International Trade circumstance in which technological leapfrogging between regions

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Abstract: International trade plays an important role in the economy of each individual country. It allows to satisfy the needs of the population; stimulates the internal development of the country. International trade is the exchange of goods and services between countries. The paper investigates circumstance in which technological leapfrogging between regions will occur. Input-output linkages between firms in imperfectly competitive industries create forces for agglomeration of industries in particular locations. A new technology, incompatible with the old, will not benefit from these linkages, so will typically be established in locations with little existing industry and consequently lower factor prices

Key words: International trade, Agglomeration, Circumstances, leapfrogging.

1.1 INTRODUCTION

There are numerous historical episodes where a technological leader loses its dominant position after some technological breakthrough. One example concerns the nineteenth century Norwegian shipping industry. The port of Risor was a major centre of sail based shipping industry. The development of steam technology rendered sail technologically obsolete, but did not lead to the abandonment of the technology in Risor. Steam based shipping activity became centred on Bergen and sail technology continued in Risor for several decades before being driven out of business. Following the eventual demise of sail, Risor never recovered its status as a centre of shipping activity. Other examples provide evidence of centres of activity that have been overtaken by new technologies, but then managed to switch to the new. In 1850, Britain was regarded as the world’s only industrial economy. Yet by the first world war industrialization had spread to other countries. Harley (1974) gives examples of British industries which were slow to adopt new techniques that were in use elsewhere. For instance Britain was slow to adopt capital using, labour saving techniques such as ring spindles in textiles and assembly line methods in the metal-working industries.

When a new technology becomes available, which is superior to and incompatible with an old technology, under what circumstances will the new technology be adopted? Will the new technology be adopted by the existing industrial leader or will it be adopted in a different location, another region or country? If the new technology is adopted in another location, will the new and old technologies co-exist or will the new technology drive out the old? Several papers have offered explanations of why there has been technological leapfrogging.1 Brezis, Krugman and Tsiddon's (1993) explanation of technological leapfrogging among countries is based on non-pecuniary externalities. They assume that production is subject to external learning effects which are specific to each country and that when there is a major technological breakthrough, it yields a higher productivity than the old technology given the same amount of experience. So for the leading country which has extensive experience with the old technology and hence a higher wage, the new technology is initially inferior to the old. In contrast, the lagging country which has little experience with the old technology and hence a lower wage, can use its wage advantage to adopt the new technology. Over time,

the lagging country gains more experience with the new technology and takes over as the leading country. The mechanism in this Chapter is quite different being based on pecuniary externalities arising from transactions in the presence of imperfect competition. I present a model with two regions, with labour immobile between the two regions, and two industries which are vertically linked. The upstream industry is a Cournot oligopoly producing homogenous components which are supplied to the downstream industry. The downstream industry is perfectly competitive producing homogenous final products which are supplied to the rest of the world. The vertical linkages between the two industries create forces for the agglomeration of the two industries in the one location as in Krugman and Venables (1995), Venables (1996a) and Venables (1996b). There are demand linkages as an increase in the scale of operation of the downstream industry benefits upstream firms. This has a feedback effect as the price of upstream goods is decreasing in the number of upstream firms, due to increased competition among upstream firms - cost linkages which benefit downstream firms. The interaction of these forces creates pecuniary externalities, encouraging regional specialisation.

Why couldn't one upstream firm enter the other region with a low price and take advantage of the lower wage there? If a single upstream firm could commit not to act like a monopolist, it would attract downstream firms to enter which would in turn attract more upstream firms to enter, creating demand and cost linkages. It would be possible for an upstream firm to commit to a low price if the staging of the game were such that upstream firms made their quantity decisions before downstream firms made their entry decisions in which case regional specialisation would never be an equilibrium. However, it seems more realistic to suppose that entry decisions are taken before quantity decisions. With this staging of the game, a potential upstream entrant cannot commit not to act like a monopolist.

Consequently, downstream firms will not enter unless the monopoly price is low enough to cover their fixed costs. The game theoretic interactions between the firms are crucial for regional specialisation in this model.

When a new technology becomes available it does not benefit from the agglomeration of firms using the old technology since it is assumed that the two technologies are incompatible, like steam and sails. The new technology, which I assume to be labour augmenting, is therefore most likely to be adopted in the

’lagging’ region where the wages are lower. I show that there is an equilibrium where the two technologies co-exist, as did steam and sails in Norway. So according to this model, Risor’s failure to introduce the new technology was because the existing agglomeration raised the prices of immobile factors (labour and also port space) in Risor relative to Bergen and its failure to switch was due to the benefits associated with the agglomeration of sail technology related activities.

The model is developed in derives the conditions for regional specialisation; analyses the circumstances under which the new technology will be adopted and where it will be adopted, concludes and briefly mentions some policy implications.

THE MODEL

I develop a model of two vertically linked industries where firms can locate in either of two regions. Firms must choose their location and their technology. Initially, only one technology is available but then there is an unanticipated technological breakthrough - a new superior technology, incompatible with the old, becomes available. Upstream firms require labour to produce components which they sell to downstream firms in their own region. And downstream firms use components and labour to produce a final, homogenous product which they sell to the rest of the world. Labour is immobile between the two regions. So the two regions are linked by their competition for final product demand from the rest of the world.

Assumptions of the Model

Assumption 1: Firms play a four stage game as follows: In stage 1, upstream firms choose whether to enter and in which region. To enter each upstream firm must pay a fixed cost, F, and choose its technology,θ^k. There are two echnologies available, indexed k=A ,B. I set out the general model where both technologies are available. When solving for equilibria, I assume that initially only one technology is available,θ^a. At some future date there is an exogenous shock where a new superior technology, incompatible with the old, becomes available,θ^b. In stage 2, downstream firms choose whether to enter and in which region. To enter each downstream firm must pay a fixed cost, f, and choose its technology,θ^k. In stage 3 upstream firms choose quantities, competing a la Cournot. In the final stage downstream firms are assumed to be price takers.

I assume that firms make their entry decisions before choosing quantities since setting up a firm takes more time than adjusting quantities. The fixed costs commit firms to a particular technology. The game is solved through backward induction so that equilibrium is subgame perfect.

Assumption 2: Demand for final products only comes from consumers in the rest of the world:

$$Y^d = p^{-\eta} \qquad (1)$$

Where Y^d is the demand for final products, p is the price of final products and η is the elasticity of demand. This functional form is chosen for simplicity.

Assumption 3: The cost function for each downstream firm in region i is

$$c_i=(w_i\theta^k)^{1-\mu}q_i^{\mu}[f+ay_i+by_i^2] \quad i=1,2 \quad a>0 \quad b>0 \qquad (2)$$

Where W_i is the wage in region i, q_i is the price of upstream components in region i, *p* is the share of costs of components in the total cost of production, and *y-t* is output per downstream firm in region i.

A Cobb-Douglas technology is chosen for simplicity. The cost function gives U shaped average cost curves and upward sloping marginal cost curves ensuring that there is a unique level of equilibrium output for each firm.

Assumption 4: The cost function for each upstream firm in region i is:

$$C_i=(F+\beta x_i)\theta^k w_i \qquad (3)$$

Where X_i is the output per upstream firm in region i and $/\beta\theta w_i$ is marginal cost.

Assumption 5: Trade costs on components produced by upstream firms are so high that no trade in components takes place between the two regions.

Assumption 6: Labour is immobile between the two regions and each region has a perfectly competitive labour market with the labour supply function, L_j^s, defined by:

$$L_i^s=0 \quad if\ w_i<w_0$$
$$L_i^s=w^{\lambda} \quad if\ w_i\geq w_0 \qquad (4)$$

If W_i is greater than or equal to the reservation wage, w_o, the elasticity of labour supply is λ. At a wage below w_o, no labour is supplied to these industries - it is all employed in some other industry which is not explicitly modelled here.Again, this functional form is chosen for simplicity.

Assumption 7: The new technology is labour augmenting, thereby affecting the cost functions of upstream and downstream firms, and it is incompatible with the old technology. The way technology enters the model does not affect the results. For instance, the new technology could be modelled as a fall in upstream firms 'marginal cost and the results would still be the same. However, the incompatibility of the two technologies is important for the results.

Solving the model

STAGES 3 AND 4

I solve for prices and quantities for a given number of upstream firms, q, and a given number of downstream firms, m_i, in each region i in three steps. First, I solve for prices and quantities in the downstream market. Second, I solve for prices and quantities in the upstream market. Finally, I determine the factor market clearing condition.

First, consider the behaviour of downstream firms. Each firm chooses how much to produce by taking the final price of goods as given. Setting price equal to marginal cost, the inverse supply function for each firm is:

$$p=(w_i\theta^k)^{1-\mu}q_i^{\mu}(a+2by_i) \tag{5}$$

Demand for inputs is derived using Shephard's lemma, where demand for components, X_i^d, in region i is:

$$X_i^d=\mu(w_i\theta^k)^{1-\mu}q_i^{\mu-1}[f+ay_i+by_i^2]m_i \tag{6}$$

and demand for labour by downstream firms, L_i^d, in region i is:

$$L_i^d=(1-\mu)w_i^{-\mu}(\theta^k)^{1-\mu}q_i^{\mu}[f+ay_i+by_i^2]m_i \tag{7}$$

The equilibrium price of final goods is determined by aggregating equation (5) across all firms in both regions and equating this aggregate supply function to the demand function given by equation (1). The equilibrium output for each firm is then determined by substituting the equilibrium price into equation (5). Second, consider the behaviour of upstream firms. Each firm chooses quantity by setting marginal revenue equal to marginal cost, taking as given the quantity of all other upstream firms, the number of upstream firms and the number of downstream firms. The first order condition for each upstream firm in region iis:

$$q_i(1-\frac{1}{n_i\epsilon_i})=\theta^k\beta w_i \qquad (8)$$

Where ϵ_i is the absolute value of the elasticity of derived demand for components. It is calculated by differentiating equations (1), (5)and (6), with respect to y_i, p,q_i and X_i^d. The derivations are in Appendix 1.

$$\epsilon_i=(1-\mu+\frac{\mu\eta(a+2by_i)^2(m_iy_i+m_jy_j)}{(f+ay_i+by_i^2)[(a+(1+\eta)2by_i)m_i+\eta 2bm_jy_j]}) \qquad (9)$$

The elasticity of derived demand can be decomposed into two effects: a substitution effect and an output effect. An increase in the price of components relative to the price of labour will lead firms to substitute labour for components. This effect is captured by the first term in equation (9), which is one minus the share of components in total costs, denoted by □, multiplied by the elasticity of substitution which is equal to one for a Cobb-Douglas technology. The substitution effect is larger the smaller is the share of components in total costs; and the larger the elasticity of substitution between factors. A change in the price of factors will also lead to an output effect. An increase in the price of components increases the cost of production and hence reduces the amount of output firms are willing to supply, which affects the price and demand for final products. The output effect is larger the larger is the share of components in total costs; and the larger is the elasticity of demand for final products,η. The output effect is smaller in this model than in the 'usual' case because the entry decisions of downstream firms have already taken place, the number of downstream firms is determined in stage 2 of the game. Equilibrium in the upstream industry is given by equating demand for components (equation (6)) to the supply of components:

$$n_ix_i=\mu(w_i\theta^k)^{1-\mu}q_i^{\mu-1}[f+ay_i+by_i^2]m_i \qquad (10)$$

Demand for labour by upstream firms, L_i^u, is derived by Shepard's lemma:

$$L_i^u=(F+\beta x_i)\theta^k n_i \qquad (11)$$

Finally, labour market equilibrium is determined by equating the labour supply in each region to the sum of labour demand from upstream and downstream firms in each region:

$$w_i^\lambda=(1-\mu)w_i^{-\mu}(\theta^k)^{1-\mu}q_i^\mu[f+ay_i+by_i^2]m_i+(F+\beta x_i)\theta^k n_i \quad if\ w_i\geq w_0 \qquad (12)$$

Downstream firms decide whether to enter, and if so in which region and with which technology. There is free entry and exit into the industry so profits are driven to zero. Since each firm is so small relative to the whole industry we can ignore the integer problem.

1.2 MATERIALS AND METHODS

The methodology of the research is presented by the method of system analysis, the method of comparative macroeconomic analysis, theoretical analysis on basis of modelling.

1.3 RESULTS

N E W T E C H N O L O G Y

Suppose that the parameter values are such that regional specialisation is an equilibrium and that the equilibrium configuration (A,0) is given by history.

Then there is a technological breakthrough where a new technology becomes available, $\theta_b<\theta_a=1$, which is superior to and incompatible with the old technology. Will the new technology be adopted? If so, in which region? What are the equilibrium configurations? For the new technology to be adopted, an existing upstream firm from region 1 must be able to make higher profits by entering either region 1 or region 2 with the new technology, given n_1^*- l upstream firms in region 1, or a new upstream entrant must be able to make non-negative profits by entering either region with the new technology, given n_1^* upstream firms in region 1. When calculating the profits of the 'deviating upstream firms, the number of other upstream firms is taken as given, as this is determined in stage 1 of the game, but the number of downstream firms, quantities and prices are re-calculated as these are determined in the subsequent stages of the game. I assume that the fixed cost is paid every period so that even if a firm continues to operate with the old technology it must pay the fixed cost again. The new technology is labour augmenting. If an upstream firm were to enter region 1 with the new technology, it does not derive any of the agglomeration benefits enjoyed by the firms operating with the old technology since the two technologies are assumed to be incompatible. The pecuniary externalities are the same in either region but the wage in region 2 is lower than in region 1. If an upstream firm were to enter region 2 with the new technology, it has the benefit of the new technology as well as the advantage of a lower wage in that region. So a profitable opportunity to enter region 2 with the new technology will arise before that of entering region 1 with the new technology. The lower is θ^b relative to θ^a, the more likely that there will be a profitable opportunity for a single upstream firm to enter region 2.Figure 4 is a plot of the maximum wage a single upstream firm can afford to pay in region 2 and the labour market clearing wage in region 2 for different values of θ^b, given there are n_1^* old technology firms operating in region 1. The number of upstream firms in region 1, n_1^* was determined by the zero profit condition in equation and illustrated in Figure 1.

Configuration (A,B) is an equilibrium if the following conditions are satisfied first, the wages in region 1 and region 2 are above the reservation wage; second no existing upstream firm from region 1 or from region 2 can make higher profits by changing its behaviour. No upstream firm will want to enter region 2 with the old technology since it does not derive any benefits from the agglomeration of new technology firms and it would have to pay a higher wage in that region. We need to check that a single existing upstream firm located in region 1 or in region 2 cannot enter region 1 with the new technology and earn higher profits.

$$\Pi_1^{\prime}(n_1(\theta^A)=n_1^*-1, n_2(\theta^B)=n_2^*, n_1(\theta^B)=1) < \Pi_1(n_1(\theta^A)=n_1^*, n_2(\theta^B)=n_2^*)$$
$$\Pi_1^{\prime}(n_1(\theta^A)=n_1^*, n_2(\theta^B)=n_2^*-1, n_1(\theta^B)=1) < \Pi_2(n_1(\theta^A)=n_1^*, n_2(\theta^B)=n_2^*)$$

Further, a potential entrant cannot enter region 1 with the new technology and earn positive profits given the number of upstream firms in region 1 operating with the old technology and the number of upstream firms in region 2 operating with the new technology. We also need to check that a positive number of old technology upstream firms in region 1 and a positive number of new technology upstream firms in region 2 are earning non-negative profits.

The configuration (A,B) will be an equilibrium for certain parameter values. If θ^b is very low, the price of final goods will fall so low due to the increasing number of new technology firms operating in region 2 that firms in region 1 will not be able to continue to make non-negative profits and will exit.After the introduction of the new technology, the new equilibrium configuration may be (A,B) or (B,A) where the two technologies co-exist. For very low values of θ^b the equilibrium configuration may be (0,B) where the industry in region 1 is completely wiped out and there is an agglomeration of new technology firms operating in region 2 or (B,0) with all the new technology firms agglomerated in region 1. Alternatively, the equilibrium configuration may be (B,B) where there is an equal number of firms in both regions operating with the new technology. If the fixed cost for upstream and downstream firms is paid every period, we cannot say which equilibrium will be the equilibrium. All we can say is that these equilibria exist. However, if the fixed cost is an entry cost which is only paid once then we could say which the equilibrium is. Suppose that (A,0) is given to us by history so that there is only one technology available and all the firms are operating in region 1. Then a new technology becomes available which makes entry in region 2 profitable. A firm in region 1 would only exit if it could not cover its average variable cost. Consequently, the equilibrium configuration would be (A,B) and not (B,A) when $\theta^B = \theta^{B*}$. As the new technology improves, technology A will be abandoned and the industry in region 1 will either disappear or adopt the new technology.

Figure 1

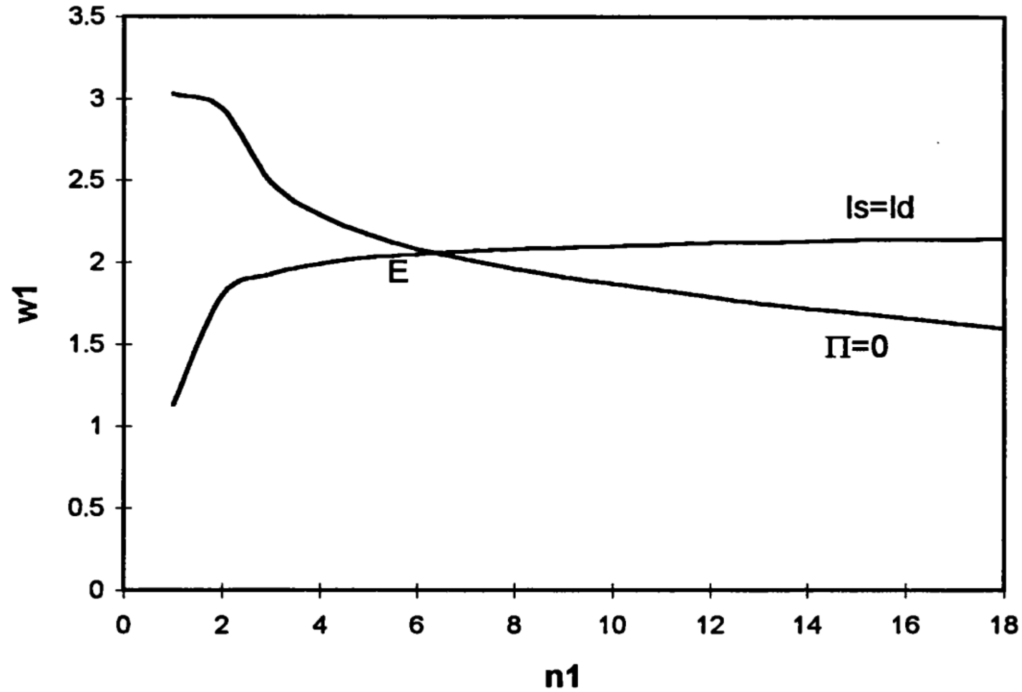
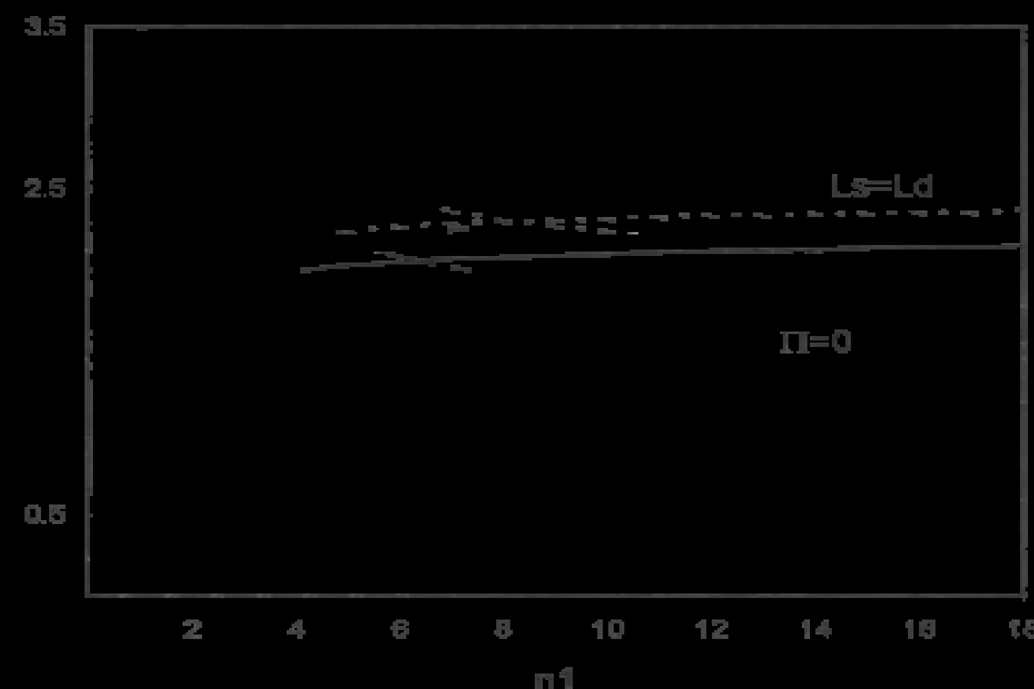


Figure 2
Increase in elasticity of demand



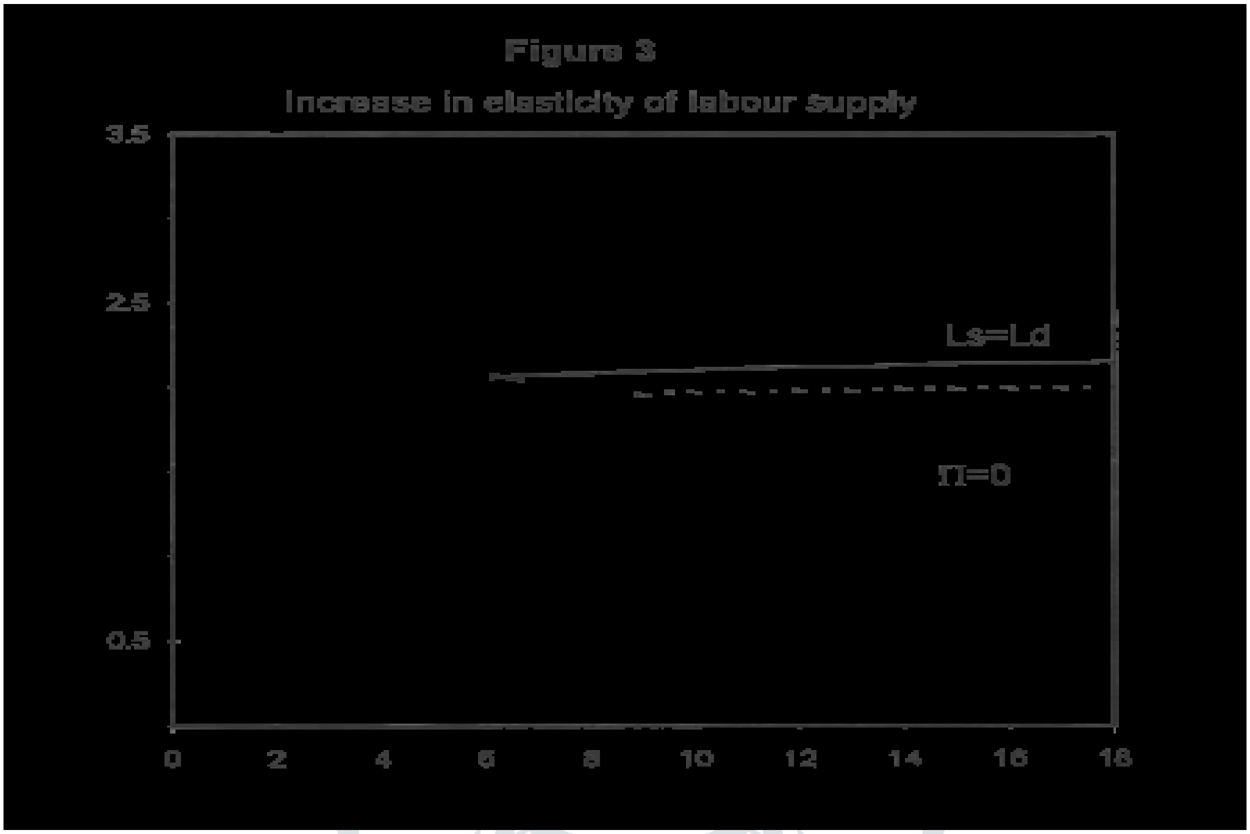
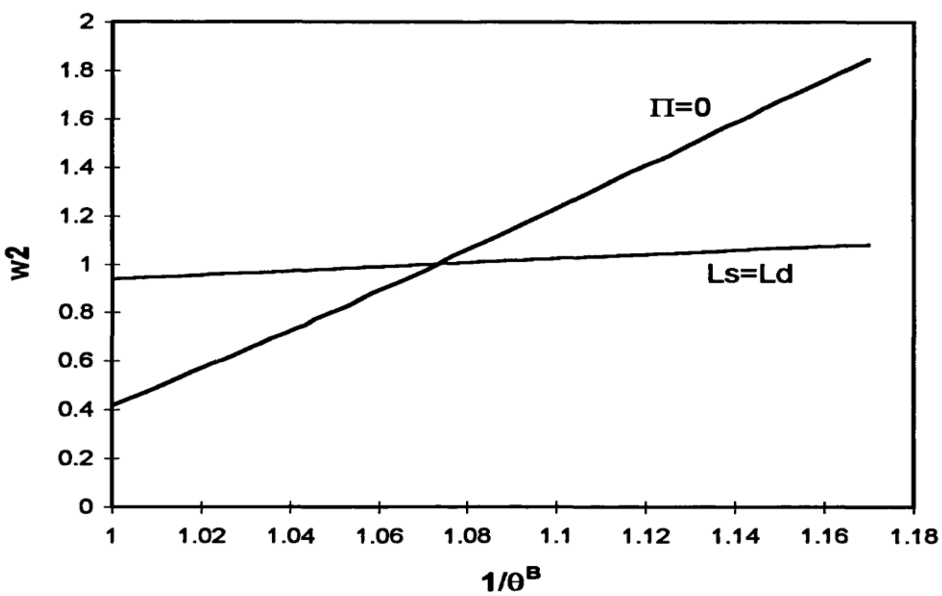


Figure 4



DISCUSSION

The simulations of the model have the following parameter values:

Figures 1, 2, 3 and 4.

μ=.6, *a* = b = f= .0 5, F = .5; β= 1; η=5; λ= 5 ; θ^A= 1;

Figure 2

A shift from η=5to η^*=6.

Figure 3

A shift from λ= 5 to λ'=6.

CONCLUSIONS

This paper suggests that at times of major technological breakthroughs a leading region may lose its dominant position to a lagging region if the new technology is incompatible with the old. The fact that it was a leading region implies higher wages which may prevent it from adopting the new superior technology. The leading region benefits from the agglomeration of firms arising from vertical linkages. When a new technology arrives, it does not benefit from the existing agglomeration since it is incompatible with the old technology. Consequently, it is more likely to be adopted in the lagging region which has lower wages.Furthermore, it is possible that the two technologies can co-exist. The new technology region has more firms operating and hence a higher wage. The old technology region has less firms operating so the agglomeration benefits are lower, but this is offset by a lower wage enabling it to continue to compete with the new technological leader.

These results raise policy questions for the A technology region. The government may want to consider a policy which would make it profitable for the new technology to be adopted as soon as it becomes available. Free entry into the industry means that profits of downstream firms are zero and at least close to zero for upstream firms. However, the wage is higher with the new technology so workers would certainly be better off. There are a number of different instruments that could achieve this objective. The government could target the co-ordination failure between the upstream firms or directly subsidise the new technology so that there is an immediate switch to the new technology.

Alternatively, the government could provide tax credits or accelerated depreciation allowances on existing capital stock.

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