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COMPETITION AND HUMAN CAPITAL ACCUMULATION: A THEORY OF INTERREGIONAL SPECIALIZATION AND TRADE

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ABSTRACT

We consider a model with several regions whose technological ability and factor endowments are identical and in which transport costs between regions are non-negligible. Nonetheless, certain goods are sometimes produced by multiple firms all of which are located in the same region. These goods are then exported from the regions in which their production is agglomerated. Regional agglomeration of production and trade stem from two forces. First, competition between firms for the services of trained workers is necessary for the workers to recoup the cost of acquiring industry-specific human capital. Second, the technology of production is more efficient when plants are larger than a minimum efficient scale and local demand is insufficient to support several firms of that scale. We also study the policy implications of our model.

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Regional agglomeration in the production of goods is pervasive: the Swiss specialize in the production of watches and chocolates; Silicon Valley in computers; and shoes, *haute couture*, and movies originate disproportionately in Italy, Paris, and Hollywood respectively. Regional specialization extends even to product subcategories. Within automobiles, luxury sedans tend to come from Germany, sports cars from Italy, and reliable forms of basic transportation from Japan. While, as the Heckscher-Ohlin model has it, some of this regional agglomeration results from differences in factor endowments, much of it is difficult to explain in that manner. For example, regional specialization in industrial products such as shoes and watches does not seem to be driven by the abundance of any particular factor.

The standard alternative explanation of regional agglomeration (e.g. Marshall (1920), Melvin (1969), Markusen and Melvin (1981) and Ethier (1982)) is that, for given inputs, the output of an individual firm is larger the larger is the aggregate output of other firms producing the same good in the same region. So, for example, the level of inputs required by a new watchmaker to produce a given output is lower if that entrant locates in Switzerland where there are other watch manufacturers. Romer (1986) and Lucas (1988) have shown that external returns of this type can also explain the fact that some nations seem to remain forever more advanced than others.

A possible source of external economies of this kind is the spillover of knowledge *i.e.*, the possibility that knowledge acquired by one agent can be used by others. In order for knowledge spillovers to provide a compelling explanation, however, it must be the case that they are somehow localized. If an engineer in Taiwan can reverse engineer a product of Silicon Valley as easily as an inhabitant of Silicon Valley, there is no good reason for

regional concentration of computer companies.

Marshall (1920) posits instead that the external economies arise from proximity to specialized inputs. As noted by Helpman and Krugman (1985), unless there is a natural comparative advantage for the production of these inputs in the region, this explanation is incomplete. The puzzle is simply rolled back to the previous production stage: Why do the producers of inputs locate in the region?

Our theory is that the location decisions of the firms and their input suppliers are interdependent. Input suppliers find it advantageous to be located where they have *several* potential customers because competition among their downstream customers assures them a fair return. In the absence of such competition, the relatively immobile suppliers would be subject to the monopsony power of the downstream firms. Foreseeing that monopsony power would be used to drive down input prices, potential input suppliers would not choose to invest *ex ante* in the accumulation of the capital necessary to supply the inputs efficiently. This critical role of competition in securing a return to suppliers is one of the elements in Porter's (1989) broad treatise on regional agglomeration.

For concreteness, the particular input we focus on is industry specific human capital which is costly for individuals to acquire, such as the specific hand-eye coordination needed to cut diamonds or the skills which facilitate the creation of a new chocolate concoction. If trained workers can choose among several potential employers, they will be paid as a function of their marginal product. By contrast, if there is only one potential employer, and it is impossible to write contracts that specify the level of training, there is no reason for this monopsonist to pay trained employees any more than untrained employees earn (in this industry or elsewhere). The hold-up problem described by Williamson (1975) arises. Confronted with the prospect of a single potential employer, workers do not find it worthwhile to accumulate human capital. Moreover, if entry by firms is costly, firms will themselves refrain from entering if they can expect to be the only firm in the industry. The industry can only exist with several closely located competitors.

If there is a minimum efficient scale below which each firm cannot operate profitably, the necessity of having several competing firms for an industry to be viable implies that the

region's output may have to be substantial. In particular, demand in the producing region itself may be insufficient to accommodate the requisite number of firms. Then the only way of ensuring competition among firms is to have several of them locate in one region and produce for the world market. We show that trade emerges between spatially separated regions with the same endowments and access to the same technology even though there are transport costs and it is technologically feasible to produce all of a region's consumption locally.[1]

Our theory involves an externality. The presence of other firms is necessary for each firm to have access to suitable workers. However, unlike the alternative theory of trade based on external returns, we do not require that the presence of other firms lower the input requirement for producing output. Instead, the technology for producing output is the same in all regions.

Because each firm needs other firms to be present for workers to become trained, it might be though that our model has multiple equilibria in some of which no firm produces. This would be true is we insisted that the entry decisions of firms all be made simultaneously. Instead, following Farrell and Saloner (1985), we model firms as making this choice sequentially so that, through their actions, they can communicate their intentions to each other. This makes it impossible for equilibria with no production to coexist with others in which production is positive.

One of the most important implications of the traditional theory of trade based on external returns is that nations can be made worse off as a result of trade (see Graham (1923) and Ethier (1982)). In our model such losses from trade are possible as well. These losses are intimately linked to the existence of multiple equilibria. In some equilibria (the agglomerated equilibria) only one region produces the good even though, in autarky, the good is produced in both regions. At these agglomerated equilibria the importing region can be worse off. In our model this happens because there are transportation costs so that an imported good costs more than a locally produced good. In Ethier (1982) it occurs

[1] Note that while monopsony power plays a role in our story, our formal model is rather different from those in the earlier literature on monopsony and trade (Feenstra (1980), Markusen and Robson (1980), McCulloch and Yellen (1980)). In those models monopsonists are active in equilibrium. By contrast, in our model, the only sectors that are viable in equilibrium have several firms competing for labor.

when one region produces nothing other than the good subject to external returns. This can lead its price in terms of the other good to rise relative to autarky (even though it is produced more efficiently) because factor demands rise in the producing region.

We show that, in our context at least, the equilibria with losses from trade are not robust. They, again, depend crucially on the absence of any mechanism that allows the agents to tell each other that they would like to produce the good subject to the externality.[2] Formally, losses from trade can occur in our model if workers must make their decision whether to become trained simultaneously. To capture the possibility that workers can communicate their intentions to each other we consider a variant of our model in which workers become trained in sequence. In this case, the equilibrium is unique and trade can only be beneficial.

One difference between our theory and the traditional external returns approach is in the role ascribed to antitrust policy. In the traditional theory, relaxation of antitrust policy can be socially desirable. Cooperation among firms can lead them to internalize whatever externality leads the production by one firm to lower the input requirements of the others. This logic has led Jorde and Teece (1988), for example, to conclude that antitrust exemptions are essential for certain US high-technology industries to succeed in a world scale.

By contrast, in our theory as well as in Porter (1989), society benefits from competition. The more competition among firms the potential suppliers of labor expect, the more willing they are to make industry specific investments. Thus a vigorous antitrust policy can play an important role in promoting the creation of viable export industries.

Section 1 presents the simple partial equilibrium setting in which workers decide simultaneously whether to acquire industry specific human capital. Section 2 embeds this model in general equilibrium and considers trade among *ex ante* identical regions. That section has several subsections in which we discuss the patterns of trade that emerge as the number of goods and the number of regions that trade varies. In one of these subsections we present our argument that if workers decide whether to become trained in sequence,

[2] The low welfare-low activity equilibria in the rather different pecuniary externality models of Murphy, Shleifer and Vishny (1989) lack robustness for the same reason.

every region benefits from trade.

In section 4 we consider the policy implications of our theory. In particular we study industrial policy, tariffs, and antitrust. Industrial policy encompasses those policies that governments pursue to affect the location of industries. In our model, such policies can raise welfare in the region imposing them. The reason is that the goods subject to the externality are sometimes produced disproportionately in one region. But, the presence of transport costs implies that regions benefit from having such goods produced locally. Therefore, policies that ensure local production of these goods can be desirable from the region's point of view.

While tariffs can be a tool of industrial policy, they can also be imposed in situations where they do not affect the regional pattern of production. The usual "optimum tariff" argument implies that, after workers in the other region have become trained, importers benefit from such tariffs beacuse they improve the importer's terms of trade. However, workers in the exporting region who foresee that tariffs will be levied, have a smaller incentive to become trained. So, the perception that tariffs will be imposed raises the equilibrium price of the good in the exporting region. We show that, as a result, tariffs which are foreseen when workers seek training unambiguously lower welfare in both regions. This strengthens Lapan (1988)'s argument against tariffs.

1. The Partial Equilibrium Model

We assume that skilled labor and entrepreneurial activities are the only factors of production. The "entrepreneur", who is also a skilled worker, must perform preparatory work necessary to create the firm and enable it to function. We assume that the entrepreneur has disutility of effort e for performing those activities. If he is successful in creating a firm that actually operates, however, he derives utility of v from his success.

Thus $v-e$, which we assume to be positive, is the net utility from becoming a successful entrepreneur. We focus mainly on the case where $v-e$ is arbitrarily small. As we shall see below, the role of these assumptions on the costs and benefits of managing is to eliminate the indifference between producing and remaining idle that characterizes standard zero-profit competitive equilibria. We suspect that introducing even a minimal level of market

power would have essentially the same effect.

The other factor of production is skilled labor. At the margin, each skilled worker can produce one unit of output. However, one of the central parameters in our analysis is the minimum efficient scale of production. We capture the presence of efficient scale by assuming that, to produce at all, the entrepreneur must employ S skilled workers including himself (*i.e.*, he must hire $S-1$ additional skilled workers). An entrepreneur is thus deemed successful, so that he receives v in utility, if his firm has S skilled workers. S is a measure of minimum efficient scale, but there are constant returns to scale when the firm produces more than S. These assumptions can be formalized as follows:

$$L(\theta S) = L(S) = S \quad \text{if} \quad \theta < 1, \quad \text{and} \tag{1}$$

$$L(\theta S) = \theta S \quad \text{if} \quad \theta \geq 1 \tag{2}$$

where $L(Q)$ is the amount of labor required to produce Q units.

S determines the number of firms that the industry can accommodate. If S is zero then production exhibits constant returns to scale globally and an arbitrarily large number of firms can be present at the same time. For very large values of S the industry can accommodate at most a single firm, *i.e.*, it is a natural monopoly. In between, the number of firms that can operate in equilibrium falls as S increases.

In order to obtain the requisite skills to be useful in this industry a worker must obtain training at a cost of h to himself. If the worker chooses not to obtain training, he can earn w in an alternative occupation. Thus a worker will only be willing to become trained if he can earn $w + h$ in this industry.

The entrepreneur is the sole residual claimant of the firm: he collects revenues from customers and pays the other workers. So, in addition to his net utility from performing the entrepreneurial function, he earns whatever profits there are in equilibrium. Despite the fact that the "entrepreneur" receives both the profits and the net utility of success, for clarity in what follows we shall refer to the entrepreneur as the agent who makes the decision to form a firm and enter the industry, and the firm as the agent that, once created by the entrepreneur, makes the operational decisions of the firm such as what wages to offer workers.

The quantity of this product that is demanded equals $D(P)$ where P is the price. What matters for the form of equilibrium outcomes is the relationship between demand and minimum efficient scale S. In particular, consider the demand when price equals marginal cost $w+h$, $D(w+h)$. Then the outcomes depend on the ratio of $D(w+h)$ to S. In particular, let:

$$\bar{N} \equiv \text{int}\left(\frac{D(w+h)}{S}\right) \tag{3}$$

where "int" denotes "the integer part of". Then we will show that the form of the equilibria depends on $\bar{N}$.

Our goal is to contrast the industry outcome when there is only a single firm in the industry – and hence it is a monopsony purchaser of skilled labor – with one in which firms compete for skilled workers. Since wage competition to attract workers is a critical aspect of our theory, we explicitly examine firms' strategies in bidding for workers. By contrast, strategic interactions in the output market are unessential to our argument. We therefore assume that whenever there is more than one firm in the industry there exists a fictitious Walrasian auctioneer which clears the output market. If there is only one firm, however, we make the natural assumption that it is able to exercise its monopoly power in the output market in the usual way.

The timing in our model is as follows: First, $\bar{N}$ individuals decide to become entrepreneurs and perform the preparatory work necessary for creating their firms (incurring disutility e in the process). Second, workers, including the entrepreneurs, decide whether to obtain training. We denote the number of workers who obtain training by $\bar{L}$. Third, the firms simultaneously announce wages $\{\tilde{w}_1, \ldots, \tilde{w}_{\bar{N}}\}$. Fourth, workers decide whom to work for. If two or more firms offer the highest wage, workers are assumed to spread themselves uniformly across those firms. Finally, production takes place and goods are sold at a price $\tilde{P}$ which the Walrasian auctioneer sets to clear the goods market.[3]

Our subgame perfect equilibrium requires that: (i) Entrepreneurs are successful; (ii) Workers make optimal training decisions; (iii) Firms choose $\{\tilde{w}_1, \ldots, \tilde{w}_{\bar{N}}\}$ to maximize

[3] We could have considered another stage in which firms decide which of their workers they actually ask to produce goods. This would not change the analysis: the firms would ask all their workers to produce. The reason is that labor is the only factor of production and labor costs are sunk at the time the decision of how much to produce is made.

profits; and (iv) workers make optimal employment decisions given $\{\tilde{w}_1, \ldots, \tilde{w}_{\tilde{N}}\}$.

We consider two cases separately. In the first case $\bar{N}$ is greater than or equal to 2 while in the latter case it is smaller. In the former case it is feasible for two or more firms to produce at minimum efficient scale when the "competitive" price $w + h$ prevails. In the latter case that is not feasible: The industry is a natural monopoly.

1.1. Case (i): $\bar{N} \geq 2$

We show that, for v sufficiently close to e, the equilibrium has $\bar{N}$ firms and produces the "competitive" outcome. In particular, prices and wages equal marginal resource costs (including training), $P = \tilde{w}_i = w + h$, and the number of workers who obtain training is exactly the number required to satisfy market demand at that price ($\tilde{L} = D(w + h)$). To do this, we begin by exogenously specifying the number of entrepreneurs $\tilde{N}$ that enter, and examine equilibria of the subgames that ensue.

(a) $2 \leq \tilde{N} \leq \bar{N}$

We informally describe why the competitive outcome is *an* equilibrium of the subgame. In Appendix A we provide a formal proof and in Appendix B we show that it is *the only* one that can emerge in equilibrium.

Consider first the entry decision of entrepreneurs. With $\tilde{P}^* = w + h = \tilde{w}_i^*$, firms break even as long as they can produce at minimum efficient scale. Thus entrepreneurs gain $v - e$ by entering as long as N is in the range specified. From the workers' point of view, anticipating wages of $w + h$, any worker is indifferent between getting trained at a cost h (and receiving a wage of $w + h$) and not becoming trained and taking alternative employment at a wage w. Moreover, since all firms offer the same wage in equilibrium, workers are happy to spread themselves uniformly across the firms. Thus workers have no incentive to deviate. Finally, consider the firms: If a firm unilaterally lowers its wage it attracts no workers,[4] if it raises its wage it loses money on each sale since then $\tilde{w}_i > \tilde{P}^* = w + h$. So the firms have no incentive to deviate.

[4] To be more precise, the firm attracts no workers with the possible exception of the entrepreneur himself. If $S > 1$ this will ensure that the firm doesn't deviate by lowering the wage. If $S = 1$ the "firm" can offer the "entrepreneur" (in his role as skilled worker) $w + h - (v - e)$ and still attract him. Even in this extreme case, however, the amount by which the wage can fall below $w + h$ vanishes as $v - e$ vanishes.

To understand the motivations of the agents, consider first the firms' wage announcements. In equilibrium the firms correctly anticipate the market clearing price. Any firm, if it believes that its rivals are offering wages below the equilibrium market price, will itself offer a tiny amount more than the highest wage being offered by a rival, attract all the workers, and thereby maximize its profits. This logic drives the firms to bid the wage up to what they believe the market clearing price will be. That is to say, they behave analogously to Bertrand rivals in homogeneous goods output markets.

The workers, for their part, understand that the wage will be bid up to the price which will be set to clear the market given that $\tilde{L}$ workers are employed. They therefore correctly anticipate that the wage will equal $D^{-1}(\tilde{L})$. Therefore, additional workers obtain training until the number trained workers drives the market clearing price down to the wage at which a worker is willing to become trained and work in this industry, $w + h$.

Although the industry can accommodate up to $\bar{N}$ firms in the competitive equilibrium, the competitive outcome can be sustained with just two firms in the industry and the entry of additional firms doesn't affect the price or wage that results (as long as $\tilde{N} \leq \bar{N}$). This is because Bertrand competition drives the equilibrium wage to the level of the final goods price with just two firms in the market.

Firms make zero profits in equilibrium. However, entrepreneurs who have entered are not indifferent about producing. They derive utility v from producing. Therefore, each entrepreneur tries to attract sufficient workers to produce at least S. So, trained workers can feel sure that entrepreneurs who have entered will compete for their services and drive the wage to $w + h$.

(b) $\tilde{N} > \bar{N}$

The only possible equilibria have the wage equal to $w + h$.[5] We show, however, that for v sufficiently close to e there is no equilibrium where the wage equals $w + h$ when $\tilde{N} > \bar{N}$. To do this we suppose, in contradiction, that the wage equals $w + h$ and consider, seriatim, the possibility that an equilibrium exists where (i) $\tilde{N}S$ or more workers obtain training, and (ii) fewer than $\tilde{N}S$ workers do.

[5] The proof in Appendix B applies to this case as well.

If $\tilde{N}S$ workers or more obtain training and all obtain employment in this industry the market clearing price is equal to $D^{-1}(\tilde{N}S) < w + h$. But then if all the firms produce, the workers are spread evenly over the firms and the entrepreneurs earn $v - e + D^{-1}(\tilde{N}S) - (w + h)$. For v sufficiently close to e, this expression is negative (because $D^{-1}(\tilde{N}S) < w + h$).[6]

If fewer than $\tilde{N}S$ workers obtain training it is not possible for all $\tilde{N}$ entrepreneurs to be successful, *i.e.*, there are insufficient trained workers for every entrepreneur who entered to produce at minimum efficient scale. But then the unsuccessful entrepreneurs could have done better by not entering (and saving the disutility of effort e).

(c) $\tilde{N} = 1$

If only one firm has entered and some number of workers, $\tilde{L}$, has obtained training, the firm will pay them just slightly above their alternative wage w and charge a price equal to:

$$\max\{D^{-1}(\tilde{L}), \arg\max_z D(z)(z - w)\}. \tag{4}$$

The first expression is relevant when $\tilde{L}$ is small so that the firm hires all the trained workers and charges a price which clears the market. The second expression is relevant when $\tilde{L}$ is very large so that the firm can act in the usual monopoly fashion in the goods market.

Note that after the workers have obtained training, no-one has an incentive to deviate: Workers will work for this firm because they do not have a viable alternative. The result, of course, is that, anticipating that they will not be compensated for their training costs, workers do not obtain training in the first place. This in turn means that the single entrepreneur suffers in vain his disutility of effort e.

(d) Entry

We have discussed these outcomes by fixing the initial number of firms and have shown that entrepreneurs gain utility in equilibrium if the number of them who enter is between 2 and $\tilde{N}$ but lose utility otherwise. We now turn our attention to the question of the number of entrepreneurs who will enter initially.

As in other models of external economies, the entry decision of firms is subject to

[6] The remaining cases here - those where some of the trained workers are not employed in this industry, or where some of the entrepreneurs who have entered do not produce - are uninteresting: the workers who end up unemployed and the entrepreneurs who do not produce in equilibrium could have done better by not obtaining training or not entering respectively.

a coordination problem. If potential firm i believes that no other potential entrants will enter, then it won't enter either. If it is the only firm that enters, potential workers know that it would end up paying a wage of w and will not become trained. Thus the firm would not have a workforce and the entrepreneur would lose e. If, on the other hand, firm i believes that another firm will enter, then workers will obtain the necessary training, and the entrepreneur will gain $v - e$.

We follow Farrell and Saloner (1985) and assume that potential entrants must decide whether to enter in sequence, *i.e.*, the second potential entrant decides whether to enter only after he knows whether the first potential entrant will enter. This ensures that firms can communicate their intentions *vis-a-vis* entry through their actions. In the case where only a few firms will ever enter this seems more appealing than making all firms decide whether to enter simultaneously. That assumption forces firms to make their decision in the absence of any information about what other firms are planning.[7]

With sequential entry the Farrell and Saloner (1985) reasoning eliminates no-entry equilibria in this case. Indeed, the only equilibrium has $\tilde{N}$ equal to $\bar{N}$. All entrepreneurs that can possibly receive positive utility in equilibrium enter. Since the $\bar{N}$'th entrant enjoys positive utility $v - e$ by entering if another entrepreneur has already entered, if there has in fact been a prior entrant, it enters too. But then any prior potential entrant, knowing that the $\bar{N}$'th entrepreneur will follow, enters and obtains net utility of $v - e$ too. The result is that the first $\bar{N}$ entrepreneurs enter. For sufficiently small $v - e$ no more than $\bar{N}$ firms enter because the $\bar{N} + 1$'st entrant would be sure to suffer a loss in utility.

1.2. Case (ii): $\bar{N} < 2$

This is the second major case, the natural monopoly case, where it is impossible for two firms to both produce at minimum efficient scale S and also sell at the competitive price $w + h$. In this case the industry is not viable under laissez faire. The reason is that, as we saw above, there is no equilibrium in which workers become trained when there is a single firm. We also demonstrated that firms cannot break even when the number of

[7] In fact, it is not necessary for the sequencing of moves to be exogenously specified. As long as there is an interval of time during which entry can take place, if firms endogenously select when to enter the same outcome results. Farrell and Saloner (1985) also show that straw polls can have essentially the same effect as sequential entry in their model.

existing firms $\tilde{N}$ exceeds $\bar{N}$. Therefore, equilibria with more than one active firm also fail to exist.

1.3. Discussion

The results of the model can be summarized as follows. If $D(w+h) \geq 2S$, the competitive outcome emerges. The social marginal resource costs are $w+h$, and the competitive output when price is equal to those costs is $D(w+h)$. The number of workers who become trained is exactly sufficient to produce that quantity, the maximum number of entrepreneurs who can create firms that produce at minimum efficient scale enter, and competition among them drives the wage up to $w+h$. If, on the other hand, $D(w+h) < 2S$ so that demand cannot support two firms operating at minimum efficient scale when price is equal to marginal costs (including training), the industry is not viable. No firms enter and the good is not produced. This outcome results because the firm cannot commit not to exploit the workers once they have obtained their training, and hence they have no incentive to become trained.

This latter conclusion hinges critically on our assumption that workers choose their training before they have had any formal relationship with the firm. We are thus ruling out any initial long term contract which guarantees the workers a wage of $w+h$ if they do become trained. Similarly, we are ruling out arrangements in which the firm trains workers at a cost of h to itself. In the presence of such employer-provided training the wage could be w and the allocation would be the same as when the worker is sure to be paid $w+h$ if he becomes trained.

Our assumption that these alternative arrangements are impossible is only a convenient simplification. We expect that similar conclusions would follow in the more realistic setting where such contracts are possible but involve a variety of costs which are absent when (as in the case of multiple firms) the workers make their own training decisions. Such costs arise because long-term contracts that specify future payments as a function of worker training are hard to enforce and because it is difficult for firms themselves to provide the appropriate training.

Consider first the "solution" where the firms assume responsibility for the training

of the workers, *i.e.*, they train their workers at a cost per worker of h to the firm. The immediate problem with this is that the workers may not all be equally suited for training or may need different types of training. For instance, training may improve the skill of some workers but not that of others. If workers know whether training will improve their skill *ex ante* while firms only discover this *ex post*, the equilibria with two firms considered above induce the right workers to obtain training. By contrast, if the firm pays all workers w *ex post* and simply pays for their training, it is likely to obtain a rather mixed group of trainees.[8]

Similar problems arise if the firm signs a contract committing it to pay $w + h$ to workers who obtain training. The difficulty here is in defining "training" in a way that is contractually implementable. If the contract only specifies that a specific training course must be taken, then the difficulty is the same as when the firm provides the training course itself: adverse selection results in the "wrong" workers becoming trained. Instead, the firm might try to write a contract that specifies a required level of acquired skill. The problem here is that it is much more difficult for a third party to verify skill itself than the completion of some training course. So, the workers cannot be sure that the firm will not attempt to exploit them *ex post* by claiming that they are insufficiently skilled and therefore do not qualify for a skilled wage.

2. General Equilibrium Models

In this section we consider general equilibrium models in which trade among regions arises precisely because workers only obtain training if they can be sure of competition among firms located within the region in which they work. We show that equilibrium can entail the emergence of "developed" regions that trade high wage goods among themselves and who also trade their high wage goods for the low wage goods of "undeveloped" regions.

We build up to a model with three regions and two high wage goods, by first considering two simpler models. in Section 2.1 we consider a model with two regions and two goods. We derive conditions under which equilibrium entails one developed region which

[8] In practice those volunteering to join a training program could well end up being those least suitable for training. They are likely to include those who are unemployed precisely because they are not very suitable.

produces a high wage good of the kind we analyzed above, and which exports it to the undeveloped region which produces only a low wage good. In Section 2.2 we then consider a model with two regions and two high wage goods. We derive conditions under which each region specializes in one of the high wage goods, exporting it to the other. Finally, in Section 2.3, we combine these elements in considering a model with three regions but only two high wage goods.

2.1. A Model with Two Regions and Two Goods

One of the two goods, good Y, is of the kind analyzed above: it can only be produced by workers who have received training, each skilled worker can produce a single unit of Y, and there is a minimum efficient scale S. The other good, Z, which acts as the numeraire, is also produced with constant returns to scale but there is no minimum efficient scale. One unskilled worker can produce w units of good Z. Good Z serves as a competitively supplied good that is produced in both regions. The presence of such a common good ensures that, in some sense at least, workers are paid the same in both regions. As in Helpman and Krugman (1989) the presence of this good achieves at least a limited form of factor price equalization.

There are M workers in each region, each of whom supplies one unit of labor inelastically. These workers are geographically immobile, they can only produce in their own region. We assume that $M > 2S$ so that there are sufficient workers for two firms to produce at minimum efficient scale in each region.

Each individual's utility function is given by:

$$U(C_y) + C_z - \kappa_h h - \kappa_e e + \kappa_v v \tag{5}$$

where C_i represents the consumption of good i. The κ's are indicator variables; κ_h is one if the individual becomes trained, κ_e is one if he becomes an entrepreneur, κ_v is one if the individual who has become an entrepreneur produces at least S units. Hereafter we shall assume that $v - e$ is arbitrarily small.

Goods are costly to transport between regions. In particular, an amount t of good Z is spent when one unit of good Y is transported from one region to the other.[9] Thus a well

[9] For simplicity we ignore transport costs on good Z.

meaning social planner would avoid interregional trade, if possible. Assuming an interior solution where both goods are produced, a Pareto Optimal allocation where each region is self sufficient would have C_y set at a level where marginal utility equals marginal cost, *i.e.*, where $U'(C_y) = w + h$. Such a Pareto Optimum would therefore involve training L^* individuals in each region where L^* satisfies:

$$U'(\frac{L^*}{M}) = w + h, \tag{6}$$

since L^*/M is the per capita consumption of good Y. Finally, since entrepreneurs derive utility from owning active firms, this production should be spread across as many firms of minimum efficient scale as possible.[10]

Note that our assumptions on preferences make this general equilibrium model essentially identical to the partial equilibrium model of section 1. If we write $d_y(p)$ for the amount demanded by each individual as a function of the price, then utility maximization implies $U'(d_y) = p$, or $d_y(p) = U'^{-1}$. Since there are M individuals in each region, the aggregate amount of Y demanded in one region as a function of price is now given by

$$D = Md_y = MU'^{-1} = M(\frac{L^*}{M}) = L^*. \tag{7}$$

For both goods to actually be produced in positive quantities at the Pareto Optimal allocation it must be possible to satisfy the total domestic demand for good Y by employing domestic workers. This requires that L^* be no greater than M.

We now analyze the conditions under which equilibria exist which result in the Pareto Optimal allocation, and those under which equilibrium involves interregional trade. We assume free entry into the production of good Z so that the wage in terms of Z is w. The issue then is how many firms enter industry Y. As before we assume that entry decisions are made first. There are two main cases to consider, depending on whether or not $L^* > 2S$.

2.1.1. Case (i): $L^* > 2S$

When L^* exceeds $2S$ there is sufficient demand for two firms to produce at minimum efficient scale in both regions. There is then an autarkic equilibrium in which each region

[10] Note that if $v - s$ is large, the Pareto Optimum would involve creating even more firms and having them produce at less than minimum efficient scale in order to allow more individuals to experience the joy of entrepreneurship.

has $\bar{N} = \text{int}(L^*/S)$ active firms. Once $\bar{N}$ firms have entered, L^* workers are happy to obtain training and the firms have enough workers to produce at minimum efficient scale. The Farrell and Saloner (1988) reasoning we employed in the previous section implies that this is the only autarkic equilibrium. The Pareto Optimal outcome is thus an equilibrium when trade is impossible. It obviously remains an equilibrium when trade is allowed between regions since there is no incentive to for interregional trade at this equilibrium.

Even though the Pareto Optimal outcome is an equilibrium, there may also exist another class of equilibria when there is free trade. These equilibria have regional agglomeration; one of the regions produces all of good Y and the other produces only Z. These are the only other equilibria. In particular there do not exist equilibria in which one of the regions both produces some of Y domestically and also imports some. To see why, suppose to the contrary that there are two firms producing Y in one of the regions and that this region also imports Y. Suppose workers in the exporting region earn $w + h$. Then, wages must equal $w + h + t$ in the importing region. But that would mean that more workers in the importing region would obtain training. Similarly, if the wage in the importing region is $w + h$ it is less than that in the exporting region and workers do not have an incentive to become trained there.

The agglomerated equilibria, if they exist, can be of two types depending on the magnitude of M. The first applies when M is "large" in a sense to be made precise shortly. Then, the firms in the region that produces Y pay their workers a wage of $w + h$ and charge $w + h$. Denote the producing region as the foreign region while home is the importing region. The landed cost (including transportation) in the home region is $w + h + t$, so that home demand is $MU'^{-1}(w + h + t)$. Aggregate demand at a price of $w + h$ is therefore given by:

$$\begin{aligned} & M\Big[U'^{-1}\Big(w + h + t\Big) + U'^{-1}\Big(w + h\Big)\Big] \\ & = MU'^{-1}(w + h)(1 + \lambda), \quad \text{where } \lambda \equiv \frac{U'^{-1}(w + h + t)}{U'^{-1}(w + h)}, \\ & = (1 + \lambda)L^*, \quad \text{since } MU'^{-1}(w + h) = L^*. \end{aligned} \tag{8}$$

The parameter λ represents the per capita consumption of the high wage good in the

importing region relative to that in the producing region. Since U'^{-1} is decreasing in its argument, λ is less than one. This is merely a reflection of the fact that transportation costs raise prices for the high wage good in the importing region above $w + h$ so that per capita consumption of it is lower there.

The maximum number of firms that can operate abroad at minimum efficient scale is given by int$[(1 + \lambda)L^*/S]$. This is therefore the number of entrepreneurs that enter in the agglomerated equilibrium. It is now clear what it means for M to be large: For this type of equilibrium to exist M must exceed $(1 + \lambda)L^*$. Otherwise, even if all available workers seek training, the market clearing price exceeds $w + h$. Such is the situation in the other type of agglomerated equilibria which arise when M is less than $(1 + \lambda)L^*$. These agglomerated equilibria, if they exist, have higher wages and prices.

In order for an equilibrium with agglomeration of either type to exist the transportation cost, t, must not be "too large". The reason is that, if t is high, the price of Y in the importing region is high as well. Such high prices create an incentive for two firms to enter and produce $2S$. This incentive is even higher when M is less than $(1+\lambda)L^*$ since, in this case, the price exceeds $w + h$ in the exporting region as well. For purposes of illustrating these incentives we thus focus on the case where M exceeds $(1 + \lambda)L^*$.

Suppose, for argument's sake, that the exporting region produces $(1 + \lambda)L^*$ and that two entrepreneurs enter in the importing region and produce S each. Output in that region is $2S$ which, by assumption is less than L^*. The equilibrium price can now have one of two forms depending on the sign of $U'(2S) - U'(L*(1+\lambda)) - t$. If it is negative, the difference between the prices in two regions when each region consumes its entire production is less than t. Thus there is no incentive to trade in this case; the price in the home region is $U'(2S)$ and that in the foreign region is $U'(L^*(1+\lambda))$. If, instead, $U'(2S) - U'(L*(1+\lambda))$ is greater than t, there would be an incentive to trade if both regions consume their entire production of Y. Therefore, the home region imports some of good Y and the equilibrium price abroad P^f is between $U'(2S)$ and $U'(L*(1+\lambda))$ while that at home equals $P^f + t$. In this case:

$$M\left[U'^{-1}\left(P^f + t\right) + U'^{-1}\left(P^f\right)\right] = (1 + \lambda)L^* + 2S.$$

If t is zero and $S > 0$, the equilibrium is of this second type and P^f exceeds $w + h$. However, the larger is t, the more likely that the resulting equilibrium with trade has $P^f + t$ bigger than $w + h$ or that $U'(2S) - U'(L*(1+\lambda)) - t$ is negative. In either case the domestic price exceeds $w + h$ so two entrepreneurs can enter in the importing region, produce at minimum efficient scale, offer their workers $w + h$, and make nonnegative profits. But then the Farrell and Saloner reasoning implies that they will enter. There thus cannot be agglomeration of the production of Y in one region if t is sufficiently big.[11]

Similarly, for a given t, there always exists a sufficiently small $\hat{S}(t)$ such that for S smaller than $\hat{S}(t)$, $P^f + t$ is larger than $w + h$. Thus, the findings of this subsection can be summarized as follows: if S is small relative to t the unique equilibrium is autarkic, otherwise there are multiple equilibria: both the autarkic equilibrium and equilibria in which one of the regions specializes in the production of Y exist. We argue in our section on gains from trade (and prove in Appendix C) that if workers also make their training decisions sequentially in each region, the Farrell and Saloner reasoning eliminates the equilibria with agglomeration. Thus the autarkic equilibria are more robust when $L^* > 2S$.

2.1.2. Case (ii): $L^* < 2S$

As long as L^* exceeds S, the Pareto Optimal allocation with no trade is still feasible. However since $L^* < 2S$, it is not possible for two firms to operate at minimum efficient scale in each region and so, for the reasons explored in Section 1, there is no laissez-faire equilibrium in which the good is produced by each region for its own consumption.

The only possible equilibria where good Y is supplied in positive quantities must therefore have only one region supplying the good, as in the equilibrium with agglomeration of the previous subsection. For such an equilibrium to exist here aggregate demand at a price of $w + h$ must exceed the sum of the firms' minimum efficient scales, *i.e.*, we must have $(1 + \lambda)L^* \geq 2S$.

Compared to autarky, trade for these parameter values is clearly beneficial to both regions. Under autarky, since $L^* < 2S$, the regions do not get to consume good Y at all. The change from autarky to free trade keeps the wages of workers the same. On the other

[11] A similar argument demonstrates that such agglomeration is impossible (even for zero t) if M is substantially smaller than $(1+\lambda)L^*$.

hand consumers gain the consumer surplus:

$$\int_0^{\frac{L^*}{M}} \Big[U'(a) - (w+h)\Big]\,da \tag{9}$$

in the producing region and

$$\int_0^{\frac{\lambda L^*}{M}} \Big[U'(a) - (w+h+t)\Big]\,da \tag{10}$$

in the other region.

Trade is driven by external returns. The presence of numerous trained workers makes it possible for the two firms producing good Y to be viable in one region. Similarly, the assurance of competition among firms makes training worthwhile for workers. However, the external returns are not the usual ones. They might rather be viewed as a pecuniary externality: The presence of another firms affects the competition for workers and this makes workers available to both firms where one firm cannot obtain workers by itself.

Figure 1 is useful for describing the outcomes as L^*/S varies. The Pareto Optimal allocation involves no trade as long as $L^*/S \geq 1$. However we can support the Pareto Optimal allocation without trade as an equilibrium only if L^*/S is greater than 2.[12] The reason is that otherwise we cannot have two active firms in each region, and with only one firm there is not sufficient competition for skilled workers. When L^*/S is between $2/(1+\lambda)$ and 2 the equilibrium has positive production of good Y in one region. In this region, the equilibrium has international trade even though the Pareto Optimal allocation is feasible and does not involve trade. The reason for this is that it is necessary for a region to produce a relatively large amount of the good for there to be effective competition for workers.

For L^*/S between 1 and $2/(1+\lambda)$, by contrast, the Pareto Optimal allocation has production in both regions while the equilibrium involves production in neither. This region arises because λ is strictly less than one. Put differently, the costs of trade raise prices in the region that does not produce the good above $w+h$. This reduces sales of Y and makes it more difficult for both firms in the producing region to exceed their minimum efficient scale.

[12] For sufficiently large L^*/S this is the only equilibrium.

The Pareto Optimal allocation continues to involve positive production for certain values of L^*/S below 1. Let $\bar{S}$ denote the highest S for which the Pareto Optimal allocation involves positive production. Then $L/\bar{S}$ is smaller than $1/(1+\lambda)$. But for L/S between $1/(1+\lambda)$ and 1 there is no production without government intervention.

2.1.3. The Gains from Trade

When L^* is less than $2S$ trade is beneficial in that the regions can consume the good with trade but not without trade. When L^* is greater than $2S$, the autarkic allocation remains an equilibrium even with free trade. This does not establish that free trade is as good as autarky in this case because, for sufficiently low transportation costs, there also exist equilibria where only one region produces good Y. In these equilibria the importing region is worse off.

These losses from trade as a result of multiple equilibria are analogous to those explored by Graham (1923), Melvin (1969), Markusen and Melvin (1981) and Ethier (1982). A slight difference with Ethier (1982) is that he obtains losses from trade only when the exporting region is fully specialized in the production of the good subject to external returns. These losses are analogous to those we obtain in the absence of transport costs when M is less than $(1+\lambda)L^*$. They come about because, in this case, the price in the exporting region exceeds the autarky price $w+h$. In our model with transport costs, by contrast, we obtain losses from trade even when the exporting region is not fully specialized.

The equilibria in which trade leads to losses rely on a coordination failure. Workers in the importing region do not believe that other workers will enter in sufficient numbers to make the industry viable. This leads them not to get trained when they expect $(1+\lambda)L^*$ workers to get trained in the other region. Because these equilibria rely on the inability of workers to communicate to each other their willingness to become trained one would expect them not to be robust to changes in the informational structure. This is what we argue next.

Following Farrell and Saloner (1985) we capture the possibility that workers can communicate to each other their intentions by assuming that they take the decision to become trained in sequence. First one worker has the option of becoming trained, then another and

so on. Once a worker becomes trained this becomes known to all other potential trainees. To ensure that the two regions are treated symmetrically we assume that the location of the worker who has the option of becoming trained alternates between the two regions. First one worker in one region has the option, then a worker in the other region and so on.

We show in Appendix C that if training decisions take this form, the autarkic equilibria are the only equilibria when $L^* > 2S$. Thus, with this small modification in the game, trade is always beneficial.

2.2. A Symmetric Two-Region Version

The outcome involving trade is the previous subsection is asymmetric: only one region produces good Y and, because of the transport costs, ends up slightly better off as a result. We now present a symmetric version of the two-region model which has two high-wage goods.

The technology for producing goods Y and Z remains the same as before. There is now also a third good, X, whose technology is identical to that of good Y. Thus there are now two goods which are produced by a relatively small number of large firms employing specialized labor.

The preferences of the representative worker are now given by:

$$U(C_x) + U(C_y) + C_z - \kappa_h h - \kappa_e e + \kappa_v v \tag{11}$$

A benevolent central planner would avoid the transport costs on goods X and Y by having $2L^*$ trained workers in each region, half of whom produce good X while the other half produce good Y. Again, however, if L^* is smaller than $2S$, there is no equilibrium where both goods are produced in both regions. The only equilibria where goods X and Y are produced involve regional specialization even though this specialization leads to the expenditure of transport costs.

In this model with two goods, it is much less likely that one region will produce all the goods requiring the input of trained workers. The reason is that if $2(1+\lambda)L^* > M$ no region has enough workers to supply both goods X and Y to the entire world. Then, the only equilibrium where both goods are produced has two specialized regions which trade

with each other. One region produces the world's demand for good X and the other the world's demand for good Y

2.3. An Asymmetric Model with Three Regions

Combining elements developed in each of the previous subsections, we now show that our model is capable of explaining the coexistence of multiple "developed" regions and an "undeveloped" region in which the "developed regions" export high wage goods to the less developed region, and also trade with each other. The less developed region has lower wages than the developed region. Moreover workers employed in the export sector of the developed region earn wages that are higher than the average for the region as a whole.

To derive these results we consider a model in which there exist the same three goods X, Y and Z but where there are three identical regions. Demand in any one region for X (or Y) at a price of $w + h$ is too small for two firms to produce at minimum efficient scale (*i.e.*, $L^* < 2S$), but the overall demand from all three regions is sufficient to do so ($(1 + 2\lambda)L^* \geq 2S$). Moreover, $2(1 + 2\lambda)L^*$, the aggregate demand for both X and Y, exceeds M, so that no one region can produce both on a world scale.

Then the only equilibrium where all three goods get produced has two "developed" regions each of which exports one high wage good and imports the other, and one "less developed" region which imports both X and Y. All three regions produce good Z. In what follows we refer to the region that produces X (Y) as Region X (Y), and the region that produces only Z as Region Z.

To develop implications for wages, note first that some workers in the developed region earn w while other earn $w + h$. This means that the average wage in the region exceeds that in the undeveloped region where all workers earn w. Moreover, the wage of those employed in the exporting region of the developed region is $w + h$ so that it exceeds the average wage in the region.

This is also an implication of the symmetric model of the previous subsection. This implication of these models is consistent with the evidence of Katz and Summers (1989). They find that, in industrialized countries, the average wage paid by a country's exporting industries exceeds the average wage paid in that country's manufacturing sector as a whole.

Our model also gives some guidance as to why Katz and Summers (1989) and others have found it difficult to account for inter-industry wage differences by looking at differences in the amount of formal education the workers in different industries possess. In our model, wages are determined by *industry-specific skill* which is often obtained in ways other than through formal education. For example, workers often acquire those skills on the job.[13] This could explain why the wages of workers who move from one industry to another change in ways that are related to the inter-industry wage differentials. Workers who have acquired some industry-specific skill in one industry and move to another where those skills are not valued, will experience a reduction in their wages. Conversely, workers who have acquired skills that are not valued in the industry in which they are currently employed but which are valuable in the one they move to will raise their wages by moving.

3. Industrial/Commercial Policy

In our models the production of some goods involves high wages while that of other goods does not. In such contexts, protection has been viewed as beneficial by numerous authors e.g. Hagen (1958), Bhagwati and Ramaswami (1963), Katz and Summers (1989).) We are thus led to explore whether a region can gain by unilaterally deviating from free trade.

We consider two types of deviations. In the first, which we call industrial policy, the central authority attempts to encourage the emergence of a specifically targeted industry. In the second, the central authority is not interested in changing the pattern of regional specialization but nonetheless taxes imports whose production requires skilled labor. While industrial policy often involves the use of tariffs, we distinguish between the two policies because the first tries to affect the composition of trade without trying to affect its level while the second affects mainly the level.

3.1. Industrial Policy.

Industrial policy can be carried out using various tools. One approach is to give a subsidy to firms who produce the desired good. Suppose, for example, that we are in the

[13] Of course one might attempt to control for that in part by including "years of experience" variables in the regression, as is typically done. However such variables do not identify time spent on the job acquiring industry- specific skills.

simple case of Section 2.1 where there are two regions but only a single high wage good. The central authority in one region, acting unilaterally, can ensure that the high wage good is produced locally by offering a subsidy to firms who produce the good. In particular, suppose it announces that *in the event that the domestic firms face foreign competition* they will receive a per unit subsidy, u, which is such that

$$u = w + h - MU^{l-1}((1+\lambda)L^*). \tag{12}$$

Then, two firms will be willing to enter the domestic market and to produce enough output to satisfy world demand *even if they do not in fact end up exporting at all in equilibrium.* The reason for this is that if the foreign market is somehow foreclosed to them, equilibrium in the domestic market will entail an equilibrium price of $P^* = MU^{l-1}((1+\lambda)L^*)$ and a wage equal to $w + h$.[14]

No foreign firms will enter this market if they know that the domestic firms have been offered this subsidy. They will decide to stay out of the market since *they* will be unable to export and their domestic market is not sufficiently large to support minimum efficient scale production for two firms. Therefore, if the central authority announces its subsidy plan *before* any entry decisions are made, the outcome will be that the domestic firms will be the sole world producers of the high wage good. Moreover, since the central authority only had to commit to paying the subsidy in the event that foreign competition materialized, domestic dominance of the industry is achieved without any subsidy actually being paid in equilibrium.

This outcome is desirable from the perspective of domestic residents since the utility of the region that produces the high wage good is higher than the utility in the other region. In the symmetric model of Section 2.2, however, the subsidy to one good makes no difference. There each region can only produce one high wage good and that is the equilibrium outcome with or without the offer of the subsidy on a single good. While the

[14] To see this note first that domestic consumers are willing to consume $(1+\lambda)L^*$ at a price of $MU^{l-1}(1+\lambda)L^*$. The revenue per unit that the firms receive (including the subsidy) is

$$MU^{l-1}(1+\lambda)L^* + w + h - MU^{l-1}(1+\lambda)L^* = w + h.$$

Thus the firms are willing to bid the wage up to $w + h$ and so workers are prepared to obtain training.

subsidy can determine which of the high wage goods the domestic industry produces by "targeting" that good, the country is indifferent in that model as to which of the goods it produces.

In a slightly richer model, however, the subsidy can be socially costly. Suppose, for example, that foreign workers can more easily become trained than domestic workers. This could arise for example where the high wage good involves a new technology and where the workers of the foreign country have built up some relevant industry-specific know-how with the old technology. In that case efficiency may call for production to be done by foreign firms whereas the offer of a subsidy may lead to the emergence (and dominance) of a domestic industry. Not only would foreign consumers be hurt by this since they must bear the transportation costs, but even domestic consumers may be hurt. While they save the transportation cost they would otherwise have to pay, they now pay for the higher training costs of the domestic workers. The industrial policy can also be implemented by imposing a prohibitive import tariff on the targeted good. By announcing the tariff before foreign firms make their entry decisions, and thereby convincing them that the domestic market is foreclosed to them, they can be deterred from entering. The end result, again, will be the emergence of domestic firms as the sole world producers of the good. This is a simple case of "import protection leads to export promotion".[15]

3.2. Nondiscriminatory Import Taxes

In this section we study tariffs which reduce the volume of trade but do not affect the pattern of specialization. This analysis is thus closer in spirit to traditional analyses of tariffs which are conducted assuming that a country will continue to import the good on which a tariff has been levied.

To make sense of such policies in the context of our model it might be best to have in mind the symmetric model of section 2.2 with M less than $2(1+\lambda)L^*$. In that model free trade has one of the high wage goods, X produced by one region while the other, Y is produced by the other. Suppose that, as described in the previous subsection, one region imposes a prohibitive tariff on good X so that it is sure to export X. The analysis

[15] See Krugman (1984) for the original statement of this possibility.

of this subsection then corresponds to the analysis of relatively small tariffs on Y levied by the other region. Such moderate tariffs on Y will not affect the regional pattern of specialization in this case.

We show that the benefits from tariffs depends critically, as in Lapan (1988), on whether the government that imposes the tariff takes the agents in the other country by "surprise". In our model this depends, in particular, on whether workers in the foreign country correctly predict the imposition of the tariffs when they make their training decisions.

Suppose first that the foreign workers do not correctly anticipate the imposition of the tariffs. Then $(1+\lambda)L^*$ of them become trained for the production of Y. A tariff on imports of Y lowers the demand for Y. Thus, for the market to clear the equilibrium price for Y must be less than $w+h$ and the wage of foreign trained workers will therefore also be below $w+h$. As long as the tariff is not too large, so that the wage for trained workers still exceeds w, the skilled workers will prefer to be employed producing Y and its output will not change. Because the tariff lowers the price charged by the foreign firms, small tariffs on imports of Y helps the domestic region. This is the standard optimal tariff argument.

Now suppose that workers in the foreign region do correctly anticipate the imposition of the tariff when they make their training decisions. Since they correctly anticipate the reduction in demand that will follow the imposition of the tariff, fewer of them obtain training. Indeed, the number of foreigners that obtains training adjusts until their wages equal $w+h$ and the price charged abroad equals $w+h$. If the *ex post* tariff is τ, the number of workers that obtain training is:

$$MU'^{-1}\Big(w+h\Big)+MU'^{-1}\Big((1+\tau)(w+h+t)\Big). \tag{13}$$

Since the price charged abroad is thus independent of the anticipated tariff rate, domestic residents lose from the tariff. Domestic consumption falls and the unit price paid to the foreign firms is unchanged. Domestic residents would be better off if the country could commit never to levy a tariff.

These conclusions are similar to, though stronger, than Lapan's. Lapan (1988) shows that when the production of output occurs before a government can levy a tariff, the

incentive to raise tariffs is larger *ex post* than *ex ante*. However, his framework is one where countries trade because they are intrinsically different. As a result, in his model a small tariff is desirable even *ex ante*. Here, by contrast, all tariffs are undesirable *ex ante* so countries are sure to gain by committing themselves never to levy a tariff in the future.

One reason to stress these results is that they differ radically from those of the standard models that explain trade among similar countries. Standard models of this type stress increasing returns and monopolistic competition as motives for trade among regions. As can be seen in Gros (1987), Venables (1987) and Helpman and Krugman (1989), under these assumptions tariffs are generally desirable even when they are correctly anticipated. What we have shown is that Lapan's (1988) case against tariffs applies even more strongly in a model where identical countries trade with each other.

4. Antitrust Policy

In the models we have presented the perfectly competitive outcome emerges even if there are only two competing rivals. In practice, however, a paucity of competitors may endow the firms in the industry with market power over their customers and suppliers. In particular, the firms may be able to restrict their consumption of inputs and thereby reduce the amount they pay to their input suppliers.

This can occur, for example, when firms interact repeatedly and implicitly collude. Suppose in particular that after entrepreneurs have entered and workers have obtained training, prices are set and demand is realized over many periods. Then the firms may be able to implement a collusive norm in which wages are set below the competitive level. That norm may be sustainable if firms fear that any unilateral deviation from the norm will lead to a breakdown in cooperation in which wages return to the competitive level.[16] Each firm would then weigh the short term gain from offering a slightly higher wage while others keep their wages at the collusive level, with the future loss that results from the elimination of the collusive gain. The result is that, as long as the number of firms is not too large, they obtain an outcome that is similar to that of perfect collusion. To keep the discussion manageable we will assume that as long as no more than $\hat{N}$ firms are present

[16] See Friedman (1971) for a theory along these lines for collusion in output prices.

they achieve the fully collusive outcome; the pay their workers w and charge a price given by (4). By contrast, if there are more than $\hat{N}$ firms, the competitive outcome obtains.

We are interested in examining the effect of a strong antitrust policy. We focus in particular on the vigor with which merger policy is established and enforced.[17] We assume that, initially, there are $N > \hat{N}$ firms. The more vigorous the antitrust enforcement, the less likely it is that a set of mergers will be tolerated which reduce the number of firms in an industry to $\hat{N}$ or fewer. Let the probability that the antitrust authorities will prevent such an increase in concentration be given by μ. That is, μ denotes the probability that competition will characterize the industry and $(1-\mu)$ is the probability that the firms will collude perfectly and drive the wage down to w.

We suppose that the initial number of firms, N, is such that they can all operate at efficient scale when the price is $w + h$. For it to be worthwhile for workers to obtain training they must expect to earn $w + h$ on average. Since they earn w when antitrust enforcement is lax, they must earn $w + h/\mu$ when antitrust enforcement is vigorous. Since the wage and price are equal in equilibrium when firms are competing, this implies that the price equals $w + h/\mu$ as well when there is effective competition.

In order for the trained workers to be fully employed in the event that antitrust policy is vigorous, the number of workers that seek training must equal $D(w + h/\mu)$. Therefore, the number of workers who obtain training is decreasing in the probability that antitrust policy enables the firms to collude, $(1 - \mu)$: A higher probability of collusion means that fewer workers obtain training. In the limit, if the probability of collusion is one (so that μ equals zero), no worker becomes trained.

When the firms collude they set a wage of w and hire all the trained workers. Thus sales equal $D(w + h/\mu)$ and the price must again equal $w + h/\mu$. So the potential for collusion raises the price whether collusion takes place or not.

We now consider international trade. Suppose that, as in the model of Section 2.1 there are two regions but only one high wage good. Suppose that in the domestic region

[17] In the U.S., for example, the Department of Justice has considerable latitude in deciding which mergers it will challenge and has set out "Guidelines" it uses in reaching those decisions. The guidelines are subject to revision and those in effect at any time leave substantial room for interpretation. Accordingly merger policy can fluctuate substantially from administration to administration.

the probability of collusion is zero. By contrast, in the foreign region the probability of competition μ is less than one *i.e.*, the foreign region has a weak antitrust policy. Then, for a sufficiently small (but strictly positive) foreign μ the foreign region must become the importer of good Y.

This can be seen as follows. Suppose first that the foreign region is the only producer of Y. Then the total number of trained workers abroad $\tilde{L}^f$ is $M[U'^{-1}(w+h/\mu)+U'^{-1}(w+h/\mu+t]$ which is decreasing in μ. So, for sufficiently low μ:

$$M[U'^{-1}(w+h)+U'^{-1}(w+h+t] \geq \tilde{L}^f + 2S.$$

Then, $2S$ workers find it profitable to become trained at home if two firms enter here. Knowing this two firms do enter and the foreign wage falls below $w+h/\mu$ even when foreign firms compete. But, this means that in this case foreign workers do not benefit from obtaining training. The only equilibrium has the domestic region, with is tough antitrust stance, exporting the high wage good.

Thus the country with the vigorous antitrust policy is better off than the country in which collusion is tolerated. This simple example suggests that relaxation of antitrust rules, particularly in industries where human capital accumulation is important, can well be detrimental to a region's welfare. Insofar as cooperation between firms allows them to exploit workers more *ex post*, fewer workers will obtain training and the region will suffer. This concern for a strong antitrust policy in order to ensure vigorous competition between purchasers of inputs echoes that of Porter (1989) who makes this argument strongly for similar reasons.

This result may appear surprising because in the usual models of external returns cooperation among firms is beneficial. When the externality is technological, so that increased output by one firm reduces the inputs needed by another, an agreement between the firms is beneficial since it allows the firms to internalize the externality, leading to a socially desirable output expansion. Similarly, in the case of localized knowledge spillovers, research joint ventures may improve social welfare. By enabling all the members of the joint venture to benefit from the research carried out by them in the joint venture, the externality from research is mitigated. Indeed, this is precisely the argument used by

Jorde and Teece (1988).[18] Our paper serves as a warning that the appearance of external returns is not enough to justify cooperation among firms. In particular, although very large research consortia might lead to greater sharing of the fruits of the research, they may also reduce the compensation of their employees, and thus reduce their incentive to acquire the knowledge and the skills needed to conduct the research.

5. Conclusions

We have presented a model of regional agglomeration in the production of specific goods where the principal motor behind a region's exports is the healthy competition among many suppliers located there. Competition ensures that workers earn high wages if they acquire industry-specific human capital which, in turn, makes human capital accumulation attractive and the industry viable.

The main message from the model is that even where it is technologically possible to obtain the same allocation with trade as without trade, trade serves a useful role. It allows industries to operate on a sufficiently large scale that it is possible to have several firms producing the same goods in one location and thereby reap the benefits that flow from regional agglomeration.

While we have focused on the salutary effect of regional agglomeration on the abuse of monopsony power, there may be other reasons why regional agglomeration enhances human capital accumulation. That is, it is an open question whether the mechanism by which having several local firms creates an incentive for human capital accumulation is through the increased competition they generate.

For example, a different advantage of regional agglomeration may be that it provides some assurance to workers that they will remain employable in the industry if conditions change in the future. That is, workers may prefer it if there is a diverse range of activities in the area that use their industry specific skills in case demand conditions or production techniques change in a way that eliminates the activity they choose to be employed in. This preference for diversity might exist even if long-term wage contracts can be written

[18] "[W]e point out that our antitrust policy ... imposes unnecessary restrictions on high technology industries ... In our view, strict antitrust enforcement is generally not needed in the circumstances we contemplate, because international competition and new and unexpected entry is especially strong."

specifying the wage that the worker will receive in a particular activity, so that monopsony power is not an issue.

Consider just three specific examples. Workers employed in the production of mid-sized automobiles may want to be located near plants that produce small automobiles in case demand shifts in the direction of the latter. Or workers employed producing computers based on a proprietary operating system, but whose skills are not specific to that operating system, may prefer it if plants producing computers based on alternative operating systems are located nearby in case theirs becomes obsolete. Finally, it could simply be that the worker is concerned that he will not get on with his supervisor or co-workers, and like to know that if he becomes unhappy in his job that he can easily shift to another.

While the existence of such diversity may be important to workers making their training decisions, it is not clear why it cannot be achieved within a single enterprise. That is, one firm could encompass a range of technologies, products, plants, and divisions. Multiple firms might have an advantage if workers are concerned about the possibility of bankruptcy and if two firms somehow have a combined probability of bankruptcy that is lower than those firms would have when rolled into one. Or it might be that workers are concerned about the "corporate culture" and that it is difficult to maintain several "cultures" in separate divisions within the same company. Such rationales for regional agglomeration must be highly speculative for the moment. Sorting out which of them, or others not suggested here, can survive the scrutiny of formal modeling is a question that awaits future research.

Another open area for research is the extent to which competition is actually associated with high wages, extensive industry specific training and exports. One problem is that, in practice, it is hard to gauge when an industry is relatively competitive. Nonetheless it is worth providing some anecdotal examples which appear to support the model. First, centrally planned economies have little actual competition for workers between the various firms and are notorious for their inability to export high wage goods. Second, consider the automobile industry. Japan, the most successful exporter of high quality mass-produced cars, has a relatively large number of firms in this industry. Similarly, Italy has several producers of high performance cars which are very successful exporters. In contrast, Italy

has only one large mass-production auto manufacturer, FIAT, whose exports to the US are minimal. Interpreted within the context of our model, the high performance Italian cars and the mass-produced Japanese cars can be thought of as high quality goods which use relatively skilled workers while FIAT can be thought of as a lower quality producer who employs less skilled workers. These anecdotes suggest that a more careful exploration of the empirical validity of the model is warranted.

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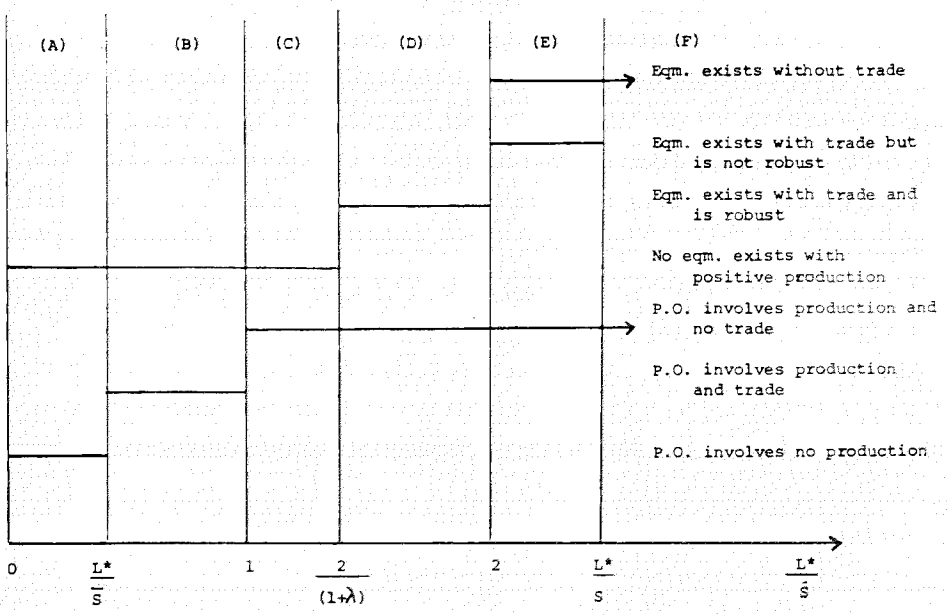

Figure 1: Equilibrium and Pareto Optimality

KEY:

(A) No production in Pareto Optimum or in equilibrium

(B) P.O. involves production and trade but there is no production in equilibrium

(C) Autarky is the P.O., but there is no production in equilibrium

(D) Autarky is the P.O., but equilibrium requires regional agglomeration and trade

(E) Autarky is the P.O. There are multiple equilibria: An agglomeration equilibrium (which is not robust) and an autarkic equilibrium

(F) Autarky is the P.O. and the unique equilibrium outcome.

Appendix A

Existence of The Competitive Equilibrium

In this appendix we prove the assertion in Section 1 that a competitive equilibrium exists when $2 \leq \tilde{N} \leq \bar{N}$.

The subgame equilibrium strategies are as follows: $\tilde{L}^*$ workers obtain training. The wages that firms offer are: (a) If $\tilde{L} < S$ all firms set $\tilde{w}_i = 0$; (b) If $S \leq \tilde{L} < 2S$ one of the firms sets $\tilde{w}_i = D(\tilde{L}) + \frac{v}{\tilde{L}}$ and the others set $\tilde{w}_i = D(\tilde{L}) + \frac{v}{\tilde{L}} - \epsilon$ for ϵ arbitrarily small; (c) If $2S \leq \tilde{L} \leq D(w+h)$ there are two cases to consider: (i) $\tilde{N} \leq N^e \equiv \text{int}\frac{\tilde{L}}{S}$: In this case the firms set $\tilde{w}_i = D^{-1}(\tilde{L})$. (ii) $\tilde{N} > N^e$: In his case N^e firms set $\tilde{w}_i = D^{-1}(\tilde{L}) + \frac{vN^e}{\tilde{L}}$ and the remaining firms set their wage equal to 0; (d) If $D(w+h) < \tilde{L} \leq D(w)$, firms all set $\tilde{w}_i = D^{-1}(\tilde{L})$; and (e) If $D(w) < \tilde{L}$ firms set $w_i = w$. In case (e) a minor modification is required for the rule that workers use in allocating themselves across firms since there are too many workers to be employed at wage w in this industry. Here we assume that $\tilde{L} - D(w)$ workers elect to work in other industries. The $D(w)$ workers that remain in this industry distribute themselves uniformly across the $\tilde{N}$ firms.

We first demonstrate that the firms' wage strategies are equilibrium strategies.

Case (a): Since here fewer than S workers obtain training, no firm is able to operate at minimum efficient scale. Thus they all refuse to hire workers (set $\tilde{w}_i = 0$).

Case (b): Since the number of workers who obtain training exceeds S but is less than $2S$, only one firm can operate at minimum efficient scale. Since the entrepreneur that succeeds in being the one who hires the worker derives utility of v, they are each prepared to bid v to the workers, or $\frac{v}{\tilde{L}}$ each, for the right to be their employer. (Note that since e is a sunk cost at this stage it is irrelevant). Since the market clearing price will be $D^{-1}(\tilde{L})$, the winning firm is willing to pay $D^{-1}(\tilde{L}) + \frac{v}{\tilde{L}}$ to each worker to be the sole producer. Since the losing firms will not attract any workers in equilibrium, they are prepared to offer a tiny amount less than the wage of the "winning firm". Doing so keeps the winning firm "honest" and eliminates an incentive for him to shave his wage offer.

Case (c(i)): If the $\tilde{L}$ workers are hired the market clearing price will be $D(\tilde{L})$ which exceeds $w+h$. Since all $\tilde{N}$ firms can produce at minimum efficient scale in this case, they will bid

the wage up to $D(\tilde{L})$.

Case (c(ii)): Here there are insufficient trained workers for all $\tilde{N}$ firms to operate at minimum efficient scale. N^e is the number of firms that can operate at minimum efficient scale. As in Case (b) the entrepreneurs are willing to pay v to be successful. Since there are $\frac{\tilde{L}}{N^e}$ workers per successful firm, the firms are willing to pay a "premium" of $\frac{vN^e}{\tilde{L}}$ per worker to attract them to the firm and be successful. Once the workers are all employed the market clearing price will be $D^{-1}(\tilde{L})$. Thus the successful firms bid $D^{-1}(\tilde{L}) + \frac{vN^e}{\tilde{L}}$ for workers. Unsuccessful firms bid 0.

Case (d): Here all $\tilde{N}$ firms can produce at minimum efficient scale. Once the workers are hired the market clearing price will be $D^{-1}(\tilde{L})$. Firms therefore bid the wage up to this level.

Case (e): If firms offer w, workers are indifferent between being employed in this industry and being employed elsewhere. Therefore it is consistent with optimizing behavior for only $D^{-1}(w)$ workers to take employment in this industry. But then the market clearing price, if they are employed, will be w. Thus firms bid the wage up to w.

Thus the firms are willing to carry out the proposed strategies for any number of workers that become trained. Those strategies are therefore subgame perfect. We turn now to the training strategy of workers. The proposed equilibrium strategy calls for $\tilde{L}^*$ workers to obtain training. If that number obtains training, Case (c(i)) is the relevant one and the wage that is offered is $D^{-1}(\tilde{L}^*) = w + h$. Since they recoup their training expenses the workers are prepared to obtain training.

No additional workers are prepared to obtain training, however. If one additional worker obtains training, Case (d) becomes the relevant one. The wage that is offered is $D^{-1}(\tilde{L}^* + 1) < w + h$, so that the deviating worker is unable to recoup his training costs. Similarly, none of the $\tilde{L}^*$ workers has an incentive to deviate by *not* obtaining training. Each worker who obtains training in equilibrium in indifferent between obtaining training at a cost h and earning $w + h$ and not obtaining training and earning w.

Appendix B

Uniqueness of the Competitive Equilibrium

In this Appendix we show that the equilibrium in Section 1, where the price and wage equal $w+h$, is unique. The proof of this proposition proceeds by contradiction for a series of exhaustive cases. Denote the price that is charged in a candidate equilibrium by $\tilde{P}^*$ and the highest wage that is offered in equilibrium by $\tilde{w}$.

(i) $\tilde{w} < w+h$: There cannot be an equilibrium where the highest wage offered to trained workers is less than $w+h$ since at least one of the workers would be able to deviate by *not* obtaining training and make himself better off.

(ii) $\tilde{w} > w+h$ and $\tilde{P}^* \geq w+h$: In an equilibrium like this it must be the case that the entire pool of untrained workers becomes trained because $\tilde{w} > w+h$. Since the pool of untrained workers is sufficient to satisfy demand when the price is $w+h$, the price must be below $w+h$ for the market to clear. But then for $v-e$ very small at least one entrepreneur can make himself better off by not entering.

(iii) $\tilde{w} \geq w+h$ and $\tilde{P}^* < w+h$: When the price is below the wage, firms that hire workers lose money. But then for $v-e$ very small at least one entrepreneur could do better by not entering.

(iv) $\tilde{w} = w+h$ and $\tilde{P}^* > w+h$: Here a firm will deviate and offer a wage above $w+h$. The reason is that a firm can raise the wage infinitesimally, attract all the trained workers and increase its profits.

Appendix C

Uniqueness of Equilibrium with Sequential Training Decisions

In this Appendix we consider the case where $L^* > 2S$ and workers get trained in sequence. We show that, in this case, the outcome where $L^*(1+\lambda)$ workers get trained in one region while none get trained in the other is not an equilibrium. The only equilibrium is the autarkic one where L^* workers get trained in each region.

Workers in each region are ordered from 1 to M. The first worker is the first to be given the option of becoming trained. If he declines he cannot later become trained. After that, the first worker at home is given the option, then it is given to the second worker abroad and so on.[19] Let s_i^h denote the strategy for the i'th worker at home while s_j^f denotes the j'th foreign worker's strategy. These strategies can take only one of two values; we let s equal one if the worker becomes trained and zero otherwise. The strategy for the i'th worker depends only on the number of workers that have decided to become trained before him. Thus:

$$s_i^h = f_i^h\Big(\sum_{m=1}^{i-1} s_m^h, \sum_{n=1}^{i} s_n^f\Big); \quad s_i^f = f_i^f\Big(\sum_{m=1}^{i-1} s_m^h, \sum_{n=1}^{i-1} s_n^f\Big) \qquad i = 1 \ldots M.$$

Suppose that at least two firms enter in each region and that X^h workers become trained at home while X^f workers become trained abroad. Given our interest, assume that X^f exceeds X^h. Then the equilibrium prices can be of two forms. If $U'(X^h) - U'(X^f)$ is smaller than t, then the price at home is $U'(X^h)$ while the price abroad is $U'(X^f)$ and there is no trade. If it is greater than t, good Y flows from the foreign to the domestic region. The equilibrium price abroad P^f is bigger than $U'(X^f)$ while the equilibrium price at home, P^h equals $P^f + t$ and is smaller than $U'(X^h)$.

We showed in section 2.1.1 that if the equilibrium is of the former type when $2S$ workers get trained at home and as many as $(1+\lambda)L^*$ workers get trained abroad, the equilibrium is unique. So, consider the latter equilibria. If $2S$ workers become trained at home, then no more than $M[U'^{-1}(w+h) + U'^{-1}(w+h+t)] - 2S$ workers are willing to become trained abroad. On the other hand, $2S$ workers are willing to become trained at

[19] The analysis would be unchanged if the first decision on training were taken by the first worker at home.

home as long as the number of foreign trained workers does not exceed $K^f \equiv M[U'^{-1}(w+h) + U'^{-1}(w+h-t)] - 2S$, which is larger. The discrepancy comes from the existence of transport costs whose presence ensures that the price abroad must be below $w+h$ if it is to equal $w+h$ at home.

We now show that, if the strategies followed by foreign workers are subgame perfect, at least $2S$ domestic workers become trained. Consider first subgames in which fewer than K^f workers ever become trained abroad. Then, $2S$ workers or more will become trained at home. To see this note that the M'th domestic worker is strictly better off by becoming trained if $2S-1$ workers got trained before him. Similarly, the $M-1$'st domestic worker will enter if exactly $2S-2$ workers got trained before him. By doing so he, just like the last worker, recoups his training cost and lowers the equilibrium price. This reasoning extends backwards so that the $M-2S$'th worker is sure to become trained if other workers did not get trained before him.

We now argue that it is impossible for K^f workers ever to become trained abroad. Suppose there exists a subgame where the i'th foreign worker becomes the K^f'th worker to become trained there. That worker would refrain from acquiring training if there were $K^h \equiv M[U'^{-1}(w+h) + U'^{-1}(w+h+t)] - (K^f - 1) = 2S + 1 + M[U'^{-1}(w+h+t) - U'^{-1}(w+h-t)]$ domestic workers already trained. In equilibrium, such a number will always be present. The $i-1$'th domestic worker would definitely become trained if there were $K^h - 1$ domestic workers already trained before him. If he does not become trained, good Y will cost $w+h+t$ (By the definition of K^h). By entering, he lowers the price of Y and recoups his training cost even if his decision to become trained triggers further training of domestic workers. Similarly, the $i-2$'th domestic worker will get trained if there are only $K^d - 2$ workers trained before him. This argument extends backwards so that the $i-K^d-1$'th domestic worker becomes trained.

So far we have argued that the home region produces at least $2S$ which justifies the entry of two firms we initially assumed. In fact the argument can be strengthened to show that the home region produces L^* and the autarkic equilibrium prevails. Suppose that, on the contrary, the foreign region produces $L^* + x$ which is less than K^f where x is positive.

For x sufficiently large the home region will import Y. The backwards induction argument implies that the domestic region will then produce $M[U'^{-1}(w+h)+U'^{-1}(w+h-t)]-(L^*+x) = MU'^{-1}(w+h-t)-x$ which exceeds $2S$ because L^*+x is less than K^f. But, then, the price and wage abroad equal $w+h-t$ which is impossible. So x must be sufficiently small that the foreign region does not export the good. But, then, x must be zero for otherwise the foreign price and wage would again be below $w+h$.