Growth Effect (%)	IS (%)	ES (%)
Unbiased	0.3	0.85	-1.2
Skilled	0.5	5.5	-8.0
Skilled with 50% remittances	0.5	5.5	7

Table 3. Growth, Immigration Surplus (IS), Emigration Surplus (ES) of Representative Households.

6.4 Changes in the Migration Equilibrium

Up to now we have studied the economic effects of a a given level of migration of a particular skill type. Our final set of steady-state simulations *endogenizes* the migration decision and examines the migration equilibrium set out in section 4.3. This depends on the migration cost parameters m_L and m_H which were calibrated using (72) to produce an endogenous baseline 10% migration rate (as a % of the Western population), equally divided between skilled and unskilled workers. The remaining parameter values are as in section 6.3.

Figures 33 and 34 allow a small decrease in the West-East TFP ratio from its baseline 1.75 (i.e., a small increase in Eastern relative efficiency). By exploring two different numerical search procedures we ere able to locate *two migration equilibria*. The first in figure 33 sees the migration rates for both skill types falling sharply as Eastern efficiency increases slightly. This shift in the working populations from the West to the less productive East results in a drop in the global growth rate. The second, less intuitive, migration equilibrium sees the migration rate of the skilled workers actually *increasing* but more than offset by a decrease in the unskilled rate. The global growth rate again falls, but by slightly less.

6.5 Stability and Transitional Dynamics

Up to now we have studied the balanced-growth steady state of the model. The full dynamic model has transitional dynamics and could in principle be unstable in the vicinity of the steady state. The full dynamic model set out in Appendix B has been set up in WINSOLVE and confirms numerically that the model indeed is saddle-path stable, for central parameter values. We also examine the speed of convergence towards the steady state.[7]

7 Conclusions and Future Research

Our results may be summarised as follows

1. This paper examines the impact of East-West European migration of different skill compositions where the East is characterized by a lower TFP and a lower skill-unskilled labour ratio calibrated to reproduce observed differences in the size of the traditional and high-tech sectors in the two regions.

2. East-West migration induces two effects: an *efficiency effect* from the more efficient use of labour in the West and a *sectoral reallocation effect* arising from the change in the skilled-unskilled wage rates. The first effect is studied by examining migration with no skill bias and the second by examining migration of exclusively skilled labour.

[7]The next version of this paper will report these simulations.

3. Both types of migration result in a increase in world growth in the steady state. Skilled-labour migration results in a shift out of the high-tech sector in the East so that eventually at a level of migration over to 5% of the Western population that sector disappears altogether. Then Eastern specialization in traditional sectors occurs.

4. Despite growth gains there are winners and losers. With skilled migration, skilled households gain in the East and lose out in the West. The representative West household gains but its Eastern counterpart loses out. The overwhelming winner is the migrant herself. An important redistributive mechanism that can mitigate these distributional effects is the existence of *remittances*. In our simulations a remittance rate of around 35% still leaves the skilled migrant better of and sees the representative household in the East joining her counterpart in the West as a winner.

There are a number of ways in which the model presented here can be developed. First, our model of the migration decision results in a the migration equilibrium that is implausibly sensitive to very small changes in Eastern relative TFP. Alternative ways of modelling this decision to capture migration sluggishness observed in previous enlargements, needs to be explored. Second, we have assumed away labour market imperfections. There are many ways of modelling these: the search-matching approach to migration and wage-stickiness of Ortega(2000) is one promising direction to go. Third, fiscal instruments can be made available to the policy-maker such as a migrants' tax. Fourth, there are unexplored issues associated with the modelling of endogenous growth. The removal of scale effects can be handled in other ways (see, for example, Segerstrom, 1998, Li 2000). We have restricted capital formation to traditional sectors for theoretical convenience. It is not obvious how to obtain balanced growth paths with constant prices if we allow for capital formation in the high-tech expanding sector and this needs to be investigated further.

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A Cost and Unit Factor Requirement Functions

We consider a general CES production function with only one type of physical capital $K_y = K_z = K$, say. (The generalization to two types is obvious throughout).

$$Y_j = \left[\gamma_{1j} L_j^\eta + (1-\gamma_{1j})[\gamma_{2j} H_j^\xi + (1-\gamma_{2j}) K_j^\xi]^{\eta/\xi}\right]^{\frac{1}{\eta}} \tag{A.1}$$

in sector $j = y, m, i$ where Y_j denotes output in sectors $j = y, m$ and $\dot{n}/\Lambda$ in the innovative sector. To ease the notation we drop the j-subscript in what follows. In in the limit as η and ξ tends to 0, (A.1) tends to the Cobb-Douglas form

$$Y = TL^{\gamma_1} H^{(1-\gamma_1)\gamma_2} K^{(1-\gamma_1)(1-\gamma_2)}$$

Consider the minimization of total costs given by $\Gamma = [w_L L + w_H H + RK]$ such that output Y is fixed and given by $Y^\eta = \gamma_1 L^\eta + (1-\gamma_1)[\gamma_2 H^\xi + (1-\gamma_2)K^\xi]^{\eta/\xi}$. To carry out this optimization problem define a Lagrangian

$$\mathcal{L} = \Gamma - \lambda \left[Y^\eta - \gamma_1 L^\eta - (1-\gamma_1)[\gamma_2 H^\xi + (1-\gamma_2)K^\xi]^{\eta/\xi}\right]$$

Then minimizing with respect to L, H and K leads to the first-order conditions:

$$\frac{\partial \mathcal{L}}{\partial L} = w_L + \lambda \gamma_1 \eta L^{\eta-1} = 0 \tag{A.2}$$

$$\frac{\partial \mathcal{L}}{\partial H} = w_H + \lambda(1-\gamma_1)\eta[\gamma_2 H^\xi + (1-\gamma_2)K^\xi]^{\frac{\eta}{\xi}-1}\gamma_2 H^{\xi-1} = 0 \tag{A.3}$$

$$\frac{\partial \mathcal{L}}{\partial K} = R + \lambda(1-\gamma_1)\eta[\gamma_2 H^\xi + (1-\gamma_2)K^\xi]^{\frac{\eta}{\xi}-1}(1-\gamma_2)K^{\xi-1} = 0 \tag{A.4}$$

Dividing (A.3) by (A.4), and (A.2) by (A.3) we can eliminate the Lagrange multiplier to arrive at

$$\frac{w_H}{R} = \frac{\gamma_2}{1-\gamma_2}\left(\frac{H}{K}\right)^{\xi-1} \tag{A.5}$$

$$\frac{w_L}{w_H} = \frac{\gamma_1}{(1-\gamma_1)\gamma_2}\left(\frac{L}{H}\right)^{\eta-1}\left[\gamma_2 + (1-\gamma_2)\left(\frac{K}{H}\right)^\xi\right]^{1-\frac{\eta}{\xi}} \tag{A.6}$$

Before proceeding let us see if these relationships make sense. First let $\eta = \xi$ and check for symmetry. Then (A.6) becomes

$$\frac{w_L}{w_H} = \frac{\gamma_1}{(1-\gamma_1)\gamma_2}\left(\frac{L}{H}\right)^{\xi-1}$$

which corresponds to (A.5) with the relative weights appropriately adjusted. Next consider the Cobb-Douglas case $\eta = \xi \to 0$. Then we have the familiar factor share results:

$$\frac{w_H H}{RK} = \frac{\gamma_2}{1-\gamma_2} \tag{A.7}$$

$$\frac{w_L L}{w_H H} = \frac{\gamma_1}{(1-\gamma_1)\gamma_2} \tag{A.8}$$

After further algebraic manipulation, using these results one can show that the unit cost function is given by

$$\Gamma = \frac{1}{T}\left[\gamma_1^{\frac{1}{1-\eta}} w_L^{\frac{\eta}{\eta-1}} + (1-\gamma_1)^{\frac{1}{1-\eta}} c^{\frac{\eta}{\eta-1}}\right]^{\frac{\eta-1}{\eta}}$$

where

$$c = \left[\gamma_2^{\frac{1}{1-\xi}} w_H^{\frac{\xi}{\xi-1}} + (1-\gamma_2)^{\frac{1}{1-\xi}} R^{\frac{\xi}{\xi-1}}\right]^{\frac{\xi-1}{\xi}}$$

Then unit factor requirements a_L, a_H and a_K are given by

$$a_L = \frac{\partial \Gamma}{\partial w_L} = T^{\frac{\eta}{1-\eta}}\left[\frac{w_L}{\gamma_1 \Gamma}\right]^{\frac{1}{\eta-1}}$$

$$a_H = \frac{\partial \Gamma}{\partial w_L} = T^{\frac{\eta}{1-\eta}}\left[\frac{c}{(1-\gamma_1)\Gamma}\right]^{\frac{1}{\eta-1}}\left[\frac{w_H}{\gamma_2 \Gamma}\right]^{\frac{1}{\xi-1}}$$

$$a_K = \frac{\partial \Gamma}{\partial w_L} = T^{\frac{\eta}{1-\eta}}\left[\frac{c}{(1-\gamma_1)\Gamma}\right]^{\frac{1}{\eta-1}}\left[\frac{R}{(1-\gamma_2)\Gamma}\right]^{\frac{1}{\xi-1}}$$

B Dynamic Set-up for Simulation

This set-up applies to the model set out where capital is perfectly immobile; i.e., $\phi = 0$. First we define shares of manufacturing varieties $\xi^b = \frac{n^b}{n}$; $b = E, W$ where $n = n^E + n^W$ is the total number. Then differentiating we have the equations

$$\dot{\xi}^W = (1-\xi^W)g - \zeta^E; \quad \xi^E = 1 - \xi^W \tag{B.9}$$

where $\zeta^E = g^E \xi^E$, the growth rate of E multiplied by its share of innovative goods.

Next we define non-trended price indices

$$\tilde{P}_m = \left[(1-\xi^W)^E (p_m^E)^{1-\epsilon} + \xi^W (p_m^W)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{B.10}$$

$$\tilde{P}^b = \tilde{P}_m^{\theta_m^b} p_y^{\theta_y^b} (p_z^b)^{\theta_z^b} \tag{B.11}$$

so that

$$
\begin{aligned}
P_m &= n^{\frac{1}{1-\epsilon}} \tilde{P}_m \\
P^b &= n^{\frac{1}{1-\epsilon}} \tilde{P}^b
\end{aligned}
$$

Then the dynamics of consumption are given by

$$
\frac{1}{\sigma} \frac{\dot{C}^b}{C^b} = r^b - \rho^b + \left(\frac{1}{\sigma^b} - 1 \right) \left(\frac{\theta_m^b g}{1-\epsilon} + \frac{\dot{\tilde{P}}^b}{\tilde{P}^b} \right) \tag{B.12}
$$

Note (as discussed above) that $\epsilon = \frac{1}{1-\alpha}$ is an average across blocs.

The consumption demand equations are unchanged:

$$
\begin{aligned}
C_z^b &= \frac{\theta_z^b C^b}{p_z^b} && \text{(B.13)} \\
C_y^b &= \frac{\theta_y^b C^b}{p_y} && \text{(B.14)} \\
P_m C_m^b &= \theta_m^b C^b && \text{(B.15)}
\end{aligned}
$$

Note that (B.15) is treated as an equation in the non-trended variable $P_m C_m$.

Write total manufacturing output in bloc b as $X^b = n^b x^b$. Then the capital stock equations can be written (after first combining (vi), (viii) and (xii) which, for the case of capital immobility, becomes $B_y^b + B_m^b = 0$; $b = E, W$) as

$$
\begin{aligned}
\dot{K}_y^b &= -C_y^b - \delta K_y^b + Y^b + (p_m^b X^b - P_m C_m^b)/p_y && \text{(B.16)} \\
\dot{K}_z^b &= Z^b - C_z^b - \delta K_z^b - G^b && \text{(B.17)}
\end{aligned}
$$

Using (iv) X^b is given by

$$
X^b = \frac{\xi^b (\theta_m^E C^E + \theta_m^W c^W)(p_m^b)^{-\epsilon}}{\tilde{P}_m^{1-\epsilon}} \tag{B.18}
$$

Capital returns are given by

$$
\begin{aligned}
R_y^b &= p_y [r^b + \delta - \frac{\dot{p}_y}{p_y}] && \text{(B.19)} \\
R_z^b &= p_z^b [r^b + \delta - \frac{\dot{p}_z^b}{p_z^b}] && \text{(B.20)}
\end{aligned}
$$

The non-traded traditional sector and manufacturing prices are straightforward:

$$
\begin{aligned}
p_z^b &= \Gamma_z^b(\mathbf{w^b}, \mathbf{R^b}) && \text{(B.21)} \\
p_m^b &= \frac{\Gamma_m(\mathbf{w^b}, \mathbf{R^b})}{\alpha} && \text{(B.22)}
\end{aligned}
$$

However, from the traded traditional sector we have one equation which defines p_y, while equating the two representations of this price yields a relationship for one of the wages:

$$p_y = \Gamma_y^W(\mathbf{w^W}, \mathbf{R^W}) \tag{B.23}$$

Before we do this it is useful to define following unit cost functions.

B.1 CES Case

$$\Gamma_l^b = \frac{1}{T_l^b}\left((W_l^b)^{\frac{\eta_l}{\eta_l-1}} + (c_l^b)^{\frac{\eta_l}{\eta_l-1}}\right)^{\frac{\eta_l-1}{\eta_l}} \tag{B.24}$$

(for $l = i, m, y, z$) where

$$W_l^b = \left(\gamma_{1l}(w_L^b/\gamma_{1l})^{\frac{\mu_l}{\mu_l-1}} + \gamma_{2l}(w_H^b/\gamma_{2l})^{\frac{\mu_l}{\mu_l-1}}\right)^{\frac{\mu_l-1}{\mu_l}} \tag{B.25}$$

$$c_l^b = \left(\gamma_{3l}(R_y^b/\gamma_{3l})^{\frac{\xi_l}{\xi_l-1}} + \gamma_{4l}(R_z^b/\gamma_{4l})^{\frac{\xi_l}{\xi_l-1}}\right)^{\frac{\xi_l-1}{\xi_l}}. \tag{B.26}$$

Note that unit factor requirements a_L , a_H etc are given by

$$a_{Ll}^b = \frac{\partial \Gamma_l^b}{\partial w_L^b} = \frac{\gamma_1^{\frac{1}{1-\mu_1}}}{(T_l^b)^{\eta_l/(\eta_l-1)}}\left(\frac{W_l^b}{\Gamma_l^b}\right)^{\frac{1}{\eta_l-1}}\left(\frac{w_L^b}{W_l^b}\right)^{\frac{1}{\mu_l-1}} \tag{B.27}$$

We now solve from the two representations of p_y to yield:

$$w_L^W = \left((T_y^W\Gamma_y^E)^{\frac{\eta_y}{\eta_y-1}} - (c_y^W)^{\frac{\eta_y}{\eta_y-1}})^{\frac{\mu_y}{\mu_y-1}\frac{\eta_y-1}{\eta_y}} - \gamma_{2y}(w_H^W/\gamma_{2y})^{\frac{\mu_y}{\mu_y-1}}\right)^{\frac{\mu_y-1}{\mu_y}} \tag{B.28}$$

For knowledge capital, we take the simplest representation, resulting from $\kappa = \infty$; with the total world labour force normalised to 1, this gives $\Lambda = n$.

We have to solve for r^b. The interest rates can be obtained from the no-arbitrage conditions, which reduce to

$$r^b = \frac{\dot{v}^b}{v^b} + \frac{1-\alpha}{\alpha}\frac{\Gamma_m^b x_i^b}{v^b}; \qquad \text{with } v^b = \frac{\Gamma_i^b}{n}.$$

Therefore,

$$r^b = -g + \frac{\dot{\Gamma}_i^b}{\Gamma_i^b} + \frac{1-\alpha}{\alpha}\frac{\Gamma_m^b X^b}{\Gamma_i^b \xi^b} \tag{B.29}$$

where we recall that $\xi^W + \xi^E = 1$.

The remaining 8 factor equilibrium equations are now used to solve for $g, \zeta^E, Y^W, Y^E, Z^W$, Z^E, w_L^E, w_H^E. Thus the equations for L^W and H^W can be inverted to yield

$$g = \zeta^E + (L^W - a_{Lm}^W X^W - a_{Ly}^W Y^W - a_{Lz}^W Z^W)/a_{Li}^W \tag{B.30}$$

$$\zeta^E = g - (H^W - a_{Hm}^W X^W - a_{Hy}^W Y^W - a_{Hz}^W Z^W)/a_{Hi}^W \tag{B.31}$$

Similarly, we invert all the capital stock equations to yield the supplies of traditional goods:

$$Y^W = ({K_y}^W - a_{K_y i}^W (g - \zeta^E) - a_{K_y m}^W X^W - a_{K_y z}^W Z^W)/a_{K_y y}^W \tag{B.32}$$

$$Y^E = ({K_y}^E - a_{K_y i}^E \zeta^E - a_{K_y m}^E X^E - a_{K_y z}^E Z^E)/a_{K_y y}^E \tag{B.33}$$

$$Z^W = ({K_z}^W - a_{K_z i}^W (g - \zeta^E) - a_{K_z m}^W X^W - a_{K_z y}^W Y^W)/a_{K_z z}^W \tag{B.34}$$

$$Z^E = ({K_z}^E - a_{K_z i}^E \zeta^E - a_{K_z m}^E X^E - a_{K_z y}^E Y^E)/a_{K_z z}^E \tag{B.35}$$

Finally, using the expressions above for the factor input shares for labour, we can invert the equations for L^E and H^E to yield

$$w_L^E = W_y^E \left[\left(\frac{\Gamma_y^E}{W_y^E} \right)^{\frac{1}{\eta-1}} \frac{(T_y^E)^{\eta/(\eta-1)}}{Y^E} (L^E - a_{Li}^E - a_{Lm}^E X^E - a_{Lz} Z^E) \right]^{\mu-1} \tag{B.36}$$

$$w_H^E = W_y^E \left[\left(\frac{\Gamma_y^E}{W_y^E} \right)^{\frac{1}{\eta-1}} \frac{(T_y^E)^{\eta/(\eta-1)}}{Y^E} (H^E - a_{Hi}^E - a_{Hm}^E X^E - a_{Hz} Z^E) \right]^{\mu-1} \tag{B.37}$$

This completes the set-up for the core model with capital immobility. The numbered equations (B.9) to (B.37) constitute the WinSolve set-up describing 30 equations in variables given on the lhs. Predetermined dynamic variables are ξ^b, K_y^b, K_z^b. For these we need to specify *initial conditions*: $\xi^b(0), K_y^b(0), K_z^b(0)$. Forward-looking jump-variables are $C^b, \tilde{P}^b, p_y, p_z^b, \Gamma_i^b$ and g and for these we need *terminal conditions*. Then $C^b(0), \tilde{P}^b(0), p_y(0)$, $p_z^b(0), \Gamma_i^b(0)$ and $g(0)$ are determined endogenously in the solution.

B.2 Cobb-Douglas Case

Here the cost functions are replaced by

$$\Gamma_l^b = \frac{1}{T_l^b} (w_L^b/\gamma_{1l})^{\gamma_{1l}} (w_H^b/\gamma_{2l})^{\gamma_{2l}} (R_y^b/\gamma_{3l})^{\gamma_{3l}} (R_z^b/\gamma_{4l})^{\gamma_{4l}} \tag{B.38}$$

and the unit factor requirements by terms of the form

$$a_{Ll}^b = \gamma_{1l} \Gamma_l^b / w_L^b \tag{B.39}$$

The expression for w_L^W is now

$$w_L^W = \gamma_{1l}[\Gamma_y^E T_y^W (w_H^W/\gamma_{2y})^{-\gamma_{2y}} (R_y^W/\gamma_{3y})^{-\gamma_{3y}} (R_z^W/\gamma_{4y})^{-\gamma_{4y}}]^{1/\gamma_{1y}} \tag{B.40}$$

and the wage equations for the east are now

$$w_L^E = \frac{\gamma_{1y}\Gamma_y^E Y^E}{L^E - a_{Li}^E \zeta^E - a_{Lm}^E X^E - a_{Lz} Z^E} \tag{B.41}$$

$$w_H^E = \frac{\gamma_{2y}\Gamma_y^E Y^E}{H^E - a_{Hi}^E \zeta^E - a_{Hm}^E X^E - a_{Hz} Z^E} \tag{B.42}$$

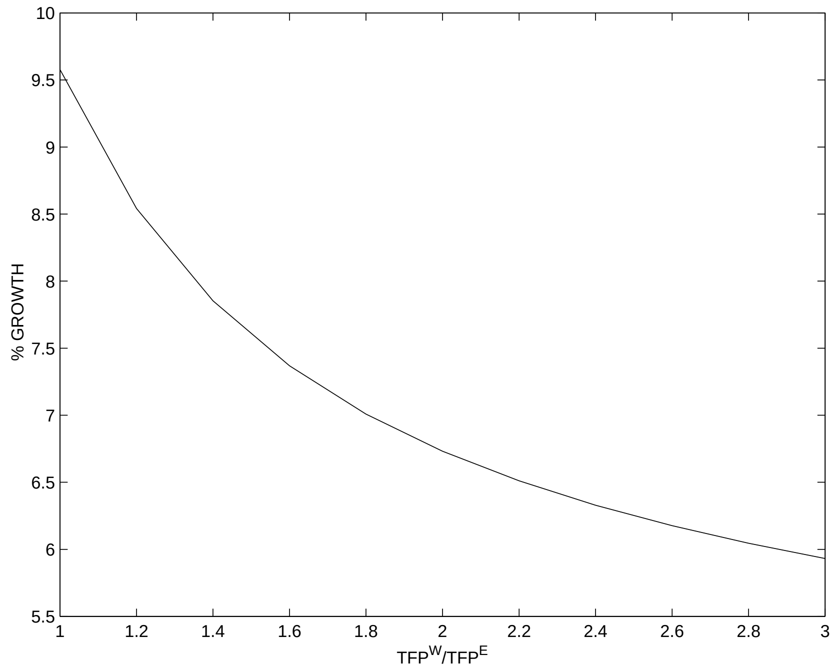

Figure 1: **WORLD GROWTH:** $H^E = L^E = H^W = L^W = 0.25$

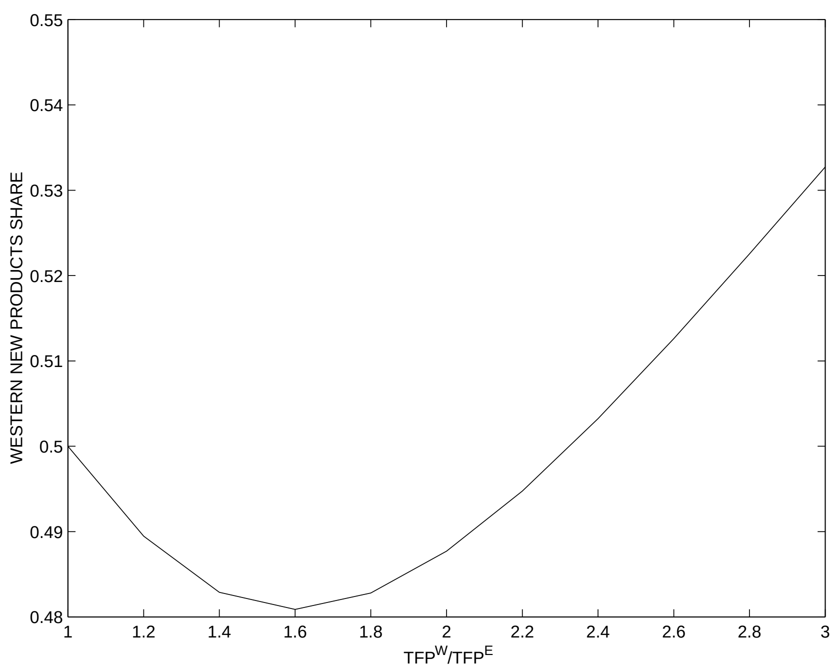

Figure 2: **WESTERN SHARE OF NEW PRODUCTS:** $H^E = L^E = H^W = L^W = 0.25$

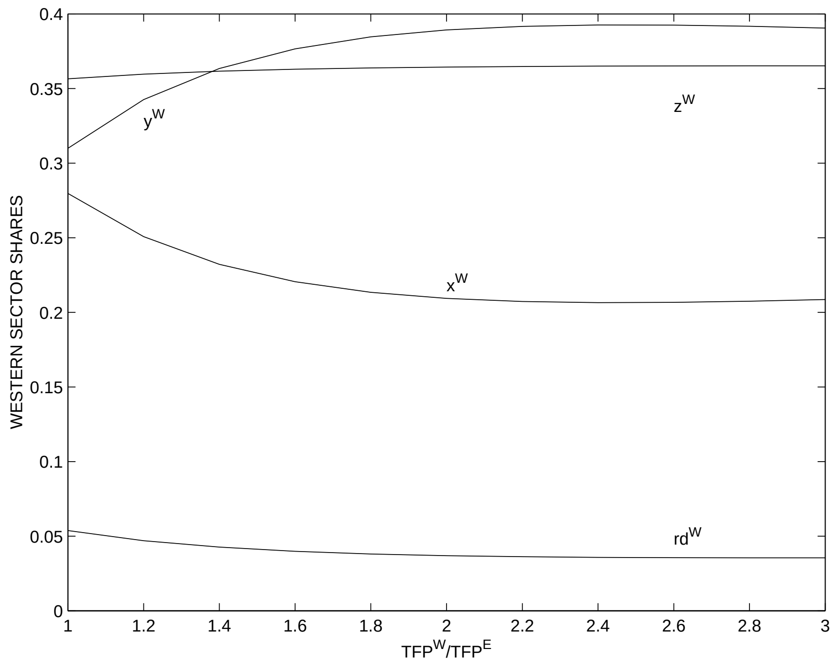

Figure 3: **WESTERN SECTOR SHARES:** $H^E = L^E = H^W = L^W = 0.25$

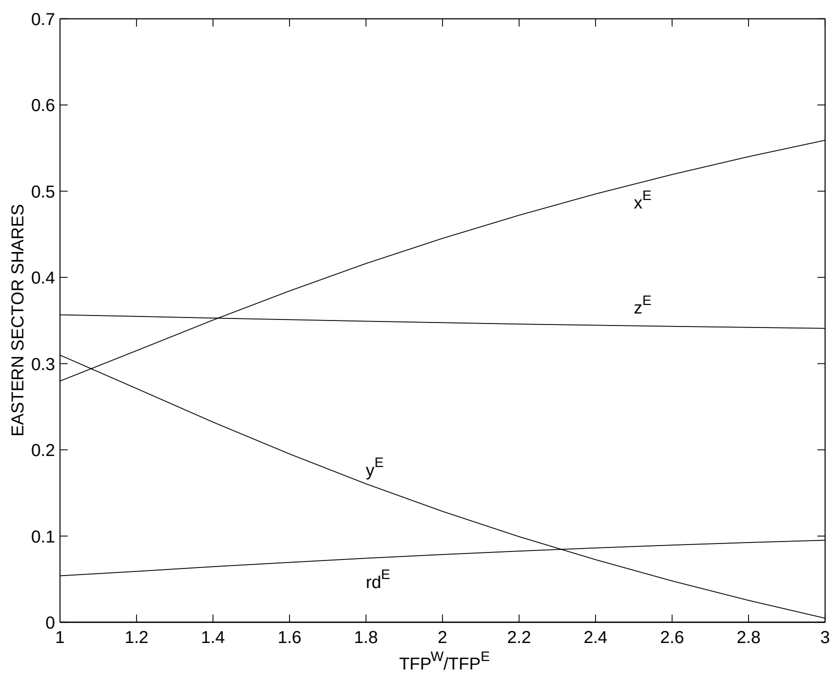

Figure 4: **EASTERN SECTOR SHARES:** $H^E = L^E = H^W = L^W = 0.25$

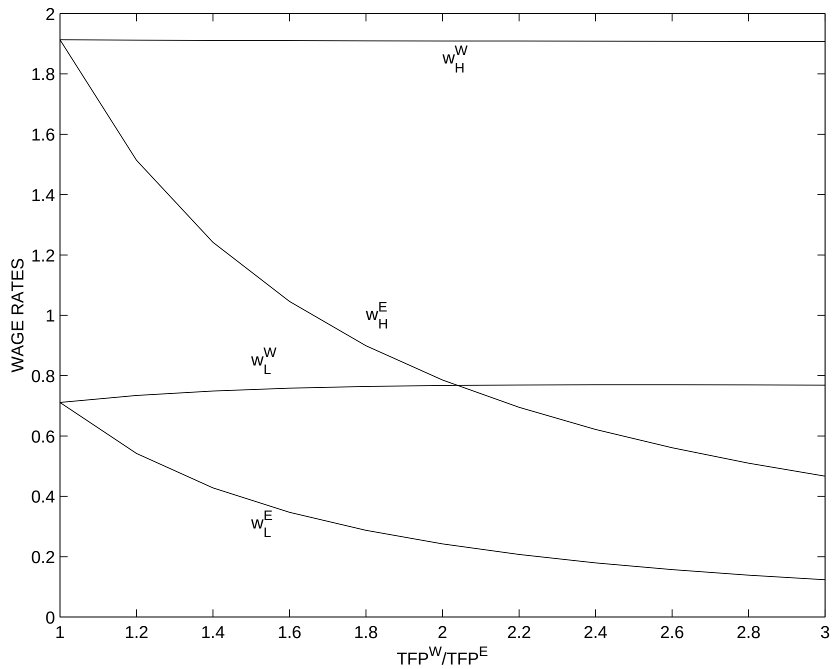

Figure 5: **WAGE RATES:** $H^E = L^E = H^W = L^W = 0.25$

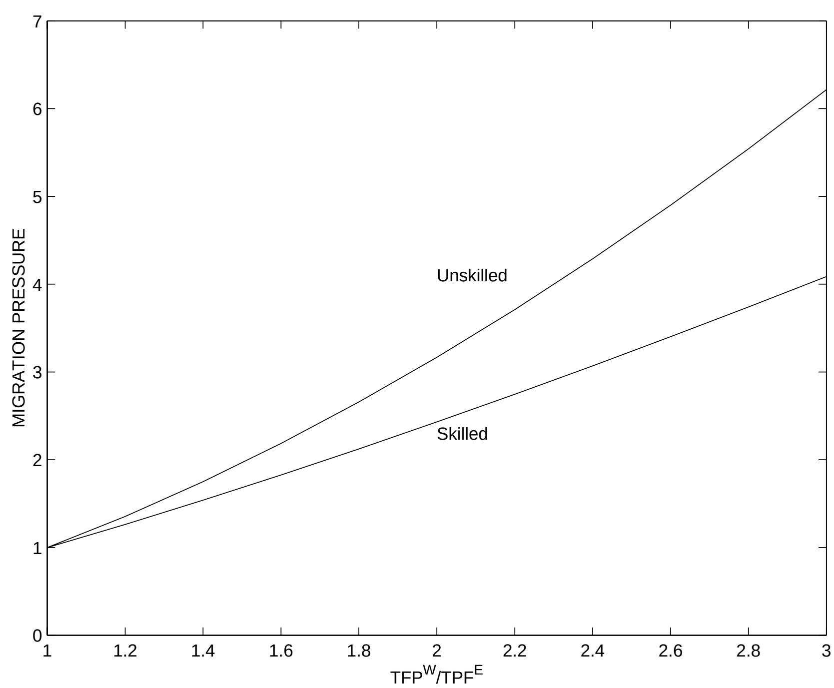

Figure 6: **MIGRATION PRESSURE: WEST-EAST WAGE RATIOS:** $H^E = L^E = H^W = L^W = 0.25$

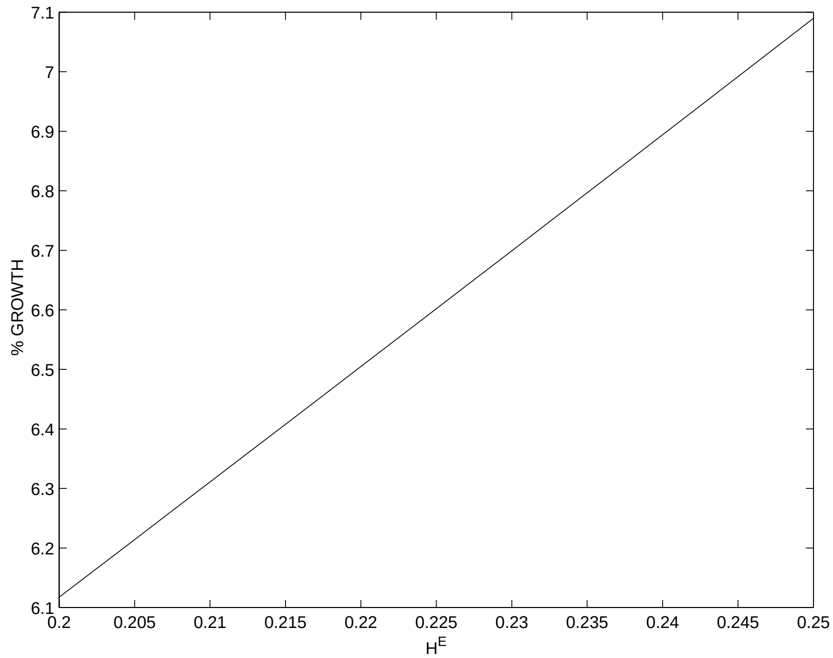

Figure 7: **WORLD GROWTH:** $TFP^W/TFP^E = 1.75$

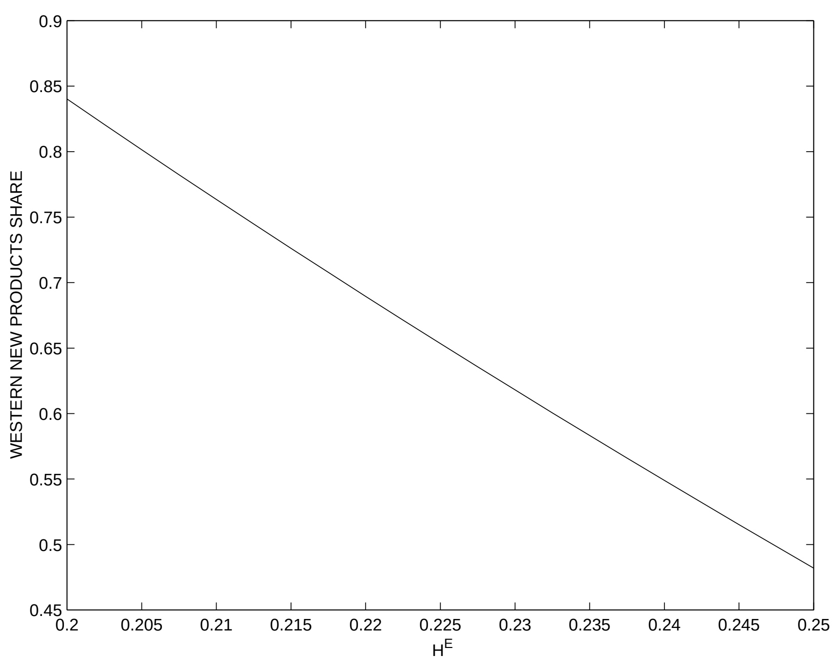

Figure 8: **WESTERN SHARE OF NEW PRODUCTS:** $TFP^W/TFP^E = 1.75$

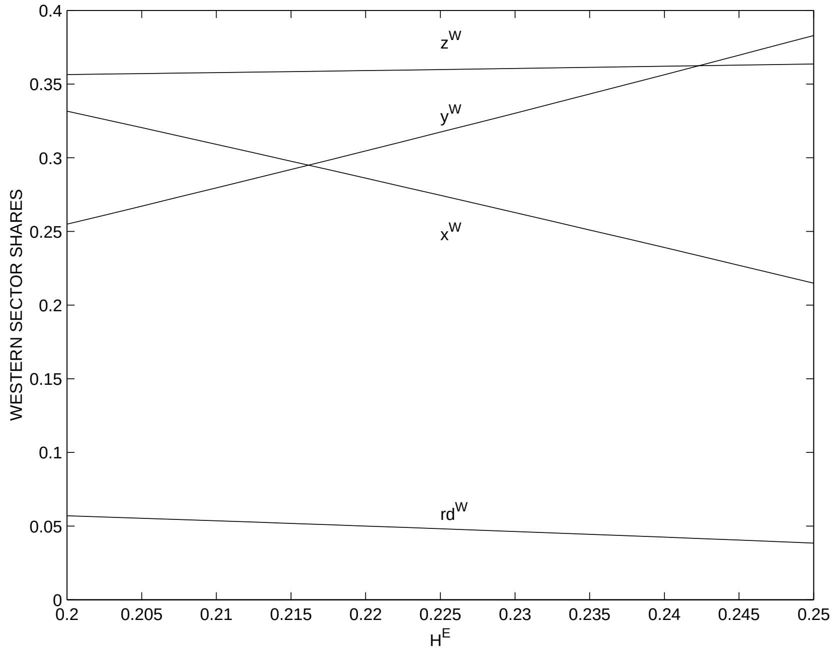

Figure 9: **WESTERN SECTOR SHARES:** $TFP^W/TFP^E = 1.75$

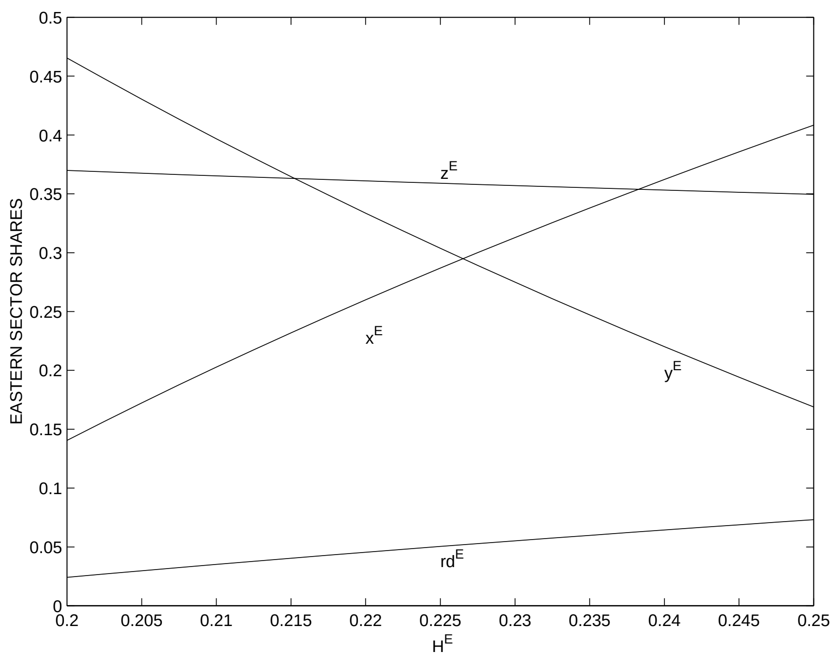

Figure 10: **EASTERN SECTOR SHARES:** $TFP^W/TFP^E = 1.75$

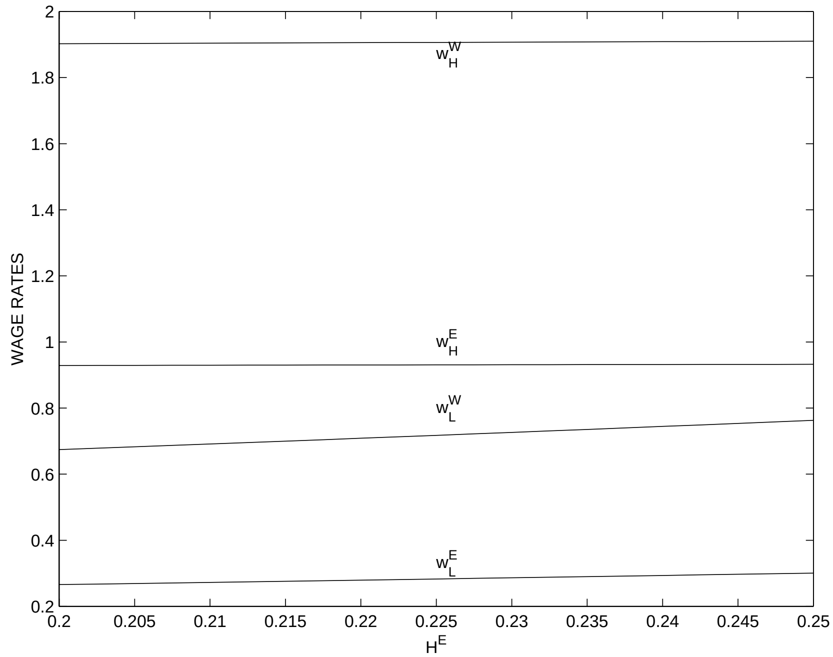

Figure 11: **WAGE RATES:** $TFP^W/TFP^E = 1.75$

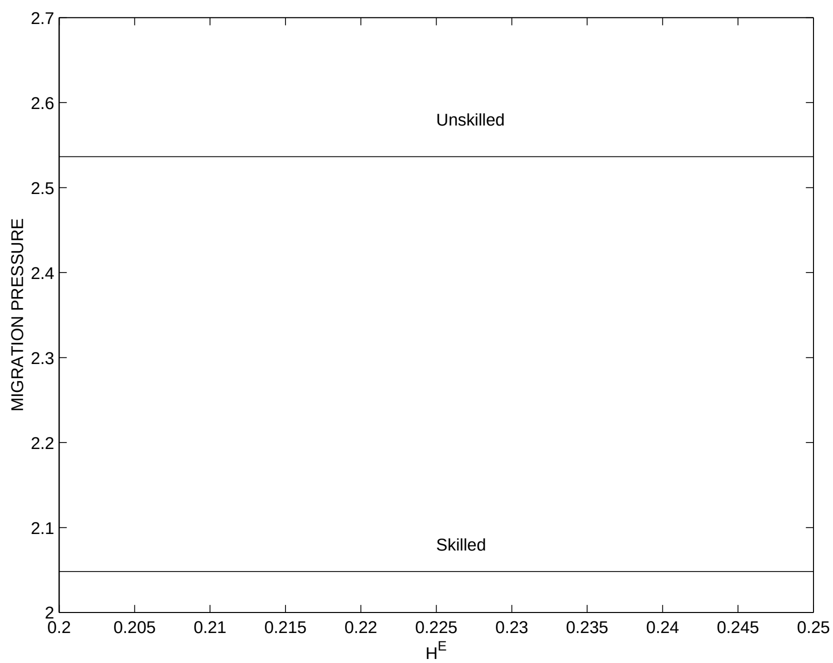

Figure 12: **MIGRATION PRESSURE: WEST-EAST WAGE RATIOS:** $TFP^W/TFP^E = 1.75$

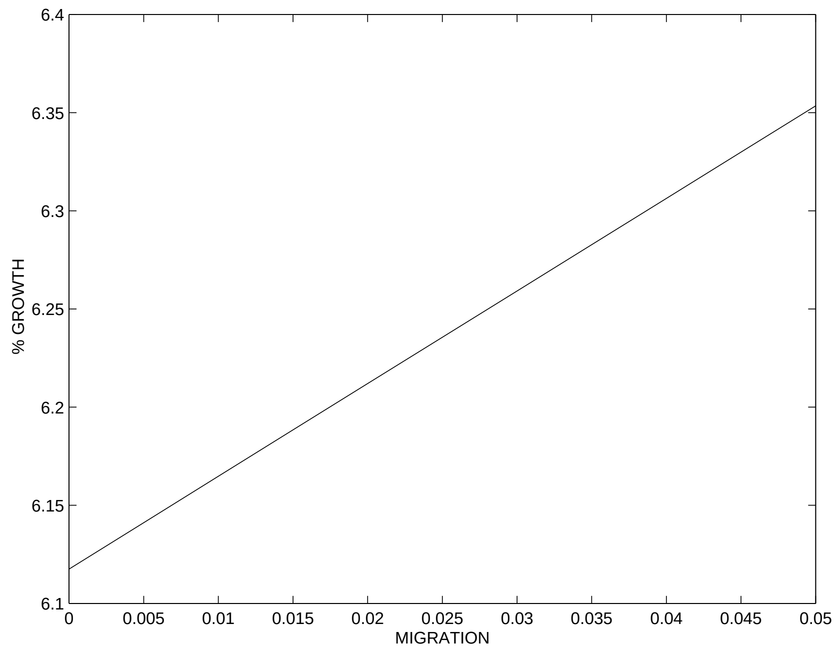

Figure 13: **WORLD GROWTH. Pre-Migration Labour:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

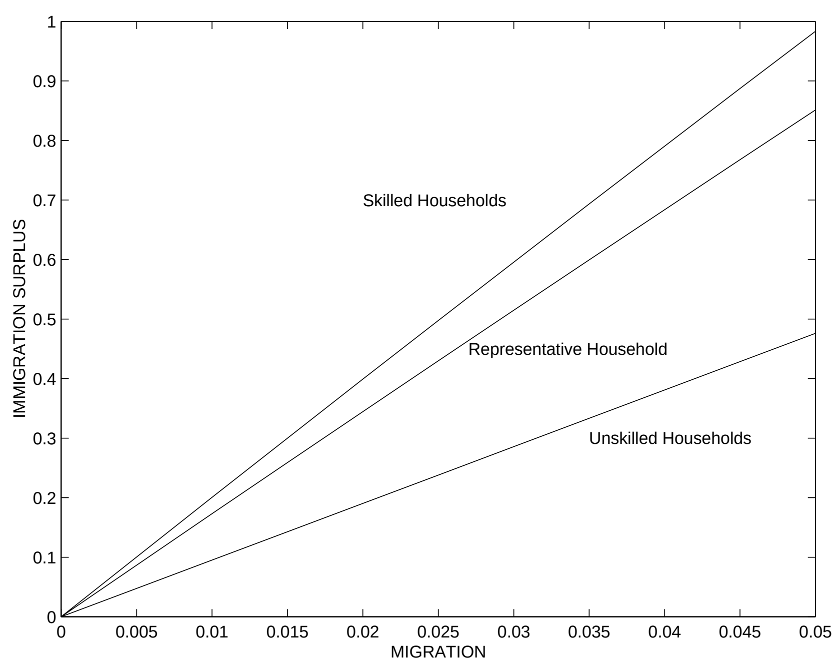

Figure 14: **IMMIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$ **;** $TFP^W = 1.75TFPE$

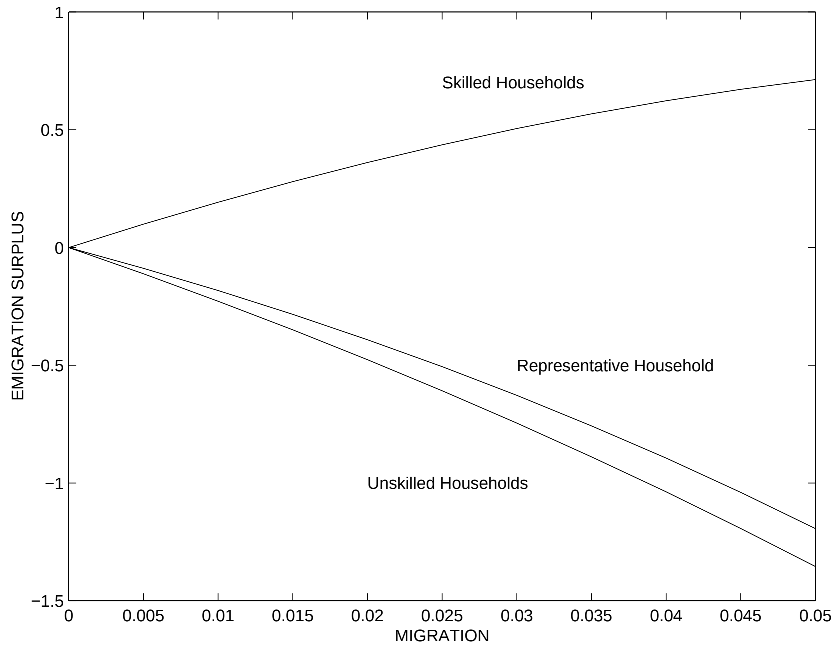

Figure 15: **EMIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\ L^E = 0.30\,;\ H^W = L^W = 0.25\,$**;** $TFP^E = 0.5TFP^W$

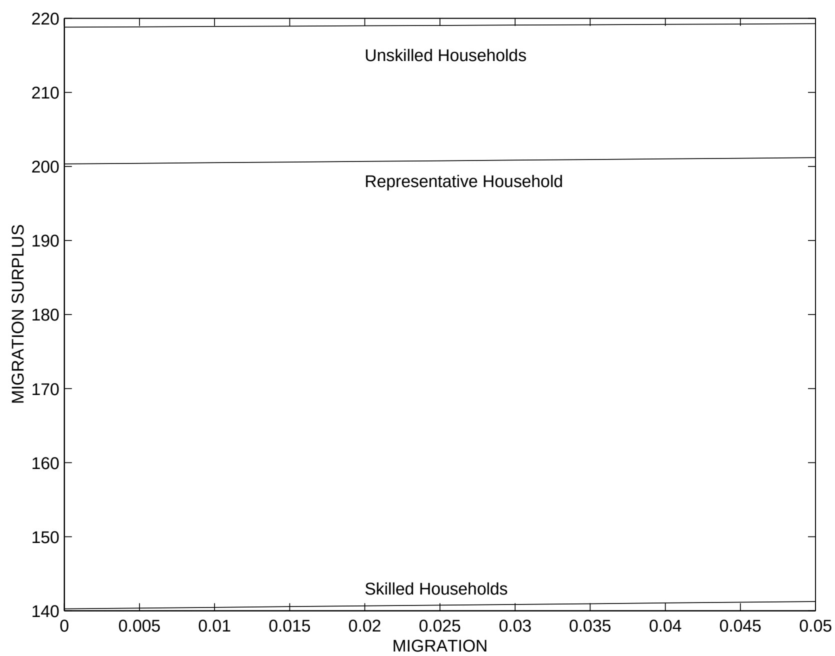

Figure 16: **MIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\ L^E = 0.30\,;\ H^W = L^W = 0.25\,$**;** $TFP^E = 0.5TFP^W$

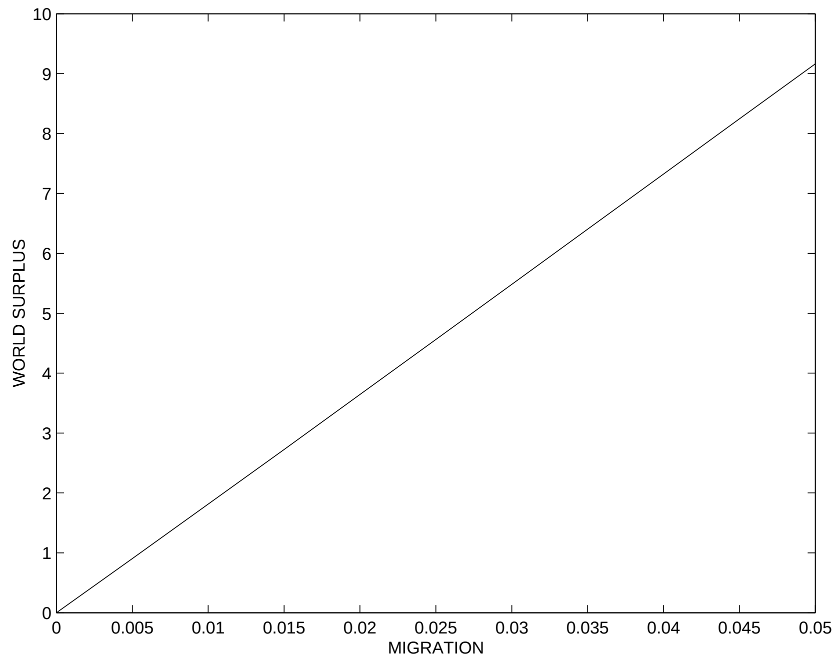

Figure 17: **WORLD SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\, L^E = 0.30\,;\, H^W = L^W = 0.25\,$**;** $TFP^E = 0.5TFP^W$

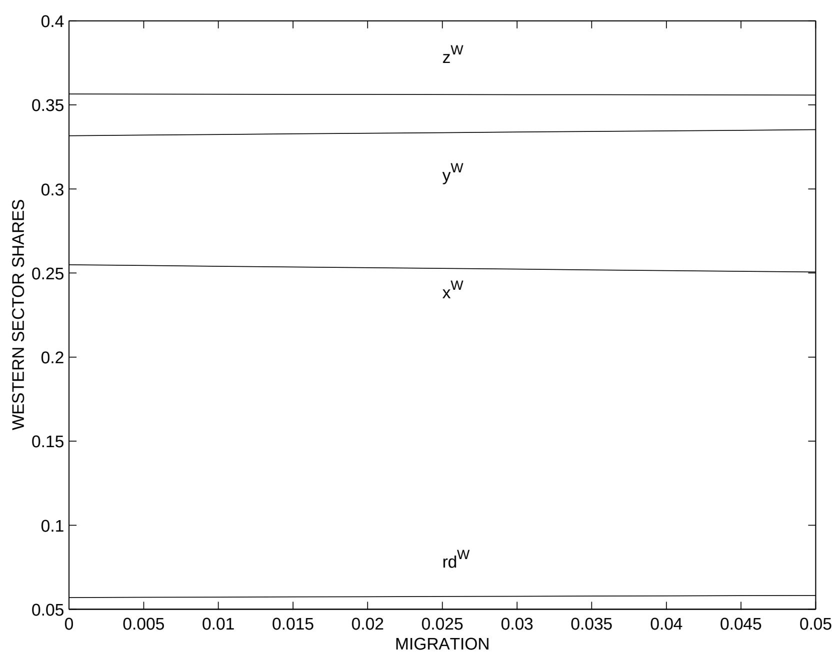

Figure 18: **WESTERN SECTOR SHARES. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

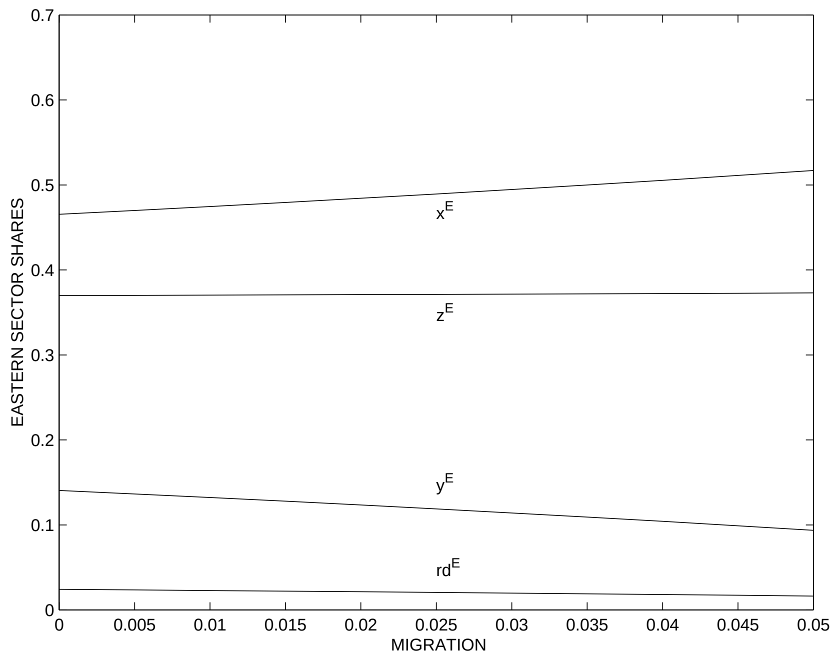

Figure 19: **EASTERN SECTOR SHARES. Pre-Migration:** $H^E = 0.20; L^E = 0.30; H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

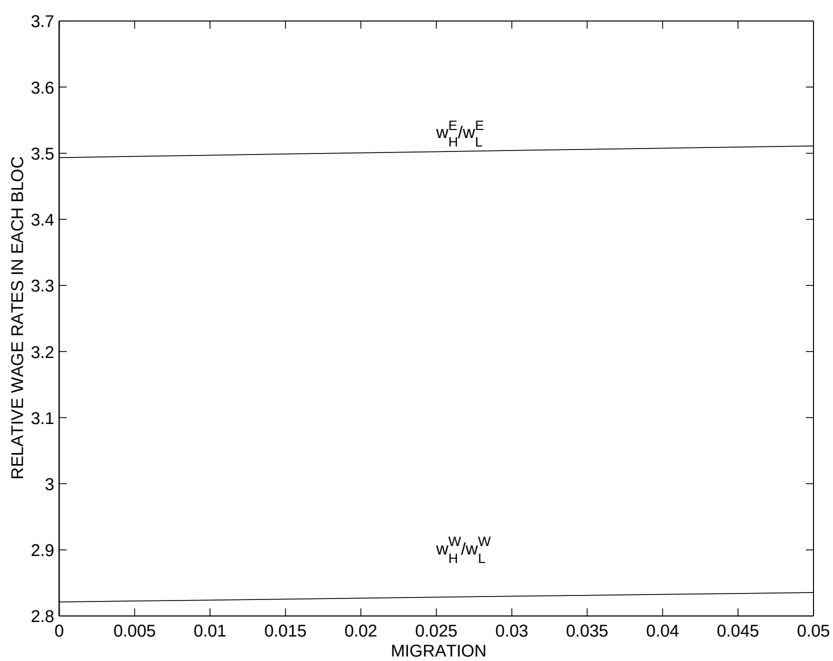

Figure 20: **RELATIVE WAGE RATES. Pre-Migration:** $H^E = 0.20; L^E = 0.30; H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

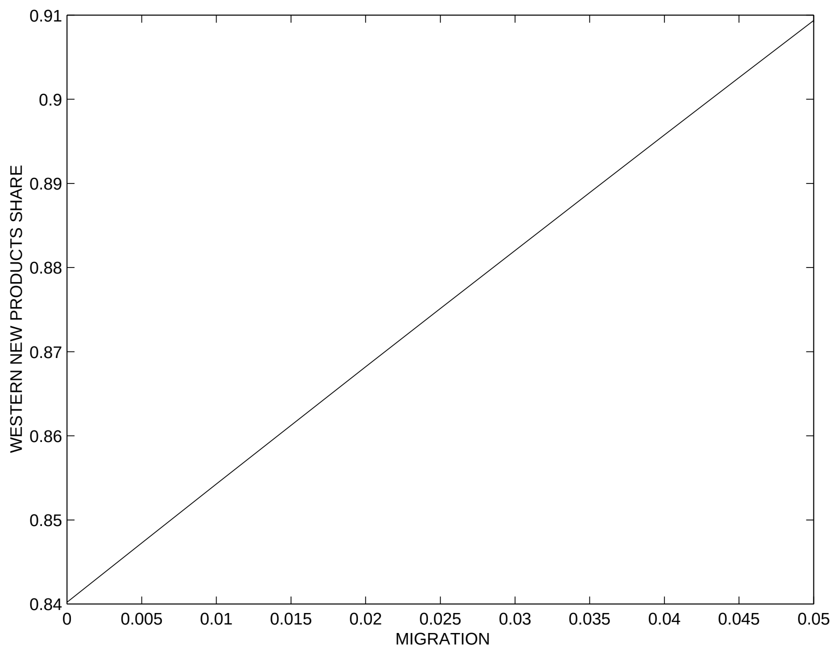

Figure 21: **WESTERN NEW PRODUCTS SHARE. Pre-Migration:** $H^E = 0.15$; $L^E = 0.35$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

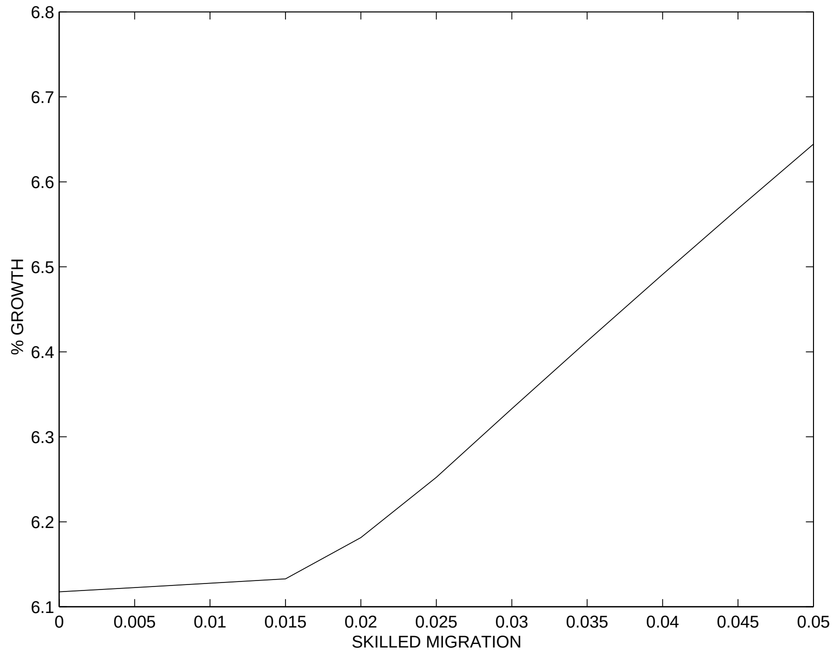

Figure 22: **WORLD GROWTH. Pre-Migration Labour:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

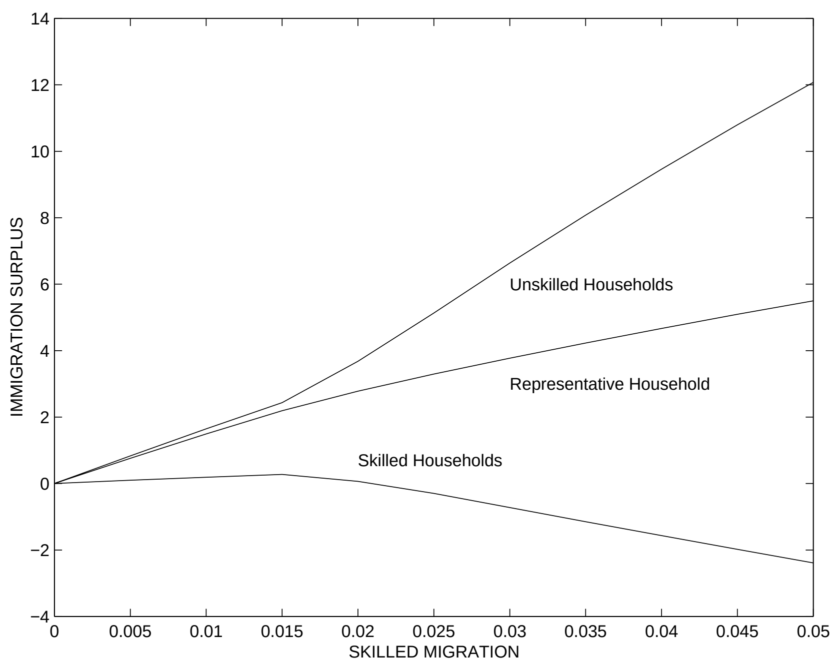

Figure 23: **IMMIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$ **;** $TFP^W = 1.75TFPE$

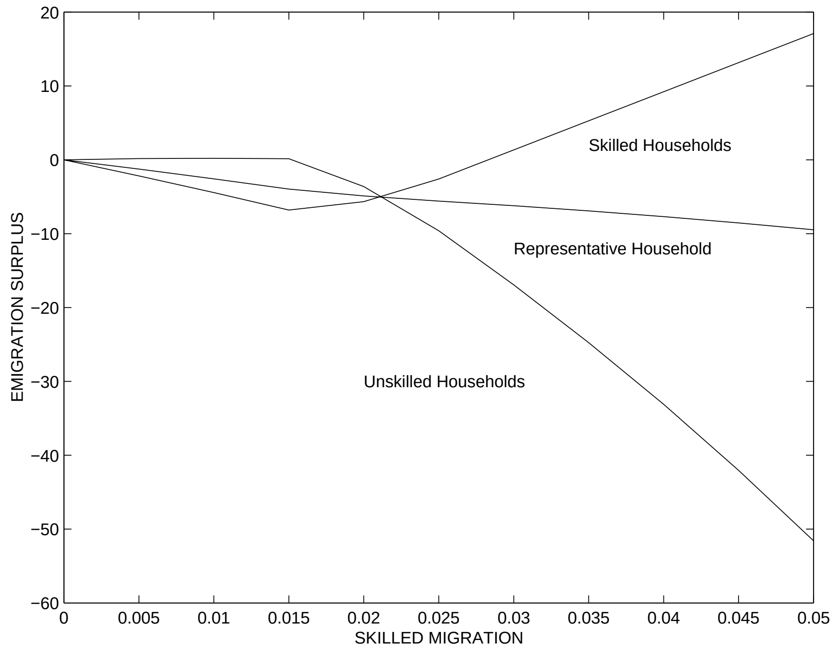

Figure 24: **EMIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\, L^E = 0.30\,;\, H^W = L^W = 0.25$**;** $TFP^E = 0.5TFP^W$

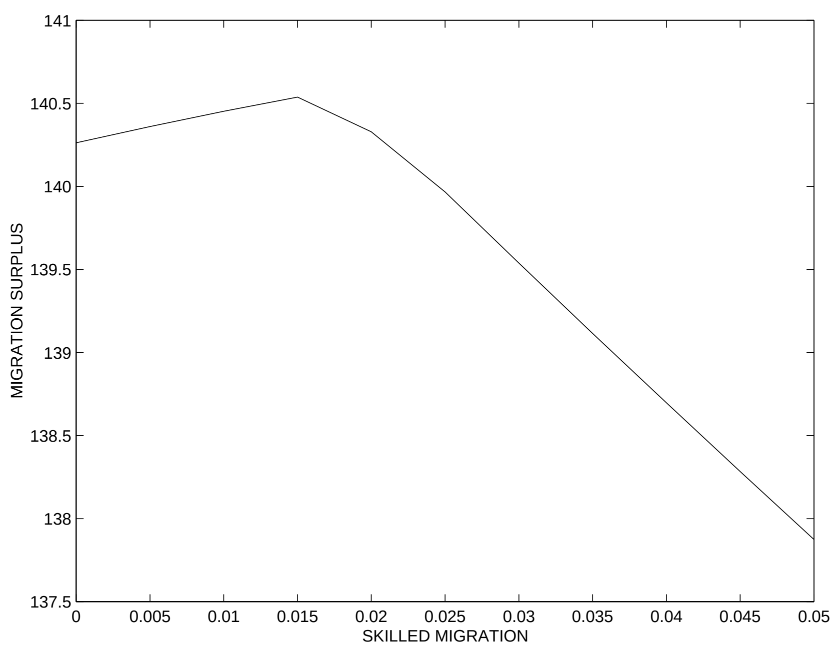

Figure 25: **MIGRATION SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\, L^E = 0.30\,;\, H^W = L^W = 0.25$**;** $TFP^E = 0.5TFP^W$

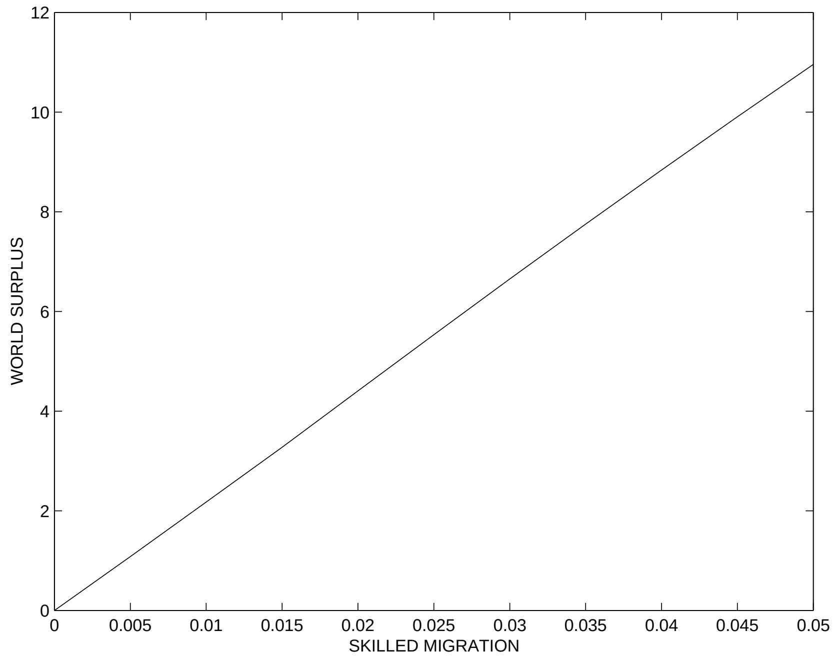

Figure 26: **WORLD SURPLUS. Pre-Migration Labour:** $H^E = 0.20\,;\, L^E = 0.30\,;\, H^W = L^W = 0.25$**;** $TFP^E = 0.5TFP^W$

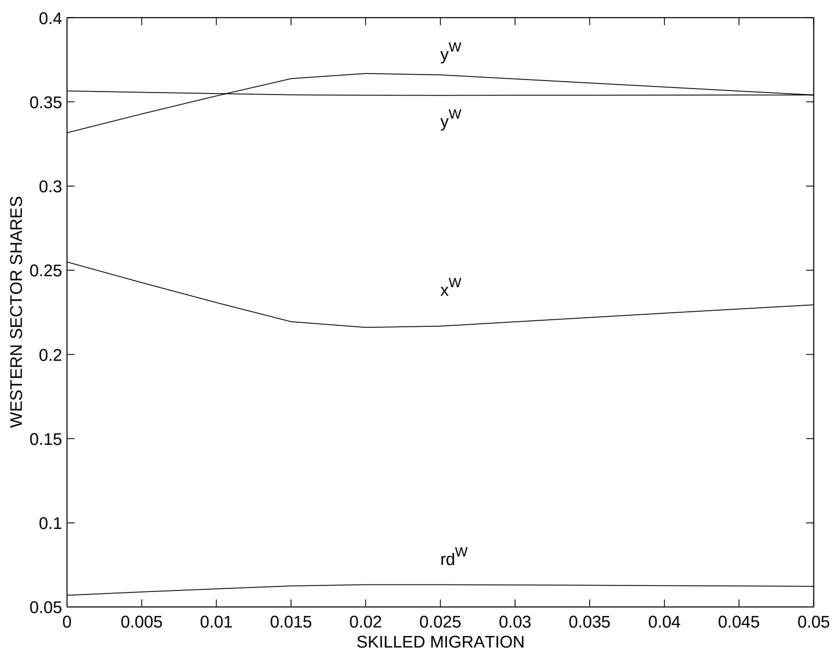

Figure 27: **WESTERN SECTOR SHARES. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

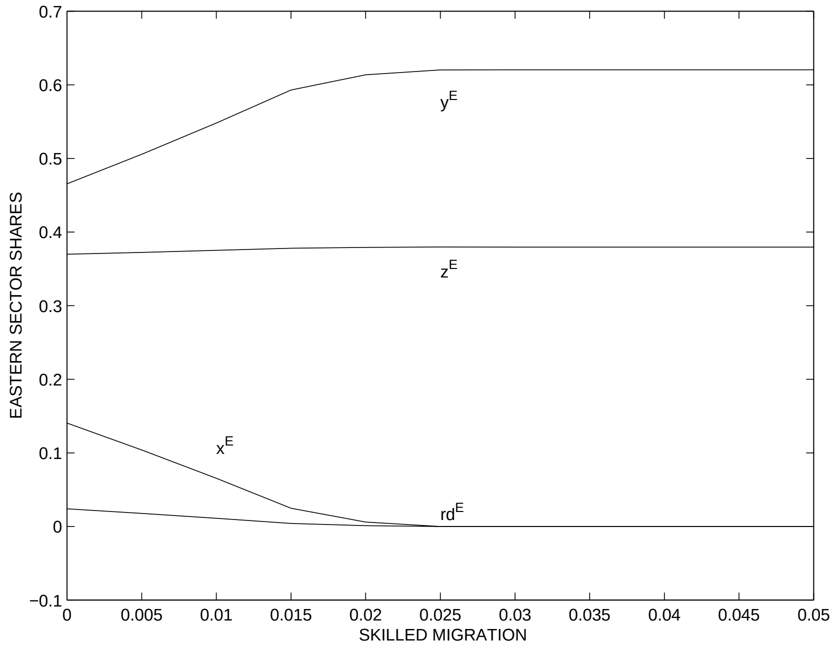

Figure 28: **EASTERN SECTOR SHARES. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

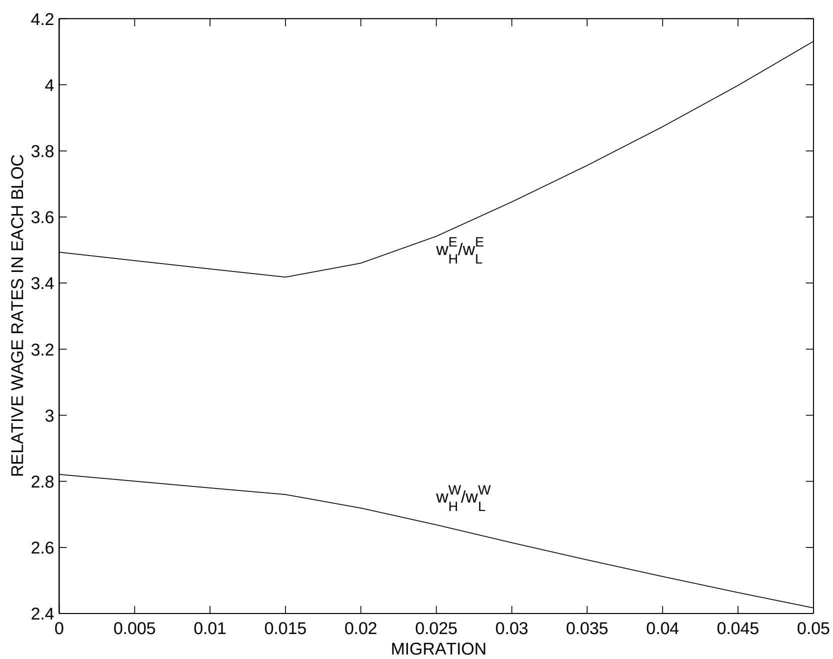

Figure 29: **RELATIVE WAGE RATES. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

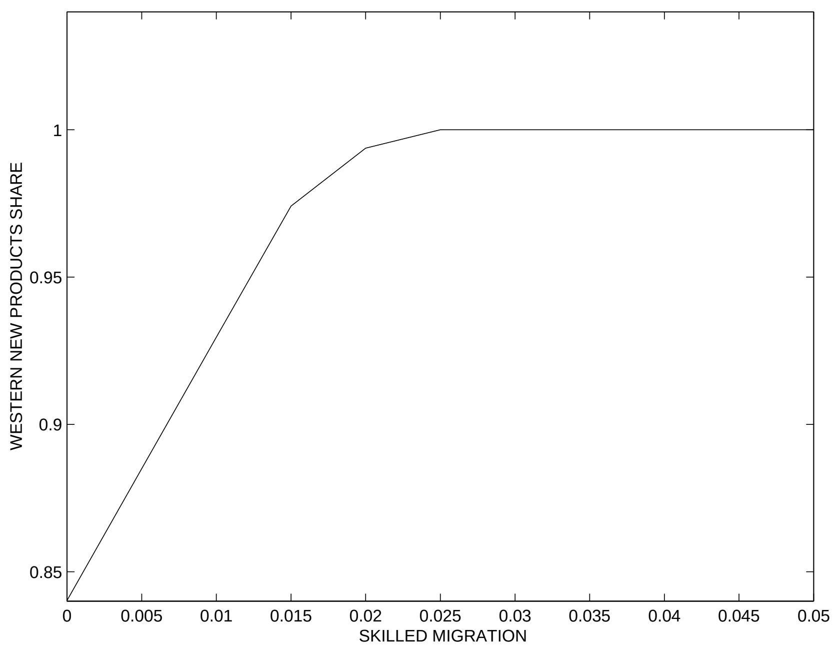

Figure 30: **WESTERN NEW PRODUCTS SHARE. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

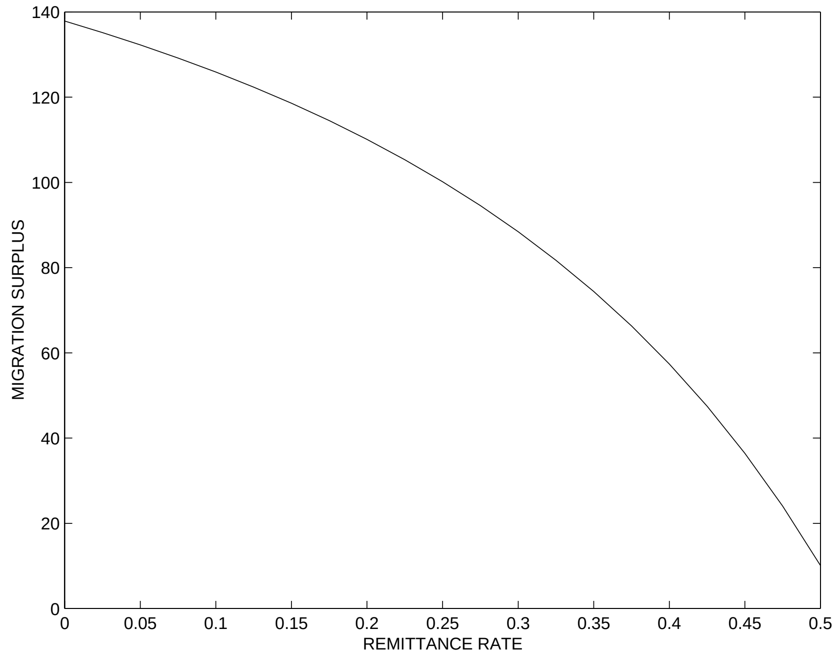

Figure 31: **REMITTANCES AND THE MIGRATION SURPLUS. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75 TFPE$

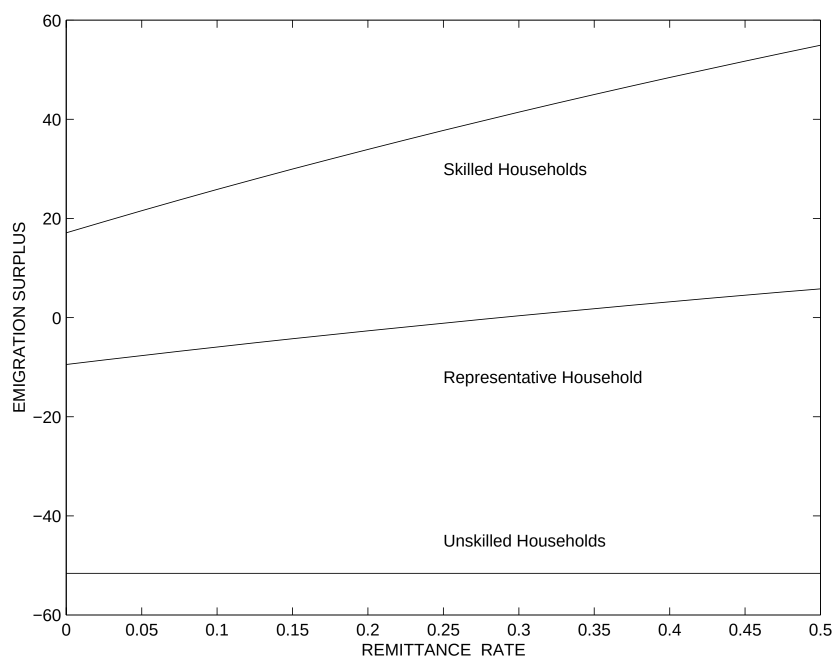

Figure 32: **REMITTANCES AND THE EMIGRATION SURPLUS. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75 TFPE$

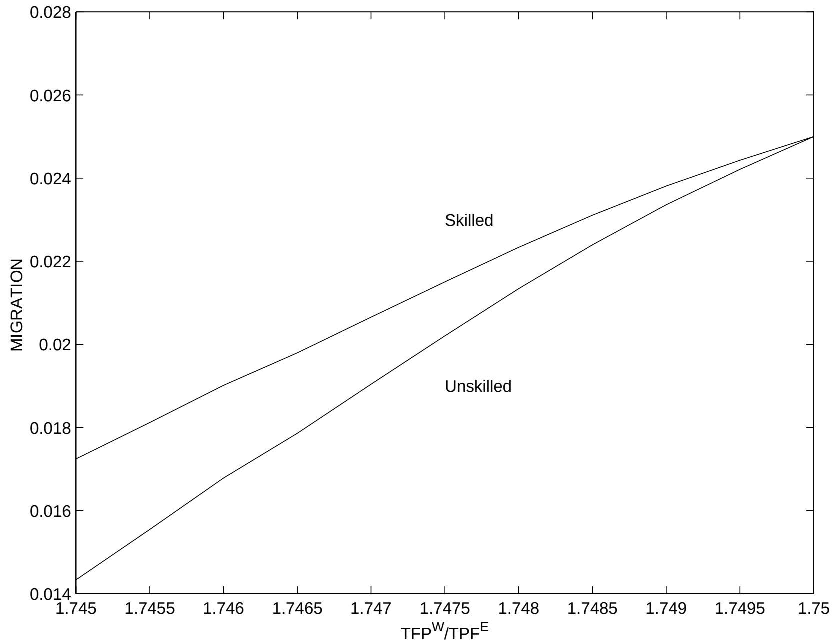

Figure 33: **MIGRATION EQUILIBRIUM 1. Pre-Migration Labour:** $H^E = 0.20\,;\ L^E = 0.30\,;\ H^W = L^W = 0.25$**;** $TFP^E = 0.5TFP^W$

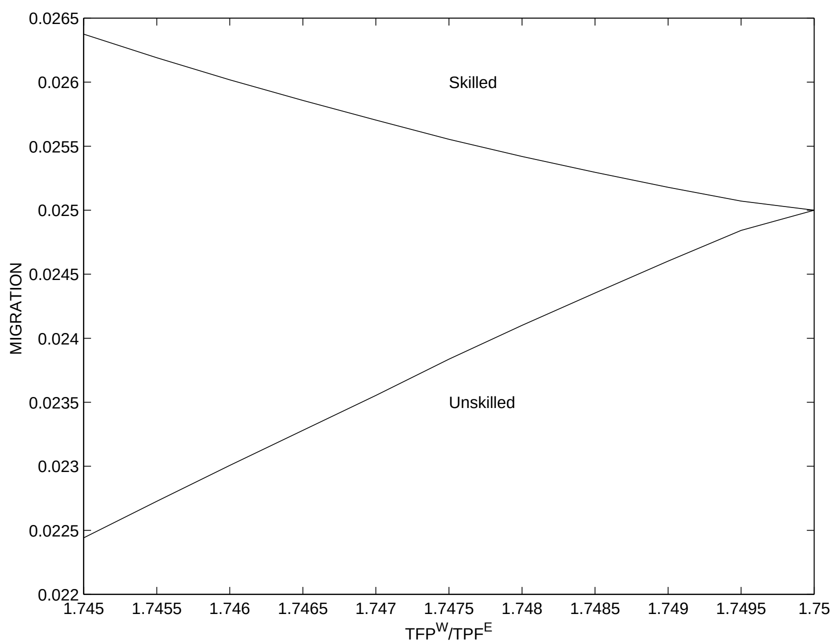

Figure 34: **MIGRATION EQUILIBRIUM 2. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$

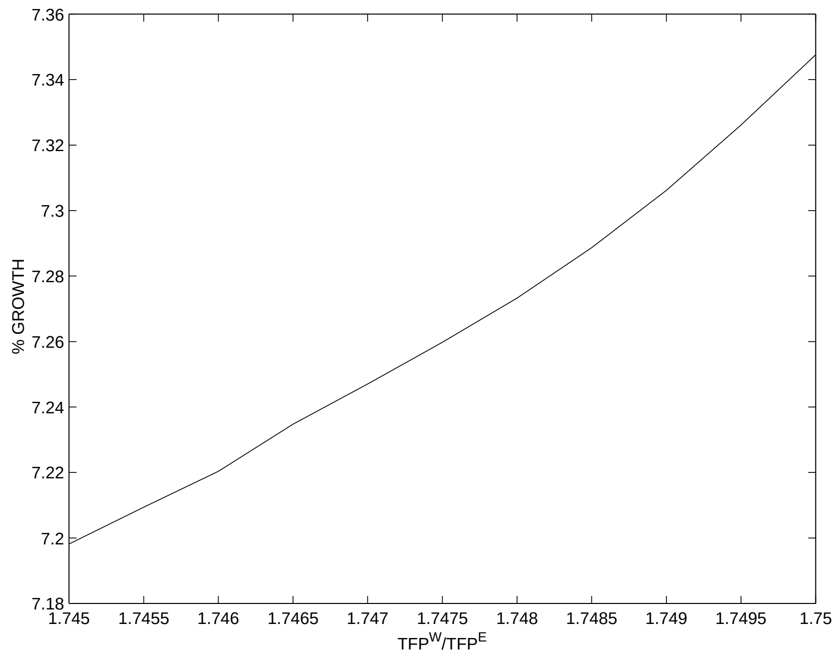

Figure 35: **MIGRATION EQUILIBRIUM 1. Pre-Migration Labour:** $H^E = 0.20\,;\ L^E = 0.30\,;\ H^W = L^W = 0.25$**;** $TFP^E = 0.5TFP^W$

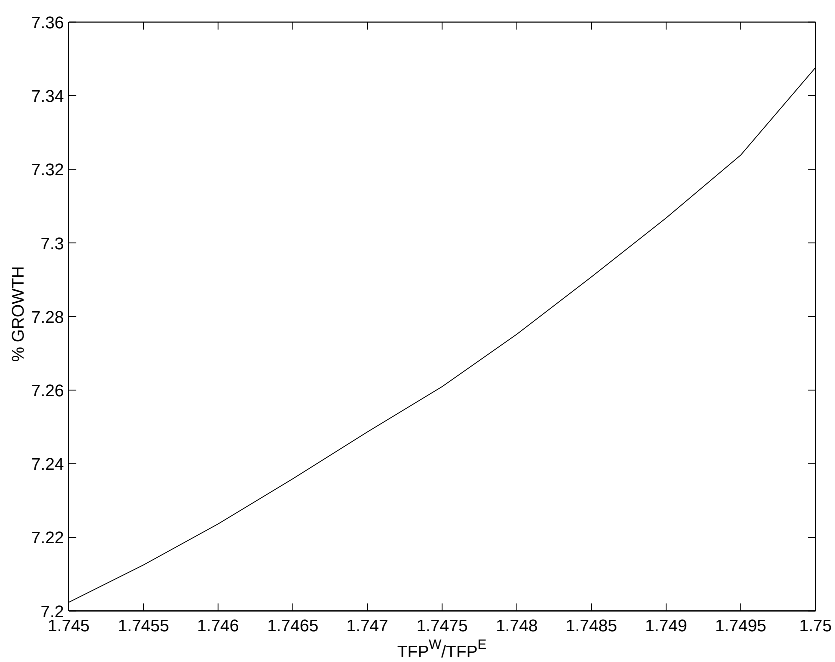

Figure 36: **MIGRATION EQUILIBRIUM 2. Pre-Migration:** $H^E = 0.20$; $L^E = 0.30$; $H^W = L^W = 0.25$**;** $TFP^W = 1.75TFPE$