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Growth, migration and trade in an enlarged European Union

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FLOWENLA Discussion Paper

Growth, migration and trade 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. The effects of quotas of skilled and unskilled East-West migration are examined separately and both the ´immigration surplus` and the ´emigration surplus` computed.

Keywords: migration, endogenous growth, international trade, immigration surplus, emigration surplus

JEL-Classification: F22, F43, O41

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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 welfare calculation for migrants, remaining residents in the East and indigenous households in the West. Each of these groups is divided into

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

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

skilled and unskilled households giving six groups in total. In the second part of this section we allow for complete capital mobility and develop a migration equilibrium. Section 4 discusses the calibration of the model. Section 5 sets out the balanced-growth steady state and provides numerical solutions. Section 6 discusses other fiscal policy instruments. The paper concludes with suggestions for future developments of the model.

2 The Basic 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 we 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 regions have available common technologies, but policy differences lead to different total factor productivities. The remaining differences between the regions are the factor endowments of skilled and unskilled labour and initial capital stocks.

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,

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

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

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

due to Dixit-Stiglitz, where n is the total number of varieties available, α is a taste parameter and x_{jl}^b is consumption of variety j by type l in bloc b.[3]

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

$$C_{yl}^b = \theta_y^b \frac{C_l^b}{p_y}; \qquad C_{zl}^b = \theta_z^b \frac{C_l^b}{p_z^b}; \qquad x_{jl}^b = \frac{\theta_m^b C_l^b p_{mj}^{-\varepsilon}}{\int_0^n p_{mj'}^{1-\varepsilon} dj'}; \qquad l = L, H, ; b = E, W \tag{3}$$

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

$$\int_0^n p_{mj}x_{jl}^b dj = \theta_m^b C_l^b = P_m C_{ml}^b \tag{4}$$

where C_{ml}^b is real consumption and

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

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

$$x_j = \sum_{b=E,W}(x_{Lj}^b + x_{Hj}^b) = \frac{\left[\sum_{b=E,W}\theta_m^b C^b\right] p_j^{-\varepsilon}}{\int_0^n p_{j'}^{1-\varepsilon} dj'} \tag{6}$$

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

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

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:

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

where $\mathbf{w^b} = [w_L^b, w_H^b]$ are the wage rates. 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:

$$
\begin{aligned}
p_y Y^b &= p_y(C_y^b + \dot{K}_y^b + \delta_y K_y^b) + B_y^b && (13)\\
Z^b &= C_z^b + \dot{K}_z^b + \delta_z K_z^b && (14)\\
p_m^b n^b x^b &= P_m C_m^b + B_m^b && (15)
\end{aligned}
$$

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 or either type with physical capital of either type.[4]

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 in 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.

[4] 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:

$$p^b = \frac{\Gamma_m^b}{\alpha} \tag{27}$$

$$x^b = \frac{\theta_m C (p^b)^{-\epsilon}}{P_m^{1-\epsilon}} \tag{28}$$

$$\pi^b = (1-\alpha) p^b x^b \tag{29}$$

$$P_m = \left[n^E (p^E)^{1-\epsilon} + n^W (p^W)^{1-\epsilon} \right]^{\frac{1}{1-\epsilon}} \tag{30}$$

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 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 allow for the *gradual diffusion* of ideas and skills, and we also 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 κ be the rate of diffusion per person per unit of time and $n = n^E + n^W$. Then knowledge capital Λ is defined by

$$\Lambda = \kappa \int_{-\infty}^{t} e^{-N\kappa(t-\tau)} n(\tau) d\tau. \tag{32}$$

Differentiating,

$$\dot{\Lambda} = \kappa(n - N\Lambda), \tag{33}$$

so that in the limit as $\kappa \to \infty$ and in the steady state for finite $\dot{\Lambda}$, we have $\Lambda = n/N$, 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

$$v^b = \frac{\Gamma_i(\mathbf{w^b}, \mathbf{R^b})}{\Lambda}. \tag{34}$$

The no-arbitrage condition is

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

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

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} < r^b \tag{36}$$

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

$$\frac{a^b_{Li}}{\Lambda}\dot{n}^b + a^b_{Lm}n^b x^b + a^b_{Ly}Y^b + a^b_{Lz}Z^b = L^b \tag{37}$$

$$\frac{a_{Hi}}{\Lambda}\dot{n}^b + a^b_{Hm}n^b x^b + a^b_{Hy}Y^b + a^b_{Hz}Z^b = H^b \tag{38}$$

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

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

$$\frac{a_{K_z i}}{\Lambda}\dot{n}^b + a^b_{K_z m}n^b x^b + a^b_{K_z y}Y^b + a^b_{K_z z}Z^b = {K_z}^b \tag{40}$$

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

2.8 Summary of Core 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

$$A^b = n^b v^b + p_y K^b_y + p^b_z K^b_z + F^b = a^b + F^b \tag{ix}$$

$$\dot{A}^b = r^b A^b + w^b_L L^b + w^b_H H^b - C^b \tag{x}$$

Eastern Debt and World Balanced Trade Condition

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

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

Capital Returns

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

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

Traditional Sectors

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

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

Manufacturing Sector

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

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

Aggregate Price Indices

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

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

Financial Sector

$$v^b = \frac{\Gamma_i(\mathbf{w^b}, \mathbf{R^b})}{\Lambda} \tag{xxi}$$

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} \geq r^b \tag{xxii}$$

World Knowledge Capital

$$\dot{\Lambda} = \kappa(n^E + n^W - N\Lambda) \tag{xxiii}$$

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), (xix) 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 perfect capital mobility from (ix) and (x) and (xxii), a little algebra gives

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

which is a national income identity equating expenditure (C^b) and investment in shares issued to finance new blue prints ($v^b\dot{n}^b$) 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 Migration and Welfare

In a dynamic set-up we start at time $t = 0$ with an initial state before any migration takes place. At time t let $M_l(t)$, $l = L, H$ be the numbers of Eastern households of type l who have migrated in time $[0,t]$. Let $\bar{L}^b$ and $\bar{H}^b$ be the pre-migration levels of households of the two skill types. Then the working populations of the two skill types are given by

$$\begin{aligned} L^E(t) &= \bar{L}^E - M_L(t) \\ L^W(t) &= \bar{L}^W + M_L(t) \\ H^E(t) &= \bar{H}^E - M_H(t) \\ H^W(t) &= \bar{H}^W + M_H(t) \end{aligned} \tag{42}$$

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

$$\dot{A}^M = r^W A^M + w_L^W M_L + w_H^W M_H - C^M \tag{43}$$

$$\dot{A}^N = r^W A^N + w_L^W (L^W - M_L) + w_H^W (H^W - M_H) - C^N \tag{44}$$

$$\dot{A}^E = r^E A^E + w_L^E L^E + w_H^E H^E - C^E \tag{45}$$

Aggregating (43) and (44) gives

$$\dot{A}^W = r^W A^W + w_L^W L^W + w_H^W H^W - C^W \tag{46}$$

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 and therefore aggregate consumption and savings decisions.

The only economic effect on the aggregate economy arises from the change in working populations given by (42). 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. In general we would like to model migration as a dynamic process in which case the incentives to migrate at time t will depend on the state of the economy and the assets of the migrant at that time. This is not an easy problem to solve so we confine ourselves to the case where *all migration is instantaneous* taking place at t=0. Thus $M_l(t) = M_l(0) = M_l$ in what follows.

3.1 Welfare Calculations

The utility of group of residential type $q = M, N, E$ and skill type $l = L, H$ is given by

$$U_l^q(t) = \int_t^\infty e^{-\rho^q(\tau - t)} \left\{ \frac{[(C_{ml}^q)^{\theta_m^q} (C_{yl}^q)^{\theta_y^q} (C_{zl}^q)^{\theta_z^q}]^{1-1/\sigma^q} - 1}{1 - 1/\sigma^q} \right\} d\tau; \quad \sum_{i=m,y,z} \theta_i^q = 1, \sigma \neq 1; \tag{47}$$

Hence differentiating we have

$$\dot{U}_l^q = \rho^q U_l^q(t) - \left\{ \frac{[(C_{ml}^q)^{\theta_m^q} (C_{yl}^q)^{\theta_y^q} (C_{zl}^q)^{\theta_z^q}]^{1-1/\sigma^q} - 1}{1 - 1/\sigma^q} \right\} \tag{48}$$

where

$$C_{zl}^q = \frac{\theta_z^q C_l^q}{p_z^q}; \; C_{yl}^q = \frac{\theta_y^q C_l^q}{p_y}; \; C_{ml}^q = \frac{\theta_m^q C_l^q}{P_m} \tag{49}$$

$$\frac{\dot{C}_l^q}{C_l^q} = (1 - \sigma)\frac{\dot{P}^q}{P^q} + \sigma^q(r^q - \rho^q) \tag{50}$$

(51)

where $r^M = r^N = r^W$ and $P^M = P^N = P^W$. The assets of groups $q = M, N, E$; $l = L, H$ accumulate according to

$$\dot{A}_l^M = r^W A_l^M + w_l^W M_l - C_l^M \,; \, l = L, H \tag{52}$$

$$\dot{A}_L^N = r^W A_L^N + w_l^W \bar{L}^W - C_L^N \tag{53}$$

$$\dot{A}_H^N = r^W A_H^N + w_l^W \bar{H}^W - C_H^N \tag{54}$$

$$\dot{A}_L^E = r^E A_L^E + w_L^E L^E - C_L^E \tag{55}$$

$$\dot{A}_H^E = r^E A_H^E + w_H^E H^E - C_H^E \tag{56}$$

To compute the welfare of the four groups treat U_l^b as an additional forward-looking variable and add equations (48) to (56) to the set-up. We still need an initial condition $A_l^q(0)$, $q = M, N, E\,;\; l = L, H$. Start out in some initial steady state before migration takes place. Let $\bar{w}_l^b$ etc, be steady-state values. Then assume assets between skilled and unskilled households are divided according to

$$\bar{A}_L^b = \frac{\bar{w}_L^b \bar{L}^b}{\bar{w}_L^b \bar{L}^b + \bar{w}_H^b \bar{H}^b} \bar{A}^b(0) \tag{57}$$

$$\bar{A}_H^b = \frac{\bar{w}_H^b \bar{H}^b}{\bar{w}_L^b \bar{L}^b + \bar{w}_H^b \bar{H}^b} \bar{A}^b(0) \tag{58}$$

where

$$\bar{A}^b(0) = n^b(0)v^b(0) + p_y(0)K_y(0) + p_z K_z(0) = \xi^b(0)\Gamma_i^b(0) + p_y(0)K_y(0) + p_z(0)K_z(0)$$

are total assets in each bloc at time $t = 0$ allowing for the forward-looking response of asset prices to migration. Migrants take their assets with them so *after migration* we have

$$\begin{aligned} \bar{A}_L^M &= \frac{M_L}{\bar{L}^E}\bar{A}_L^E\,;\; \bar{A}_L^E = \left(1 - \frac{M_L}{\bar{L}^E}\right)\bar{A}_L^E\,;\; \bar{A}_L^N = \bar{A}_L^W \\ \bar{A}_H^M &= \frac{M_H}{\bar{H}^E}\bar{A}_H^E\,;\; \bar{A}_H^E = \left(1 - \frac{M_H}{\bar{H}^E}\right)\bar{A}_H^E\,;\; \bar{A}_H^N = \bar{A}_H^W \end{aligned} \tag{59}$$

As noted previously $\xi(0)^b, K_y^b(0), K_z^b(0)$ are set exogenously (in effect as parameters) but $C^b(0)$, $\tilde{P}^b(0)$, $p_y(0), p_z^b(0), \Gamma_i^b(0)$ are determined endogenously in the solution. The problem is that we need $A^b(0)$ to obtain any solution that includes the utility. To resolve this we will need to solve for the solution with a trial value for $A^b(0)$. Since our accumulation equations do not feed back on any other variables the rest of the solution including $C^b(0), \tilde{P}^b(0), p_y(0), p_z^b(0), \Gamma_i^b(0)$ will not be affected by this trial value. Having obtained $C^b(0), \tilde{P}^b(0), p_y(0), p_z^b(0), \Gamma_i^b(0)$ we can insert the true value for $A^b(0)$ and obtain the utility values for all groups.

3.2 The Migration Equilibrium and Migration Quotas

As we have noted above we assume all migration is instantaneous and takes place at time $t = 0$. 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. The cost of migration can be divided into two parts. First there is a cost associated with the preference for consumption in one's home country arising from cultural differences between the blocs, links with family and friends etc. It is reasonable to suppose that this is some 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. The second component of the cost is the actual cost of migration. Here we assume that the moving cost is a convex function of total migration relative to the total population in the host region i.e., $\eta(M/N^W)$ where $M + M_L + M_H$, $N^W = L^W + H^W$ and $\eta(0)$, $\eta', \eta'' > 0$. Then equating the cost of migration with the benefits gives the condition for a migration equilibrium in a *laissez-faire* migration regime as

$$u_l^M - (1 + m_l)u_l^E = \eta(M/N^W) \; l = L, H \tag{60}$$

Two types of simulations can be carried out. *Migration Quota* restrict migration to levels below the migration equilibrium so that $u_l^M - (1 + m_l)u_l^E > \eta(M/N^W) \; l = L, H$. The economic effects of different quotas for the two skill types would be of considerable interest. Assuming a cost function $\eta_l(m) = \eta_{1l} + \eta_{2l} m + \eta_{3l} m^2$, which can differ between skill types, if the parameters $\eta_{il} \,;\; i = 1, \cdot\cdot, 3$ and m_l can be calibrated (see below) then the effects of allowing laissez-faire migration can also be explored.

4 Calibration

To relate the model to the real world, the first requirement of the exercise is to identify which types of labour relate to the categories of 'skilled' and unskilled', which sectors constitute traditional traded, traditional non-traded, high-tech manufacturing and R&D. We will assume identical consumer preferences in both blocs and identical technologies except that total factor productivity is uniformly lower in the East. Then we have to decide which country or countries in the West to use: e.g., Germany the 'representative' countries, or more ambitiously, averages across the large EU countries.

Simulations will solve the model starting at some initial state (e.g., at the pre-migration, pre-free trade and pre-capital mobility states) which define initial factor endowments: $L^b(0), H^b(0), K_y^b(0), K_z^b(0)$. Then to carry out the simulations the following parameter values are required:

Utility Weights, Elasticities and Discount Rates: $\theta_m, \theta_y, \theta_z$, σ, α and ρ.

Capital Depreciation Rates: δ_y^b, δ_z^b.

Production Function Weights, Elasticities and Total Factor Productivities: γ_{kj}, $k = 1, 4$; $j = m, y, z, i, \quad \eta_j, \xi_j, j = m, y, z, i, \quad T_j^b, j = m, y, z, i.$

Capital Mobility Choose $\phi \in [0, 1]$; $\phi = 0$ is the case of capital immobility. Run simulations for the full range of ϕ.

Migration Costs $\eta(\cdot)$.

The procedure commonly referred to as "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 over a number of years on consumption shares and factor shares. Elasticities in production are selected using econometric estimates. We have assumed Cobb-Douglas consumption functions. Then using data on consumption shares weights θ_i in the utility function and can be obtained using the first-order conditions for cost-minimization:

$$\theta_j = \text{consumption share of sector } j = z, y, m \tag{61}$$

On the production side, units can be chosen such that $T_m = T_y = T_z = 1$. Assume that the East is uniformly less efficient than the West with

$$\frac{T_j^E}{T_j^W} = \beta < 1 \tag{62}$$

with β to be determined. Use econometric estimates for depreciation rates, and choose a numeraire such as $w_L^E = 1$. Data on the real interest rate and the steady-state expression

$$\bar{r}^b = \rho^b - \left(\frac{1}{\sigma^b} - 1 \right) \frac{\theta_m^b \bar{g}}{1 - \epsilon} \tag{63}$$

obtained from the technical paper on setting up the model, pins down the discount rate ρ^b. In the pre-migration equilibrium this leaves parameters $[T_i^W, \{\gamma_{kj}\}, k = 1, 4; j = z, y, m, i \ , \beta] = \Xi$, say. The steady-state solves for the following observable variables: growth, $\bar{g}(\Xi)$, factor inputs, $[\bar{L}_j^W, \bar{H}_j^W, \bar{K}_{yj}^W, \bar{K}_{zj}^W] = \bar{F}_j(\Xi)$, say[5] and the unskilled wage

[5]Note that L_j^b, $j = i, m, y, z$ are the four inputs of unskilled labour on the left-hand-side of (37) and H_j^b, K_{yj}^b and K_{zj}^b are similarly obtained from (37) to (40)

ratio $\frac{\bar{w}_L^E}{\bar{w}_L^W}(\Xi)$. Let $\hat{g}$ etc denote data on g etc. Then the set of 18 equations

$$\hat{g} = \bar{g}(\Xi) \tag{64}$$

$$\hat{F}_j^W = \bar{F}_j^W(\Xi)\,;\, j = z, y, m, i \tag{65}$$

$$\frac{\hat{w}_L^E}{\hat{w}_L^W} = \frac{\bar{w}_L^E}{\bar{w}_L^W}(\Xi) \tag{66}$$

can be solved for the 18 parameters of Ξ (in Winsolve), which completes the calibration of the pre-migration benchmark model.

To calibrate $\eta(\cdot)$ and m_l suppose that we have data for four laissez-faire migration experiences comparable to East-West enlargement, say the previous enlargements involving Spain, Portugal and Greece, and the unification of Germany. Let $m_{li} = M_{li}/N$ be the observed migration proportions for these cases. We can calibrate the two-bloc model to represent Spain and the rest of the EU, etc and then simulate with migration proportions m_{li}. The model will output utilities u_{li}^M and u_{li}^E for the migrant and remaining non-migrant respectively. On the assumption that we have observed laissez-faire migration we then have

$$u_{li}^M - u_{li}^E = m_l u_{li}^E + \eta_{l1} + \eta_{21} m_{li} + a_{3l} m_{li}^2\,;\, i = 1, 4;\, l = L, H \tag{67}$$

This gives us 8 linear equations which can be solved for m_l and $\eta_{lj}\,;\, j = 1, 4$ completing the calibration of the model.

Other data and steady-state solutions can also be utilised to obtain a better empirical fit. In general suppose we have data on n variables $\hat{x}_i, i = 1, n$ and steady-state values $\bar{x}_i(\Theta), i = 1, n$ where $n > 4$. Then parameters Θ can be chosen to minimise a lose function $\sum_{i=1}^n \alpha_i(\hat{x}_i - \bar{x}_i(\Theta))^2$ where weights α_i can be chosen to reflect the importance of a particular observation. Table 1 below summarises our calibration.

Parameter	Value	Source
θ_m	0.36	Burda and Hunt (2000)
θ_y	0.29	ditto
θ_z	0.35	ditto
σ	0.4	Ogaki and Reinhart (1998)
α	0.7	Keuschnigg and Kohler (1999a, 1999b)
ρ	0.01	Calibrated to give $\bar{r} = 0.03$, $\bar{g} = 0.07$
δ	0.1	Canova 1994, 1998)
μ_j, η_j, $j = m, y, i$	0.0 (i.e., Cobb-Douglas)	Hammermesh (1993), GTAP
γ_{ky} $k = 1, 4$	$\gamma_{1y} = 0.27$, $\gamma_{2y} = 0.43$	Keuschnigg and Kohler (1999a, 1999b)
γ_{kz} $k = 1, 4$	$\gamma_{1z} = 0.17$, $\gamma_{2y} = 0.56$	Keuschnigg and Kohler (1999a, 1999b)
γ_{km} $k = 1, 4$	$\gamma_{1m} = 0.17$, $\gamma_{2m} = 0.50$	ditto
γ_{ki} $k = 1, 4$	$\gamma_{1i} = 0.08$, $\gamma_{2i} = 0.88$	ditto
T_i	1.5	Calibrated to give $\bar{g} = 0.07$
$\bar{H}$	0.5	Keuschnigg and Kohler (1999a, 1999b)
$\bar{L}$	0.5	ditto

Table 1. Summary of Calibration[6]

5 Numerical Results for the Steady State

5.1 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 and 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. Define as proportions of nominal GDP $x^b = P_m^b x^b / GDP^b$ and similarly define y^b and z^b for bloc $b = E, W$. Define the R&D and consumption shares as $rd^b = 1 -$

[6] For all sectors $j = y, z, m, i$, we assume $\gamma_{3j} = \gamma_{4j} = (1 - \gamma_{1j} - \gamma_{2j})/2$.

$x^b - y^b - z^b = \Gamma_i^b \xi_i^b / GDP^b$ and $c^b = C^b/GDP^b$ respectively. Define relative GDP as $rel^E = GDP^E/GDP^W$. Substituting these features into the model leads to the following steady state:

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

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

giving up 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.

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 endownments of the two types of labour and total factor productivites (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 the subsequent two subsections then examines the effect of skilled and unskilled East-West migration.

6.1 Changes in Eastern Total Factor Productivity

Figures 1 to 5 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 $H^E = L^E = H^W = L^W$. 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.

Figures 7 to 11 repeats this exercise for the case where the East is relatively less well endowed with skilled labour ($H^E = 0.15$, $L^W = 0.35$ and $L^E = H^W = 0.25$) as before. Now the West has a comparative advantage for skill-intensive innovative activity. The R&D sector in the East now disappears and it specialises in the traditional sectors which use skilled labour less intensively. The Western share of innovative goods is unity for all levels of TFP in the East (this figure is therefore not shown). As production in the East falls across all sectors the West must shift resources, as before, producing more of the traditional good. Resources are diverted away from R&D and growth falls.

6.2 Skilled East-East Migration

In the next two sections we consider the second case where the East is relatively less endowed with skilled labour and we put $TFP^W = 2TFP^E$. First we allow skilled labour up to 0.05 units to migrate. Figure 12 shows that the effect of this is to see world growth rise by almost 0.5%. There are two reasons for this. First as figure 13 shows the skilled-unskilled wage rate in the West falls. This has the effect of encouraging production in the skilled-labour intensive R&D and manufacturing sectors. Figure 14 shows that despite the drop in the cost of innovation its nominal share remains about constant indicating higher growth. Since workers migrate to the East, the size of the Eastern economy falls and the West must produce a higher proportion of the traded traditional good (figure 12). The second reason for the rise in growth is a country size effect. Although we have removed the scale effect for the two blocs together, there remains a scale effect for the West. Given our definition of knowledge capital, any increase in population in the innovative West increases growth, in addition to the reallocation effect of changing the *proportion* of skilled and unskilled labour.

The effect of these changes on welfare is summarised in figures 16 to 19. Figure 16 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 over 8% when migration reaches 10% of the Western workforce and is entirely skilled. This breaks down into 15% for Western unskilled workers, about -1% for native unskilled workers, giving an average *immigration surplus* of just over 4% for the representative Western native household (figure 17). For those remaining in the East skilled workers gain by over 15%, unskilled workers lose by -27% giving a average for the representative Eastern non-migrant of about 2% (figure 18). Finally figure 19 shows that the migrant gains by a substantial 44%.

7 Unskilled East-West Migration

Our final simulation looks at the effect of a 10% increase in the Western population consisting of unskilled workers. Now there is a symmetrical reallocation effect from the lowering of the proportion of skilled to unskilled workers, but there is still a positive scale effect from a population increase. Taken together growth now falls by 0.04% (figure 20). The world surplus is now a modest 2.5% (figure 21). The immigration surplus is almost 5% for skilled natives, -12% for skilled natives averaging at under 1% (figure 22). The emigration surplus is 9% for skilled, -6% for unskilled averaging at -1% (figure 23), but unskilled migrants gain substantially (figure 24).

8 Fiscal Policy

The model in its present form can be used to explore a range of issues associated with East-West migration. The model is also well-suited to the examination of the effects of increased capital mobility (by experimenting with $\phi \in [0,1]$) and the removal of remaining trade tariffs and non-tariff barriers to trade. Future developments that add more policy instruments such as taxes, tariffs and R&D subsidies, will extend the scope of these investigations.

The simplest fiscal instruments to add are taxes used to provide free public services. Let G^b, consisting of output from the non-traded z-sector, be government services. Then the accounting identity in the z-sector becomes

$$Z^b = C_z^b + \dot{K}_z^b + \delta K_z^b + G^b \tag{68}$$

and we now have to introduce a government budget constraint. Ruling out government debt, if we assume only income tax on labour this becomes

$$G^b = \tau_L^b w_L^b L^b + \tau_H w_H^b H^b \tag{69}$$

and the asset accumulation equations used to calculate welfare must replace wage rates with post-tax wage rates $(1-\tau_L^b)w_L^b$ and $(1-\tau_H^b)w_H^b$ for the two skill types respectively. Since labour supply is assumed to be fixed there are no tax distortions from income tax on labour, but this is no longer the case if we allow for the taxation of savings or VAT. Since government spending may differ between blocs we need to introduce government spending into the utility function replacing (1) with

$$U_l^b(t) = \int_0^\infty e^{-\rho^b(\tau - t)} \left\{ \frac{[(C_{ml}^b)^{\theta_m^b}(C_{yl}^b)^{\theta_y^b}(C_{zl}^b)^{\theta_z^b}(G_l^b)^{\theta_g^b}]^{1-1/\sigma} - 1}{1-1/\sigma} \right\} d\tau; \quad \sum_{i=m,y,z} \theta_i^b = 1, \sigma \neq 1; \tag{70}$$

Article 8a of the Single European Act requires a laissez-faire system of unrestricted labour mobility between members of the new enlarged Union, although as was the case for Spain and Portugal, temporary restrictions may be allowed. It follows that policy experiments that affect the migration equilibrium are of great importance. Lundborg and Segerstrom (2000) find that ceteribus paribus workers migrate to countries that subsidise R&D less and have lower tariffs. It follows that lowering tariffs in the East and raising R&D subsidies in the West will discourge migration, result that can be explored in our model.

The political economy of migration requires a careful examination of the welfare consequences of migration on the six groups of households identified in the model – skilled and unskilled workers, Eastern remaining non-migrants, migrants and Western non-migrants. The distribution of welfare benefits will then depends on the tax rate. Changes in these instruments will also affect the nature of the migration equilibrium. Generally it will be important to distinguish migration pressures due to asymmetric economies and those due to policy differences.

9 Future Developments

There are a number are ways in which the model presented here can be developed. First, we have assumed away labour market imperfections are and there are many ways of modelling these. The search-matching approach to migration and wage-stickiness of Ortega(2000) might be one direction to go. Second, the migration decision itself (with or without wage rigidity) can be modelled in different ways. The present model ignores migrants' remittances which are known to be important for developing countries. Migrants can also contribute to increased capital formation by having higher savings ratios. On both these issues there is potential for more theoretical and empirical work (in a East-West European context)[7]. Third, more 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). We have restricted capital formation to traditional sectors for theoretical convenience. It is not obvious how to obtain balanced growth paths with

[7] See Drinkwater (2001) for further discussion

constant prices if we allow for capital formation in the high-tech expanding sector and this need to be investigated further. Finally we have assumed that firms must manufacture their innovative products in the same country where the R&D sector is located. The introduction of Multinational Corporations would change this assumption as they might choose to separate these activities.

References

Borjas, G. (1995). The economic benefits from immigration. *Journal of Economic Literature*, **9**(2), 3–22.

Burda, M. and Hunt, J. (2001). From reunification to economic integration: Productivity and the labour market in Eastern Germany. *Brooking Papers on Economic Activity*, **2**, 1–92.

Canova, F. (1994). Statistical inference in calibrated models. *Journal of Applied Econometrics*, **9**, S123–144.

Canova, F. and Ortega, E. (1996). Testing calibrated general equilibrium models. *Simulation Based Inference in Econometrics: Methods and Applications, Mariano R. Schuermann and Weeks M. (eds).*

Chui, M., Levine, P., Murshed, S., and Pearlman, J. (2001a). North-South models of growth and trade: Survey and synthesis. *Journal of Economic Surveys, forthcoming.*

Chui, M., Levine, P., and Pearlman, J. (2001b). Winners and losers in a North-South model of growth, innovation and product cycles. *Journal of Development Economics*, **65**, 333–365.

Currie, D., Levine, P., Pearlman, J., and Chui, M. (1999). Phases of imitation and innovation in a north-south endogenous growth model. *Oxford Economic Papers.*

Dixit, A. K. and Pindyck, R. S. (1994). *Investment Under Uncertainty.* Princeton University Press, Princeton, New Jersey.

Drinkwater, S. (2001). Empirical research in flowenla. mimeo, Department of Economics, University of Surrey.

Faini, R. (1996). Increasing returns, migration and convergence. *Journal of Development Economics*, **49**, 121–136.

Ghatak, S., Levine, P., and Wheatley Price, S. (1996). Migration theory and evidence: An assessment. *Journal of Economic Surveys*, **10**(2), 159–198.

Grossman, G. and Helpman, E. (1991). *Innovation and Growth in the Global Economy.* MIT Press, Cambridge, Massachusetts.

Hamermesh, D. (1993). *Labor Demand.* Princeton University Press, Princeton.

Harris, J. and Todaro, M. (1970). Migration, unemployment and development. *American Economic Review*, **60**, 126–142.

Keuschnigg, C. and Kohler, W. (1999a). Eastern enlargment to the EU: Economic costs and benefit for the EU present member states? the case of Austria. Final report, University of Linz. PART I and II.

Keuschnigg, C. and Kohler, W. (1999b). Eastern enlargment to the EU: Economic costs and benefit for the EU present member states? the case of Germany. Final report, University of Linz.

Krichel, T. and Levine, P. (2000). The welfare economics of rural to urban migration: The Harris-Todaro model revisited. *Journal of Regional Science, forthcoming.*

Layard, R., Blanchard, O., Dornbusch, R., and Krugman, P. (1994). *East-West Migration: the Alternatives.* MIT Press, Cambridge, Mass.

Levine, P. (1999). The welfare economics of immigration control. *Journal of Population Economics*, **12**, 23–43.

Lundborg, P. and Segerstrom, P. S. (1998). The growth and welfare effects of international mass migration. FIEF working paper series, The Trade Union Institute for Economic and Social Research, Stockholm.

Lundborg, P. and Segerstrom, P. S. (1999). International migration and growth in developed countries: A theoretical analysis. *Economica*, **67**, 579–604.

Mountford, A. (1997). Can a brain drain be good for growth in the source economy? *Journal of Development Economics*, **53**, 287–303.

Ogaki, M. and Reinhart, C. M. (1998). Measuring intertemporal substitution: The role of durable goods. *Journal of Political Economy*, pages 1078–1098.

Ortega, J. (2000). Pareto-improving immigration in an economy with equilibrium unemployment. *The Economic Journal*, pages 92–112.

Romer, P. (1986). Increasing returns and long-run growth. *Journal of Political Economy*, **94**, 1002–1037.

Romer, P. (1990). Endogenous technical change. *Journal of Political Economy*, **98**, S71–S102.

Segerstrom, P. S. (1998). Endogenous growth without scale effects. *American Economic Review*, pages 1290–1310.

Solow, R. M. (1956). A contribution to the theory of economic growth. *Quarterly Journal of Economics*, **70**(1), 65–94.

Straubhaar, T. and Zimmermann, K. F. (1992). Towards a European migration policy. CEPR Discussion Paper 641.

A Cost and Unit Factor Requirement Functions

The aim is to minimize total costs given by total costs $= [w_L L + w_H H + R_y K_y + R_z K_z]$ such that output x is given by $x^\eta = (\gamma_1 L^\mu + \gamma_2 H^\mu)^{\eta/\mu} + (\gamma_3 K_y^\xi + \gamma_4 K_z^\xi)^{\eta/\xi}$.

It follows that marginal rates of substitution are given by $\frac{w_L}{w_H} = \frac{\gamma_1}{\gamma_2}(\frac{L}{H})^{\mu-1}$ and $\frac{R_y}{R_z} = \frac{\gamma_3}{\gamma_4}(\frac{K_y}{K_z})^{\xi-1}$ so that the elasticity of substitution between the two types of labour is $1/(1-\mu)$, and between the two types of capital is $1/(1-\xi)$.

The marginal rate of substitution between different types of labour and capital is given by $\frac{w_L}{R_y} = \frac{\gamma_1}{\gamma_3}(\frac{L}{K_y})^{\eta-1}\frac{(\gamma_1+\gamma_2(H/L)^\mu)^{\eta/\mu-1}}{(\gamma_3+\gamma_4(K_z/K_y)^\xi)^{\eta/\xi-1}}$ so that the elasticity of substitution between labour and capital is $1/(1-\eta)$, when prices of both types of capital change by the same proportion.

After further algebraic manipulation, using these three marginal rates of substitution and the production function for x, one can show that the unit cost function is given by

$$\Gamma = \frac{1}{T}(w^{\frac{\eta}{\eta-1}} + c^{\frac{\eta}{\eta-1}})^{\frac{\eta-1}{\eta}} \tag{A.1}$$

where $w = (\gamma_1^{\frac{1}{1-\mu}} w_L^{\frac{\mu}{\mu-1}} + \gamma_2^{\frac{1}{1-\mu}} w_H^{\frac{\mu}{\mu-1}})^{\frac{\mu-1}{\mu}}$ and $c = (\gamma_3^{\frac{1}{1-\xi}} R_y^{\frac{\xi}{\xi-1}} + \gamma_4^{\frac{1}{1-\xi}} R_z^{\frac{\xi}{\xi-1}})^{\frac{\xi-1}{\xi}}$.

Then unit factor requirements a_L, a_H etc are given by

$$a_L = \frac{\partial \Gamma}{\partial w_L} \tag{A.2}$$

etc.

B Quality Ladders

Quality ladders can be introduced either instead of, or alongside expanding varieties by generalizing (2) to

$$C_{ml}^b = \left[\int_0^n (\sum_m x_{m,lj}^b q_{m,j}^b)^\alpha dj\right]^{1/\alpha}; \qquad \alpha \in (0,1), \tag{B.1}$$

where $q_{m,j}$ denotes the quality of the mth generation of product in industry j. Following Grossman and Helpman (1993), if we assume that each new generation of product produces exactly $\lambda > 1$ times as many services as the previous generation, then $q_{m,j} = \lambda q_{m-1,j}$ and therefore $q_{m,j} = \lambda^m q_{0,j}$. If quality ladders replace expanding varieties, then most of the model goes through as before with the following differences: the price of the leading quality of variety j is

$$\begin{aligned} p^b &= \lambda \Gamma_m^b \text{ if } \frac{1}{\alpha} > \lambda \\ &= \frac{\Gamma_m^b}{\alpha} \text{ otherwise} \end{aligned} \tag{B.2}$$

whilst the price of the follower is Γ_m^b. The rate of change of varieities $\dot{n}/n$ is replaces with the probability per unit of time, i., a succesfull invention of a leading product in industry j. Then (31) is replaced by

$$i^b = T_i[(1-\gamma_i)L_i^{\mu_i} + \gamma_i H^{\mu_i}]^{1/\mu_i}. \tag{B.3}$$

Finally the no-arbitrage condition (35) is now

$$\frac{\pi^b}{v^b} + \frac{\dot{v}^b}{v^b} - i = r^b \tag{B.4}$$

The problem now is that there are *scale effects.* These can be removed by replacing (B.3) by

$$i^b = \frac{T_i}{L+H}[(1-\gamma_i)L_i^{\mu_i} + \gamma_i H^{\mu_i}]^{1/\mu_i}. \tag{B.5}$$

but this is not so easy to rationalize as it was for expanding varieties.

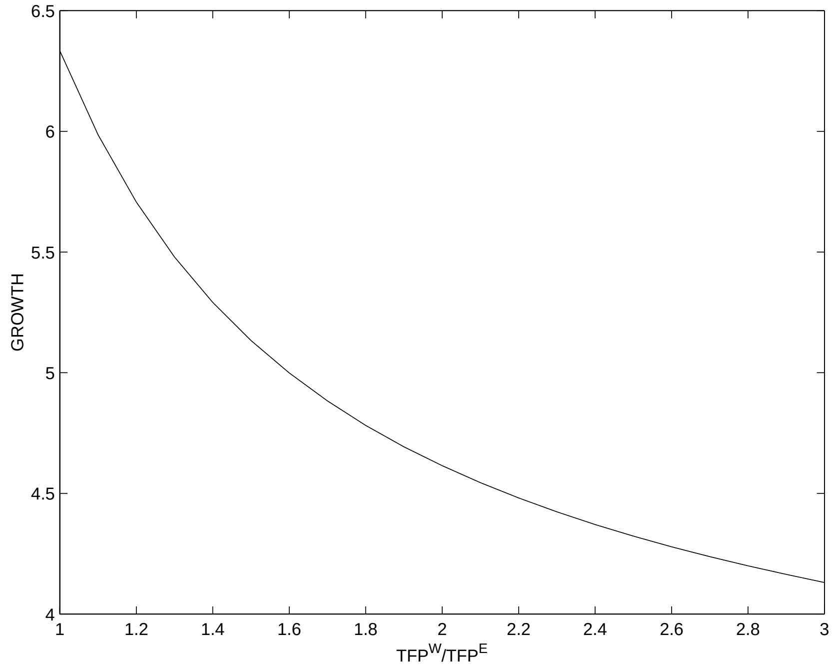

Figure 1: **WORLD GROWTH:** $H^E = L^E = H^W = L^W$

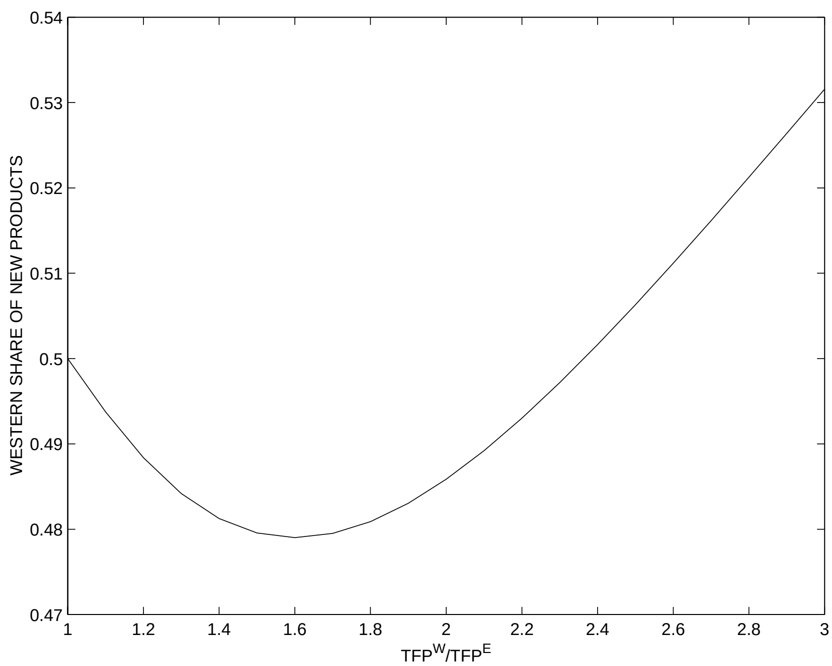

Figure 2: **WESTERN SHARE OF NEW PRODUCTS:** $H^E = L^E = H^W = L^W$

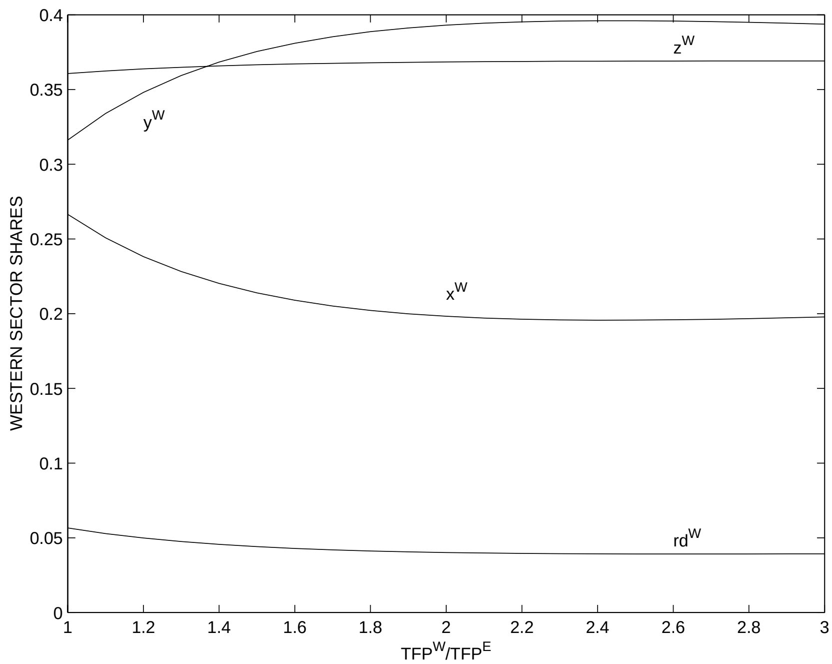

Figure 3: **WESTERN SECTOR SHARES:** $H^E = L^E = H^W = L^W$

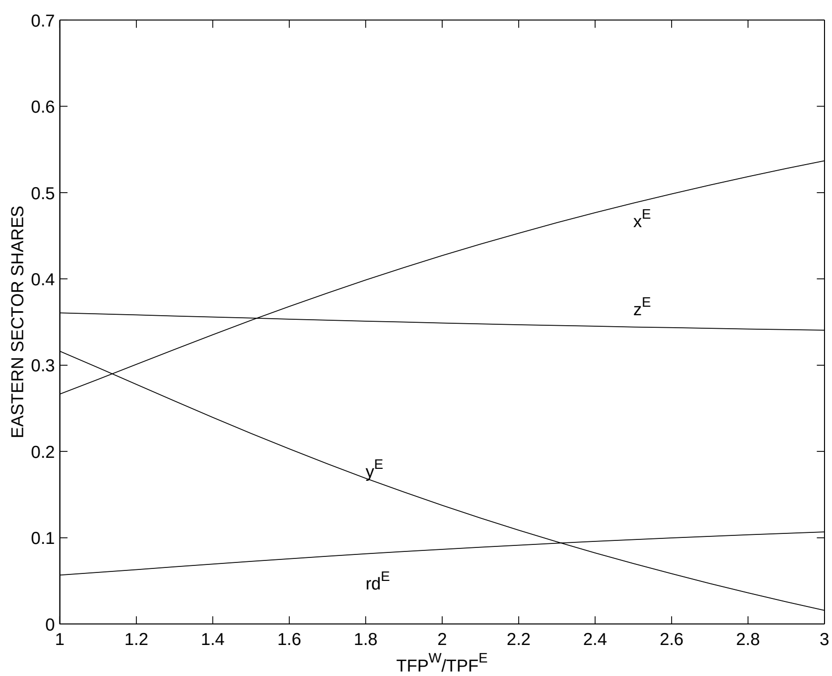

Figure 4: **EASTERN SECTOR SHARES:** $H^E = L^E = H^W = L^W$

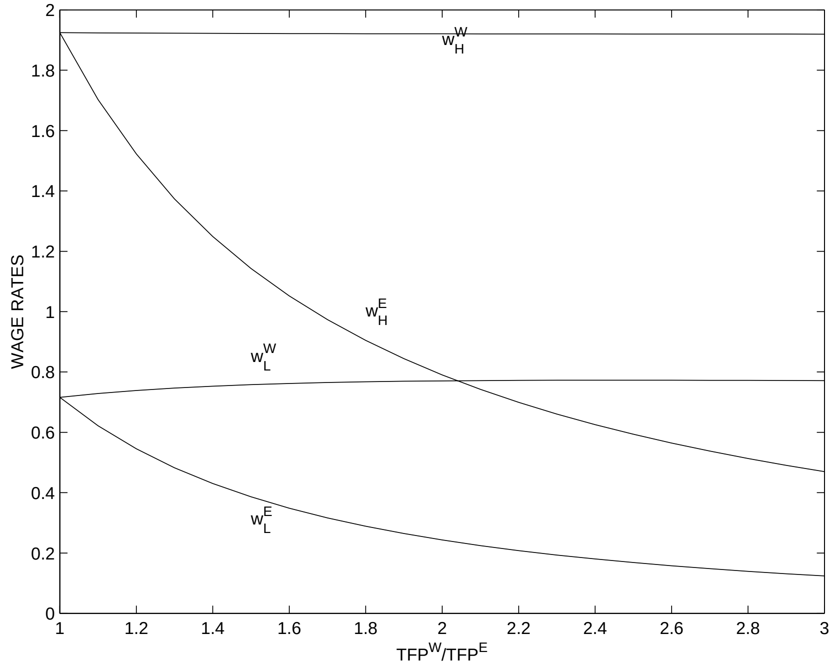

Figure 5: **WAGE RATES:** $H^E = L^E = H^W = L^W$

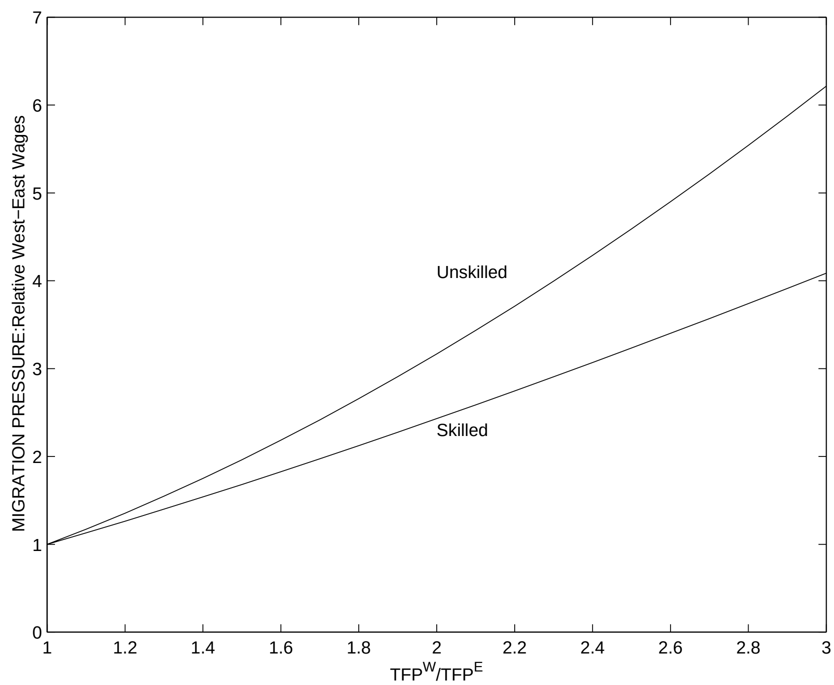

Figure 6: **MIGRATION PRESSURE: WEST-EAST WAGE RATIOS:** $H^E = L^E = H^W = L^W$

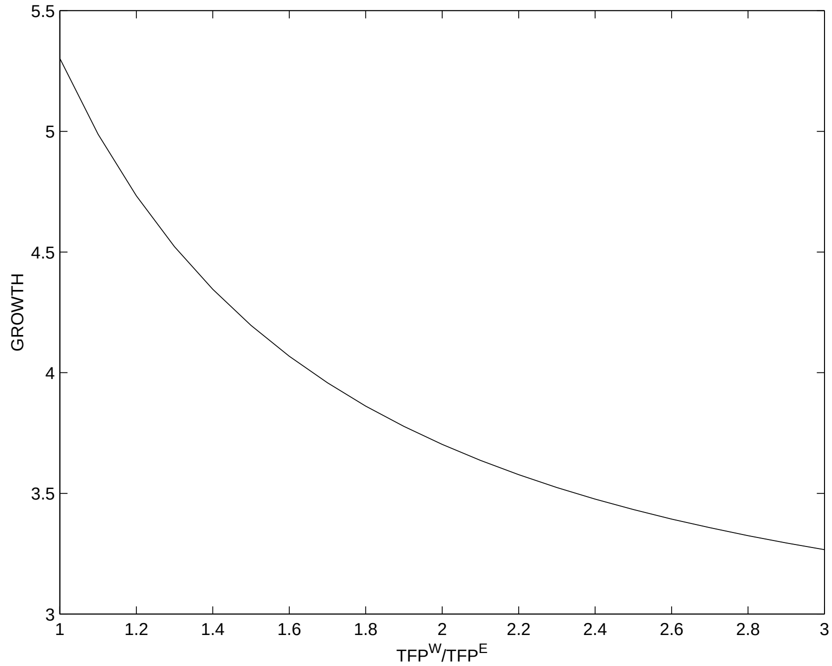

Figure 7: **WORLD GROWTH:** $H^E = 0.15$; $L^E = 0.35$; $H^W = L^W = 0.25$

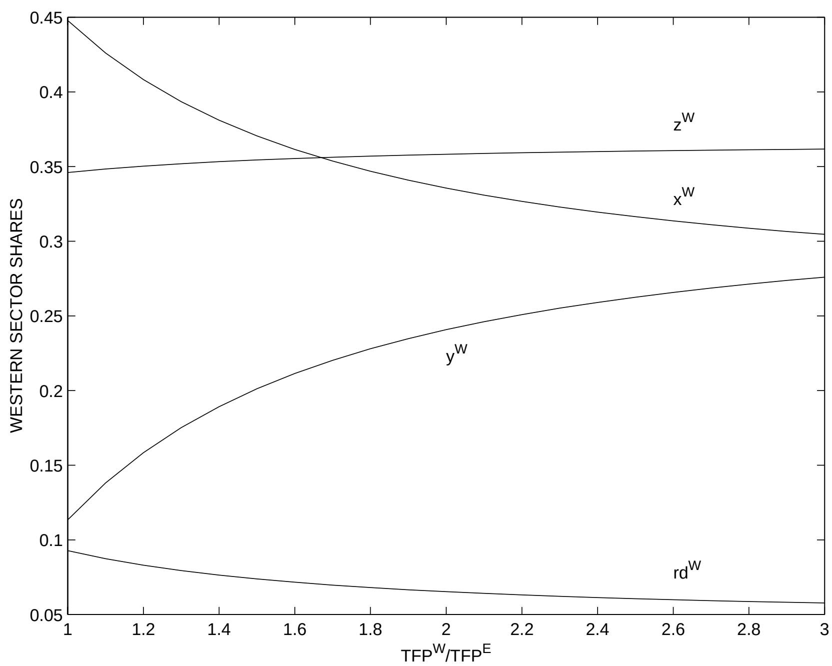

Figure 8: **WESTERN SECTOR SHARES:** $H^E = 0.15$; $L^E = 0.35$; $H^W = L^W = 0.25$

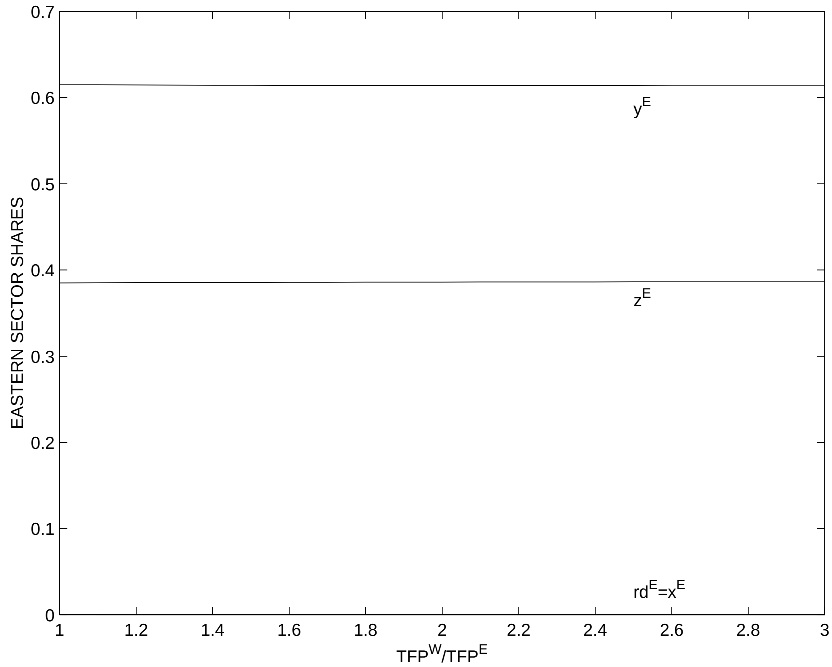

Figure 9: **EASTERN SECTOR SHARES:** $H^E = 0.15$; $L^E = 0.35$; $H^W = L^W = 0.25$

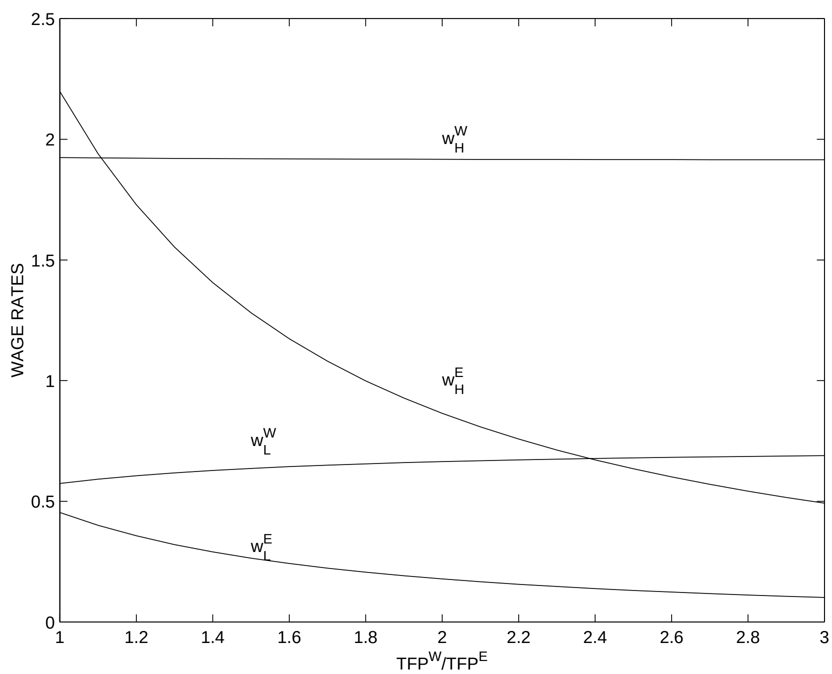

Figure 10: **WAGE RATE:** $H^E = 0.15$; $L^E = 0.35$; $H^W = L^W = 0.25$

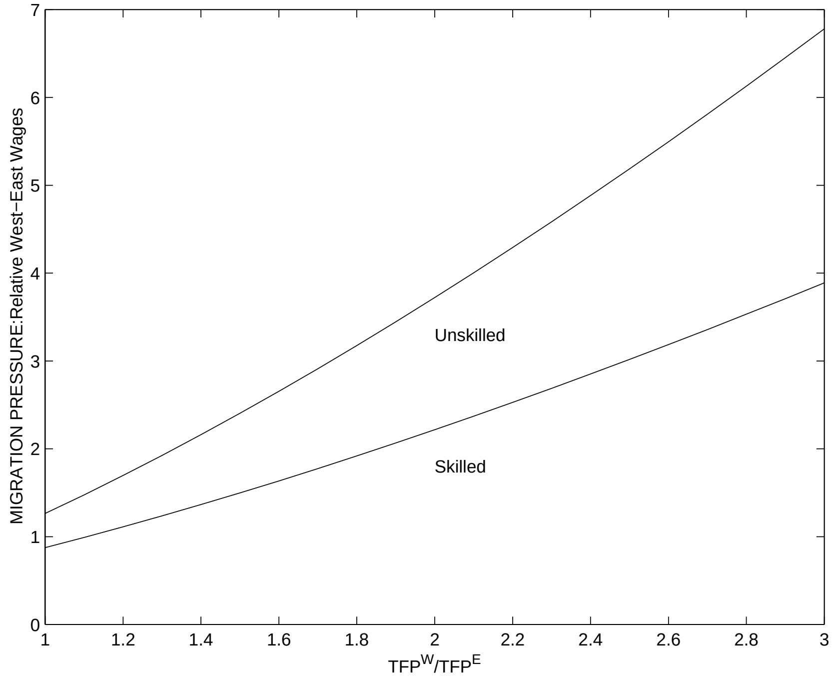

Figure 11: **MIGRATION PRESSURE: WEST-EAST WAGE RATIOS:** $H^E = L^E = H^W = L^W$

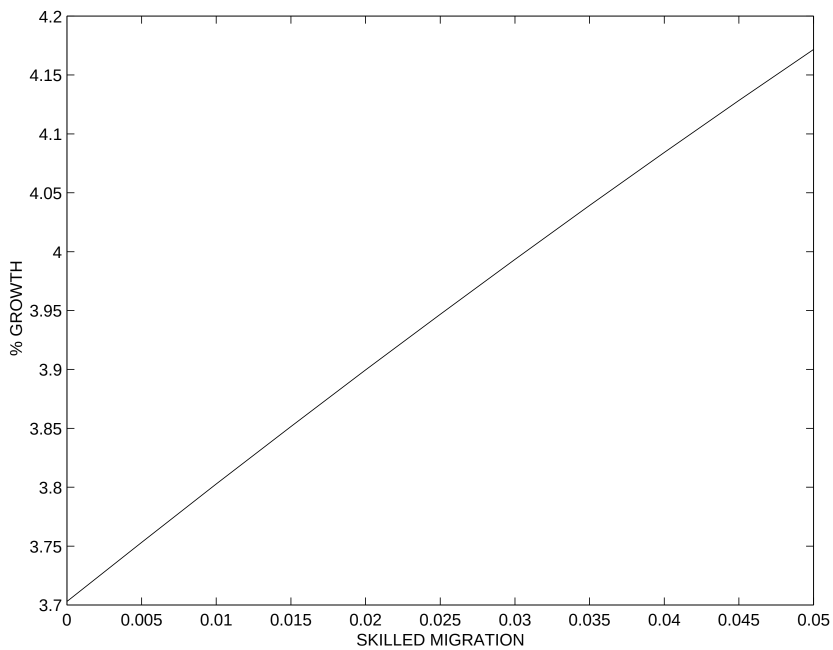

Figure 12: **GROWTH.** Pre-Migration Labour: $H^E = 0.35$; $L^E = 0.15$; $H^W = L^W = 0.25$; $TFP^E = 0.5 TFP^W$

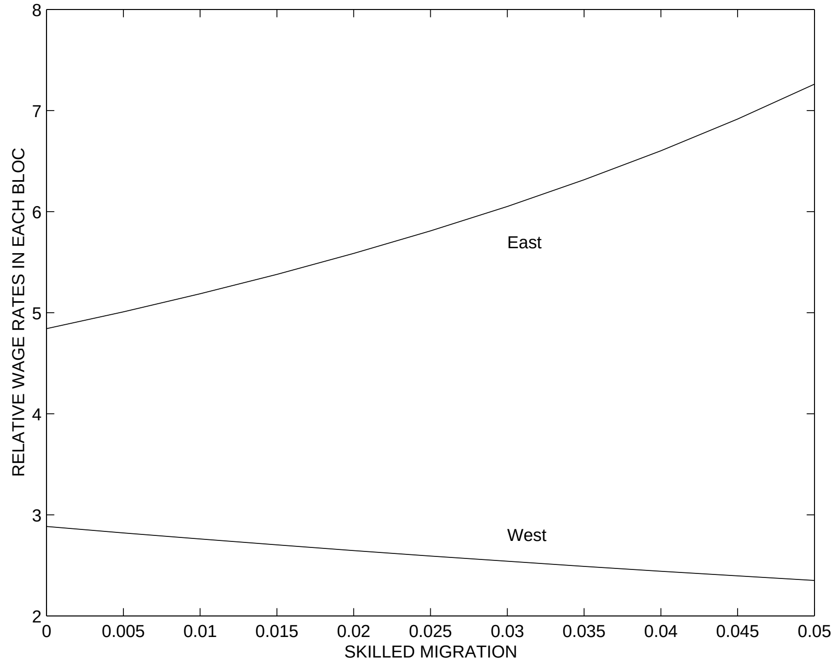

Figure 13: **RELATIVE WAGE RATES IN EACH BLOC.** Pre-Migration Labour: $H^E = 0.35\,;\ L^E = 0.15\,;\ H^W = L^W = 0.25\,;\ TFP^E = 0.5TFP^W$

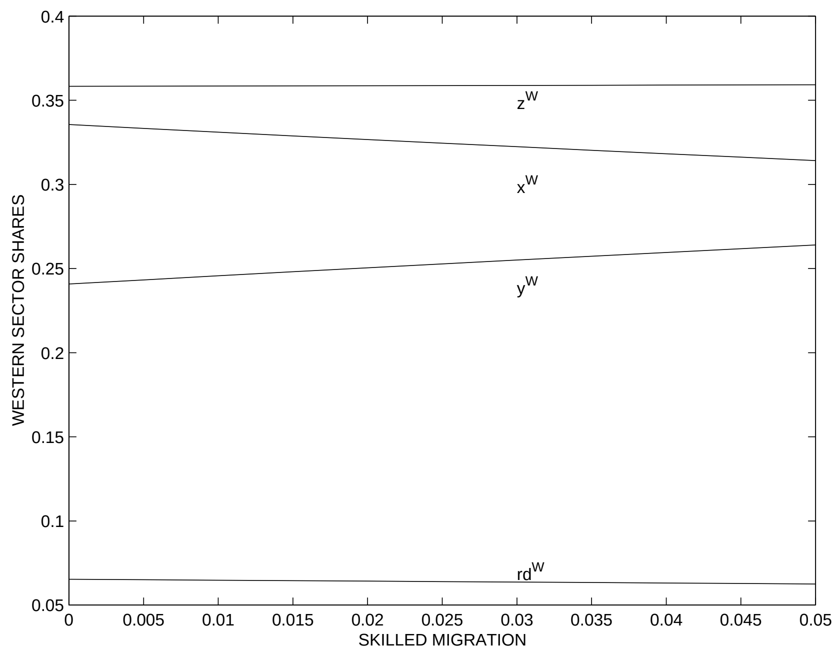

Figure 14: **WESTERN SECTOR SHARES.** Pre-Migration Labour: $H^E = 0.35\,;\ L^E = 0.15\,;\ H^W = L^W = 0.25\,;\ TFP^E = 0.5TFP^W$

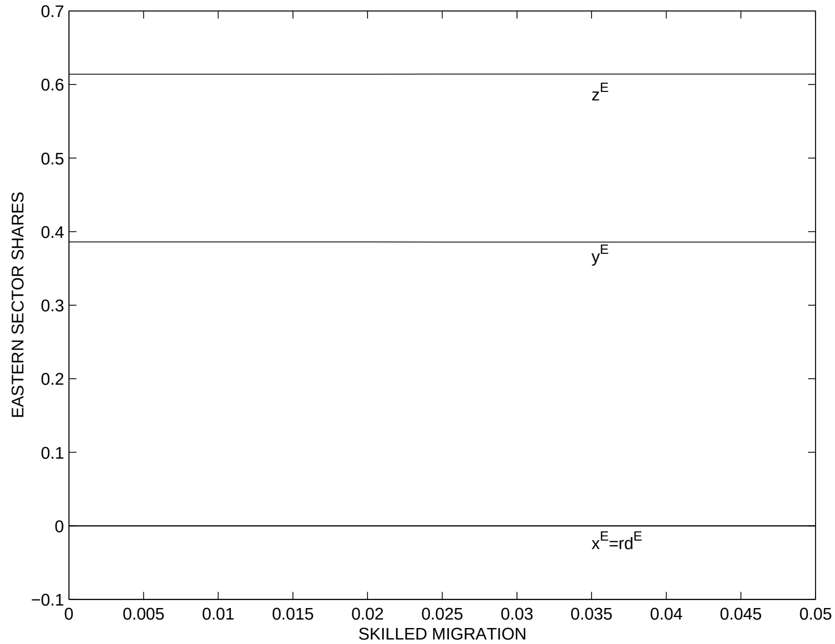

Figure 15: **EASTERN SECTOR SHARES.** Pre-Migration Labour: $H^E = 0.35\,;\ L^E = 0.15\,;\ H^W = L^W = 0.25\,;\ TFP^E = 0.5TFP^W$

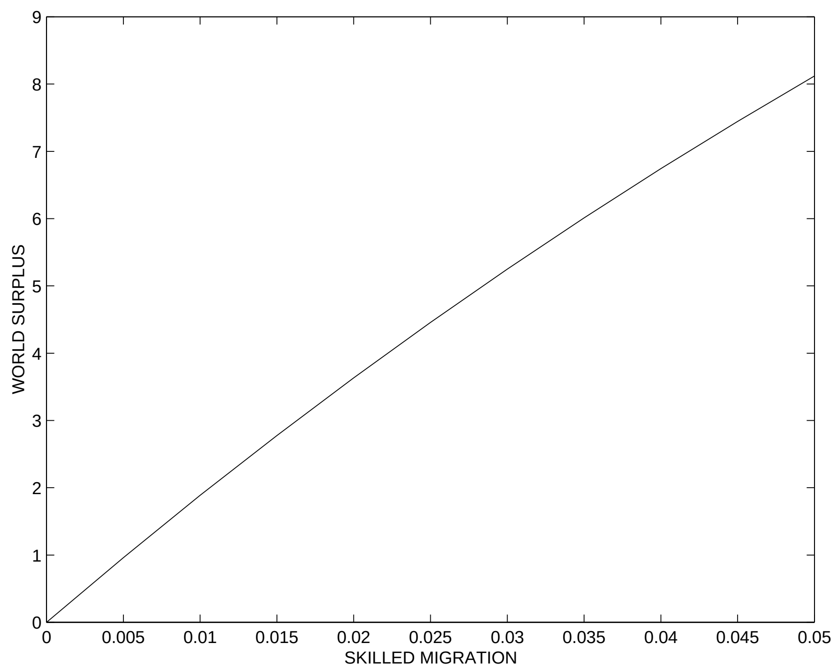

Figure 16: **WORLD SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\ L^E = 0.15\,;\ H^W = L^W = 0.25\,;\ TFP^E = 0.5TFP^W$

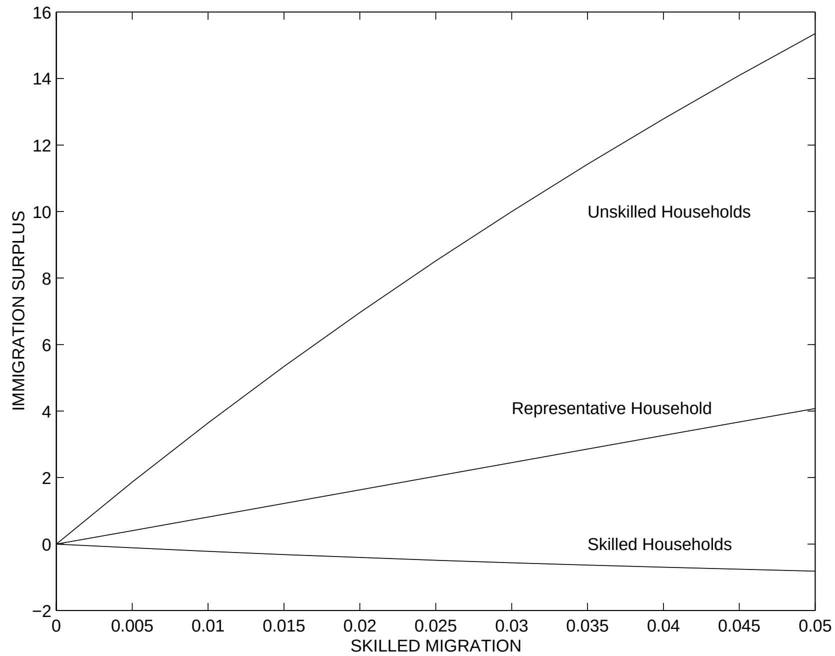

Figure 17: **IMMIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5TFP^W$

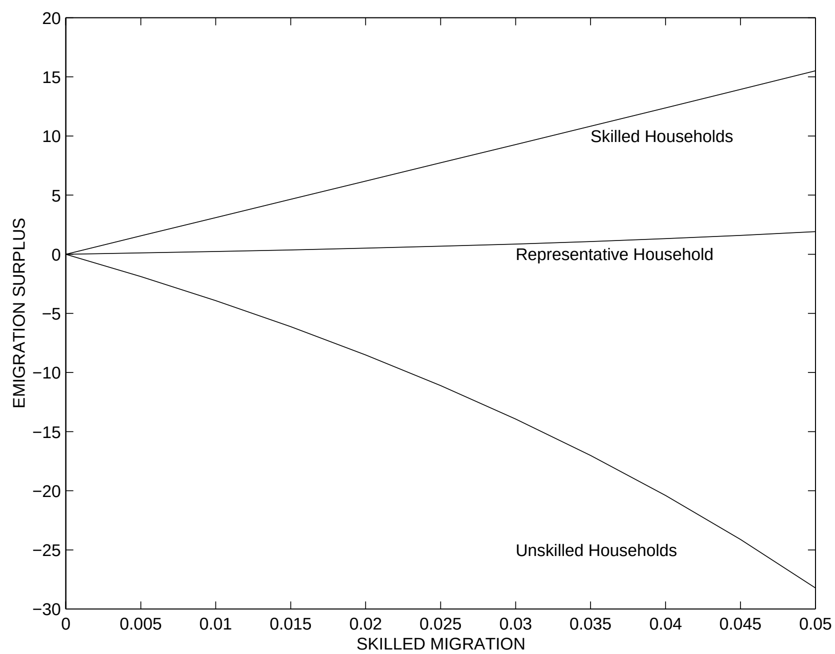

Figure 18: **EMIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5TFP^W$

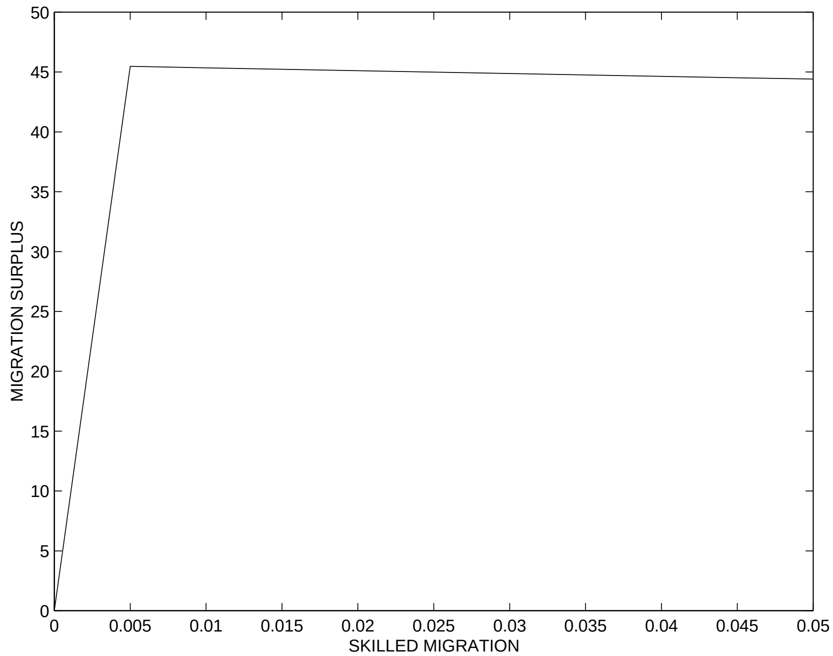

Figure 19: **MIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5TFP^W$

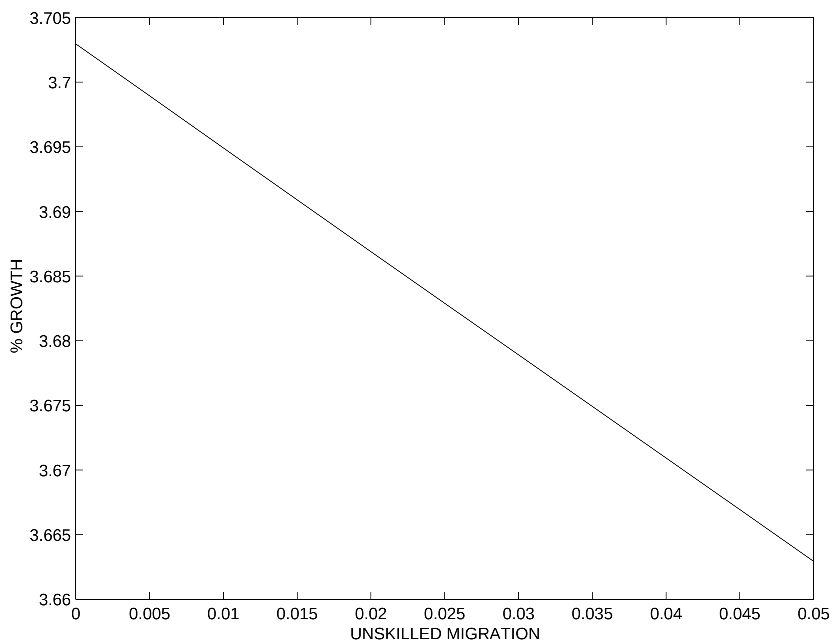

Figure 20: **GROWTH.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5TFP^W$

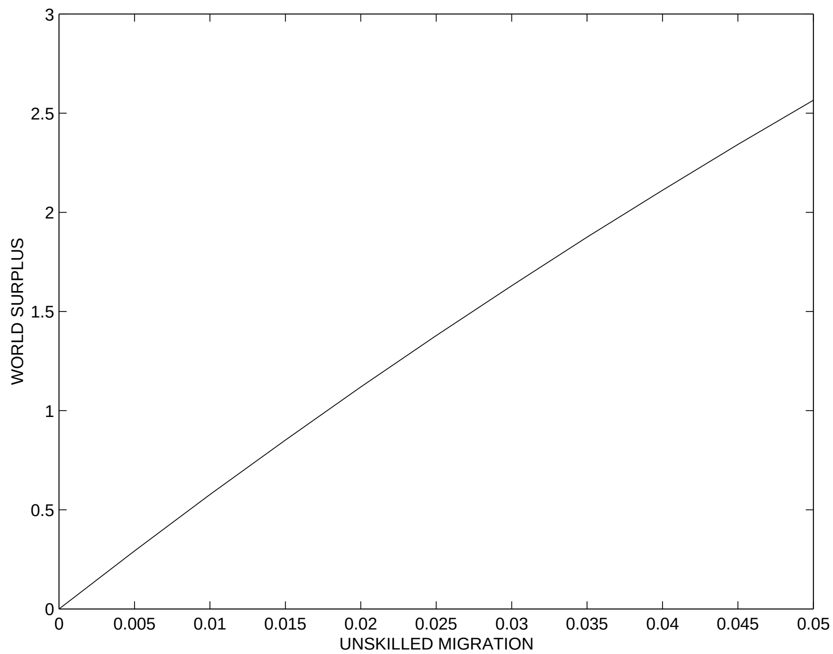

Figure 21: **WORLD SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;L^E = 0.15\,;\,H^W = L^W = 0.25\,;\,TFP^E = 0.5TFP^W$

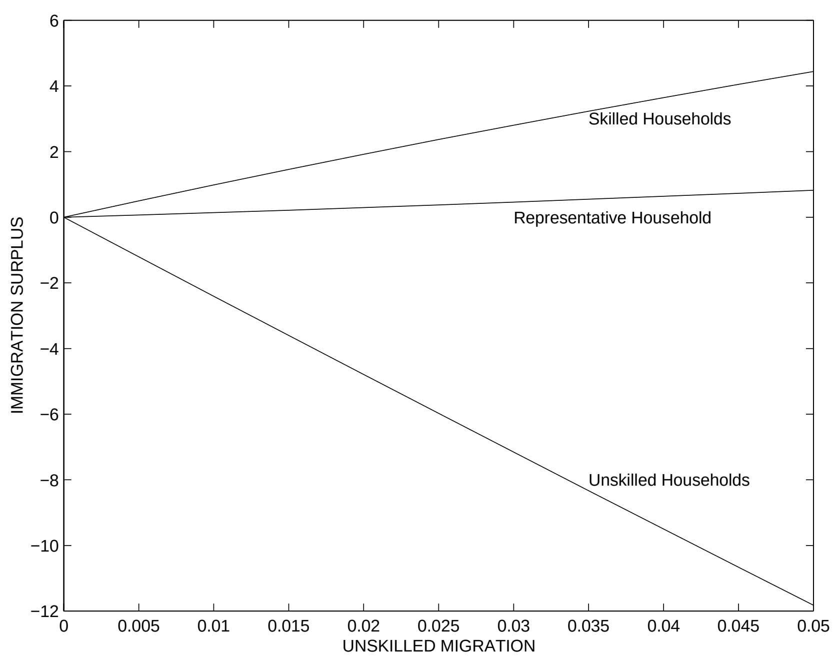

Figure 22: **IMMIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;L^E = 0.15\,;\,H^W = L^W = 0.25\,;\,TFP^E = 0.5TFP^W$

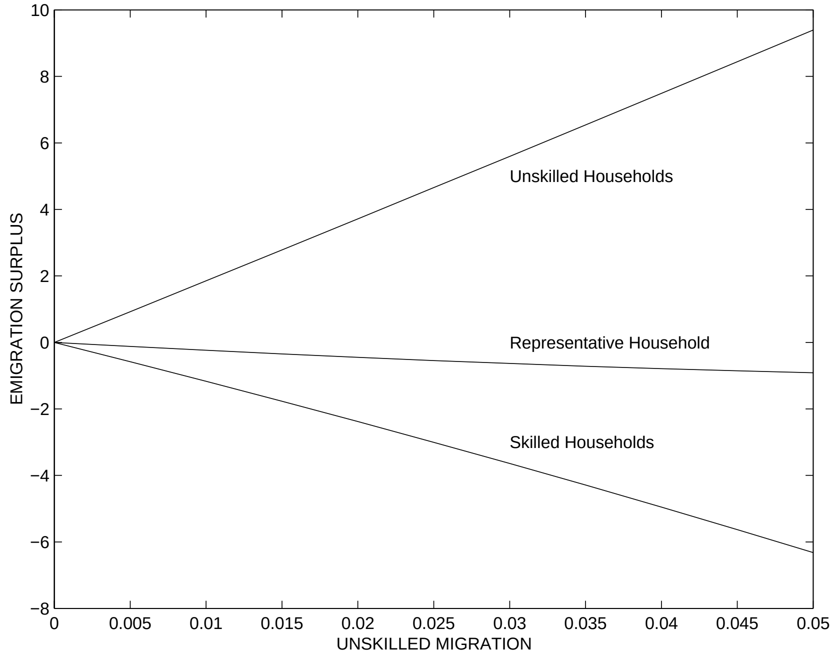

Figure 23: **EMIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5 TFP^W$

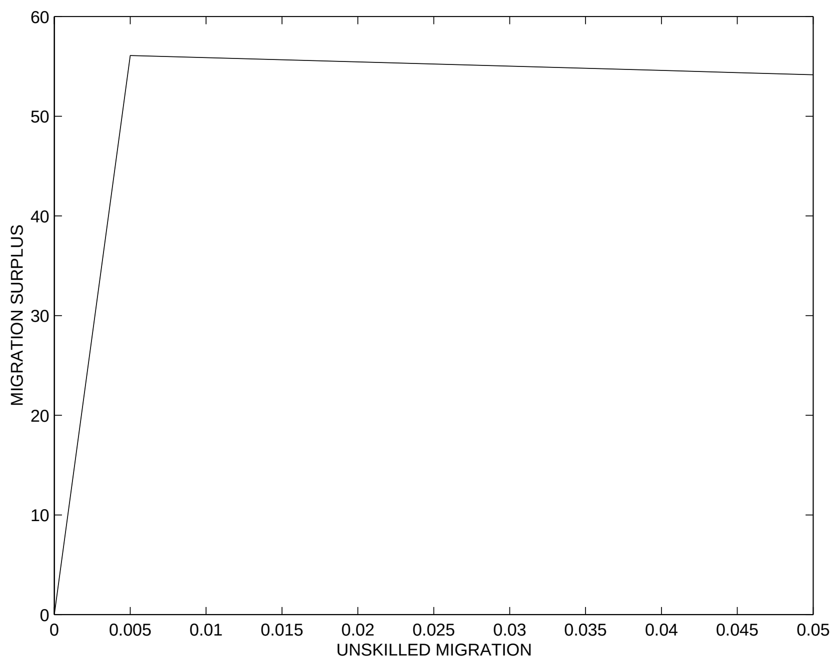

Figure 24: **MIGRATION SURPLUS.** Pre-Migration Labour: $H^E = 0.35\,;\, L^E = 0.15\,;\, H^W = L^W = 0.25\,;\, TFP^E = 0.5 TFP^W$