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New Technology and Labour Markets: Entrants, Outsourcing and Matching

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Abstract

The impact of new technology (ICT) on labour markets and welfare is analyzed in a model of matching. First, ICT lowers cost and speed of market access, thus reducing frictions in matching a searching worker to an opportunity. It raises output and lowers the cost of entry for a new firm. The rise in scale of aggregate employment raises productivity. Second, since the net effect of ICT raises the probability of a successful search by workers relative to a successful search by firms, workers share of the match surplus rises. Third, it induces more learning and innovation. Fourth, ICTs allows hitherto excluded segments to access new networks. This reduces the ability of members of an existing network to extract the entire surplus from a new entrant. Finally, it encourages cumulative improvements in technology and skills. More labour-using technological progress is induced. Multiple equilibria are possible, however, due to endogenous choice of training and technology. Therefore investment in training and technology may be at less than socially optimal levels. Policy implications follow.

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1. Introduction

Information and communication technologies (ICTs), which support the Internet and global telecommunication networks, reduce frictions and search costs in labour markets. They also allow access to geographically separated entrants. Thus it is possible for a worker in one country to be employed in, or do some work for, a firm in another country. One variant of this, business process outsourcing, affects the welfare of millions as work migrates across the globe to find the lowest cost supplier. Opportunities improve for one set of workers, but others face more competition. Since the issue is emotive but relatively new there have been many journalistic pieces and initial estimates[1], but less analysis. The latter is necessary to understand deeper causes and resulting trends. No one has applied[2] matching models to explore the effects of new technology, although they are well suited to analyze distance work.

Such models were developed to move away from a Walrasian coordination of market demand to supply to understand the disaggregated process through which unfilled vacancies and unemployed workers have to find a suitable match. The models made analysis of individual decisions possible but they could be used to understand the evolution of aggregate

[1] A report for the Information Technology Association of America (ITAA) estimates that 2 percent of ten million US computer related jobs have been sent abroad and 12 percent of IT companies have outsourced work largely to countries in Asia and Latin America (Global Insight, 2004). A high-end projection from Forrester Research predicts a loss of 3.3 million US jobs by 2015, including 1.7 million back-office jobs. But this is still only a small dent in the American labour market. Amicus, the largest British private sector union, quotes the biggest figure of an expected loss of 200,000 UK jobs by 2008. The Confederation of British Industries is worried that 43 percent of British companies are considering relocating even head office functions to India (Rajghatta, 2004). But job loss may be only temporary, as export of low skill service jobs increases high skill jobs, lowers costs and raises productivity. McKinsey Global Institute (2003) estimates that one dollar of US job loss creates from 1.45 to 1.47 dollars of global value added out of which the US gets back 1.12 to 1.14 dollars through various channels, including higher exports, while the country receiving the offshoring job gets just 33 cents. Dossani and Kenney (2003) mention that outsourcing to India saved GE $340 million annually. ITAA-Global Insight study estimates that most US industries would gain new jobs in the long run due to offshore IT outsourcing. New jobs created due to offshore IT outsourcing in 2003 were 90,264, and were projected to increase to 317,367 by 2008. Global sourcing was also projected to benefit other US economic indicators. Chris Anderson writes in “Wired” that 20 percent of the budget of American firms will be freed to come up with creativity and more workers will be focused on innovation. The rise in per capita incomes elsewhere will raise American exports.

[2] Egger and Falkinger (2003) examine the distributional effects of outsourcing in a very different general equilibrium trade model. Chen, Ishikawa and Wu (2004) focus on the strategic aspects of outsourcing. Grossman and Helpman (2002) examine the implications of incomplete contracts, and Feenstra and Hanson (1995) examine the effects of outsourcing on relative wages between skilled and unskilled workers. Kuhn

unemployment and its cyclical behaviour (Diamond, 1982, Pissarides, 1990). The difficulty of search and of making a perfect pairing meant that equilibrium unemployment would exist even with free entry. In later work matching models were extended to analyze endogenous education and technology choice, the implications for inefficiencies in training (Acemoglu, 1997) and for endogenous growth (Laing et.al., 1995).

These stochastic matching and bargaining models, with heterogeneous workers and frictions in the labour market, are applied here to analyze distance work. Frictions model the lack of perfect information in distance work; heterogeneity captures the diversity in skills of knowledge workers. These two factors imply that a match is random--attributes are not perfectly matched. ICT lowers the cost and speed of market access, facilitates better matching of skills, raises worker productivity, and lowers the entry cost of new firms. All of these are parameters in matching models. Outsourcing depends on assured quality of work, which requires harmonization of standards and relationship specific investment when contracts are necessarily incomplete (Grossman and Helpman, 2002). ICT reduces transaction costs in finding and maintaining such a relationship. It facilitates the spread of common standards and of monitoring, which can compensate to some extent for incompleteness of contracts. By creating more opportunities and making markets thicker, it reduces the degree of specificity of investment. All of this can be modeled as an improvement in matching technology. A steady-state growth rate of workers captures the effect of easier entry of distant workers. The assumption of free entry for firms gives model closure in the long-run, and captures an essential attribute of the knowledge driven economy: the decreasing importance of the physical capital constraint. The model also shifts attention away from the short term and direct job relocations to indirect and long-run effects, and to policy that can improve the short and the long-run. Although labour market flexibility increases, labour's bargaining power actually rises over time.

(2003) surveys work on the effect of the Internet on labour markets using matching models, but the focus there is on traditional questions of duration of unemployment.

We explore the effects of ICT first in a stochastic matching model in which opportunities in one region are randomly matched to searches made by entrants, who could belong to another region. Under free entry of firms the result is that higher productivity and scale economies benefit both parties. In such models, heterogeneity and the absence of a spot market implies that returns are not driven to the outside options or opportunity costs. A match occurs only if it creates a surplus. Relative bargaining power decides the distribution of this match surplus. While improved matching benefits both firms and workers equally, reduction in the cost of entry for employers (technological innovation), and higher employee productivity (training and technology) raise employees share of the match surplus. Since the net effect of ICT raises the probability of a successful search by workers relative to a successful search by firms, workers benefit. Benefits to workers come from more jobs, higher wages and distribution of match surplus[3].

Second, making technology and education choice endogenous reinforces the results. In addition multiple equilibria occur. Policy can have a major impact by ensuring the better equilibrium.

Third, modeling aspects of networks shows that shares of new entrants may be low because established firms can leverage their large networks. Strategic dynamic effects influence bargaining positions (Farrell and Klemperer, 2002). ICT makes it feasible for new entrants to participate in networks. But for this open standards and the creation of institutions that support specialized open networks are essential. In the ICT industry itself open standards are the rule, because when network effects are large all parties benefit from standardization, which increases network size. Globalization and the use of ICT make networks important in other activities as well.

Wider access to ICT is important, but its major impact on equality comes through inducing more training and innovation. Therefore policies should focus on these factors in both

[3] These factors imply that wages can rise sooner with trade in services (which is another definition of outsourcing) compared to the standard result that wages first fall and then rise with freer trade (Rama, 2003)

regions. Open standards are especially necessary for intermediate products. Markets access combined with strict output quality standards can induce skill development. A ban on outsourcing will harm this innovation process, and especially if imposed unilaterally by one country, would harm its firms and leave it behind in the global development process. Since firms make large transient profits, a low temporary profit tax may be used to create a welfare fund for training and redeploying local workers who loose jobs due to outsourcing. If there is free entry of firms, and skill upgradation of workers, fears of sustained local unemployment due to some jobs being matched abroad are unfounded. More local jobs will be created as profits rise and activity expands.

The paper develops the matching model and presents its results in section 2, brings in endogenous training and technology choice in section 3, presents a simple model of networks and surplus extraction in section 4, and draws together detailed policy conclusions in section 5. Proofs are in the appendix.

2. A Model of the Matching Process

We adapt a matching model to examine the effect of new technology and of policy related to it, on labour markets. The technology allows distance workers in underdeveloped region B to be matched to firms in developed region A. Workers will be used as a generic term, which could stand for service providers, traders, or firms. We abstract from the process that matches region A workers to firms in the same region. Region A has thicker markets and higher productivity so that wages in region A are higher than in region B.

There is a continuum of heterogeneous workers who search (S) for an employment opportunity. Firms create opportunities (O). O and S are aggregate measures of opportunities and searches. A stochastic CRS matching technology M is a proxy for the complex process of bringing together firms and workers. In order to focus on the effect of reduction in match frictions, we rule out increasing returns in the technology itself. For the same reason, we also abstract from credit constraints, aggregate demand externalities, and other sources of increasing returns. Technological externalities do not arise since the output of a pair does not depend on other agents in the economy. The workers and firms are risk-neutral so that the wage does not perform an insurance function.

A firm incurs a cost *c* to acquire the technology and then employs at most one worker to create output *y*. New opportunities can be created and eliminated costlessly. A filled opportunity (F) and an employed worker (E) quit the search market. Employed and searching workers add up to the total labour force. Since there is no spot market determining a uniform competitive wage, wages they are not driven to the outside option. There is a match surplus (*MS)*, which is shared by a Nash bargaining process. The share of the *MS* going to the worker is ϕ, while the firm gets 1-ϕ. Agents are infinitely lived, in a continuous time framework, and new agents enter at the rate β. Each agent has an identical instantaneous discount rate $r > 0$.

Opportunities (O) and searches (S) yield a flow of new jobs according to a matching function M, which has constant returns to scale, is concave, increasing in both its arguments, and satisfies the Inada conditions. Although scale improves matching, there are also negative effects of scale as screening costs rise. Thus although matching improves with O and S, there are constant returns to scale, and the effect of ICT is modeled through a rise in $m_o > 0$, which parameterizes search frictions. A rise in m_o implies a reduction in these frictions and a rise in the matching rate. It captures the effect of ICT in reducing transaction costs, improving monitoring, and reducing the relationship specificity of investment. Thus:

$$M : R_+^2 \to R_+ \qquad such\ \ that$$
$$m = m_o M(O,S) \tag{1}$$

The flow probability or the rate per unit time that a searching worker locates an opportunity is given by:

$$\mu = m_o M(O,S)/S \tag{2}$$

The rate at which an opportunity locates a worker is:

$$\eta = m_0 M(O,S)/O \tag{3}$$

Since an opportunity is utilized by only one worker,

$$\mu\, S = \eta\, O \tag{4}$$

In steady state, this must equal β, which is the entry rate of new workers.

The model is solved in the appendix to determine a unique wage offer function w(y, μ, η, r) for lifetime earnings (Equation A14). Comparative static results derived in the Appendix are:

Result 1: *A rise in η raises the firm's outside option and therefore lowers its wage offer; a rise in y raises the total available for distribution and therefore raises wages; an improvement in the worker's bargaining position ϕ will raise wages; with a rise in μ, the flow probability of locating a vacancy, more options become available to workers thus raising their wage offer; a rise in entry cost c raises the value of the firm's outside opportunity and therefore lowers its wage offer.*

The expanding use of ICT and the Internet will raise m_o or the efficiency of the matching process and per worker output *y*, and reduce *c* or the cost of entry. Result 2 gives the comparative static results of changes in these three parameters on steady-state values of $w^*(y, c, \mu, \phi)$ and the quadruple $(\mu^*, \eta^*, S^*, O^*)$.

Result 2: All these three factors will raise equilibrium wages w^*; only m_o will increase both μ and η; the fall in *c* and rise in *y* will raise μ but lower η; S will fall and O rise, with the fall in *c* and rise in *y*; both will fall with the rise in m_o.

We know that μ > η benefits workers, since opportunities exceed searching workers. Alternative options become available for workers and therefore their bargaining position improves. The match surplus will rise and so will firm's profits initially, but the free entry assumption implies that these will be competed away. The fall in *c* and rise in *y* will attract more firms and thus benefit workers in the steady state. Entry of distant workers ICT facilitates raises β, and thus has permanent scale effects, raising S*, and O*, which in turn improve matching thus benefiting both firms and workers.

The effect on (μ^*, η^*) can also be seen graphically. The free entry condition defines an implicit function OO along which $\delta O/\delta t = 0$. This gives the combinations of μ and η for which O is unchanging over time, since costs equal benefits of entry for firms. The CRS matching technology M defines another implicit function SS in η and μ space along which $\delta S/\delta t = 0$. This gives the combinations of μ and η for which S does not change, since costs equal benefits of searching for workers. The OO and SS curves are graphed in μ η space in Figure 1. OO is linear and upward sloping and SS convex to the origin and downward sloping (the slopes are derived in the Appendix).

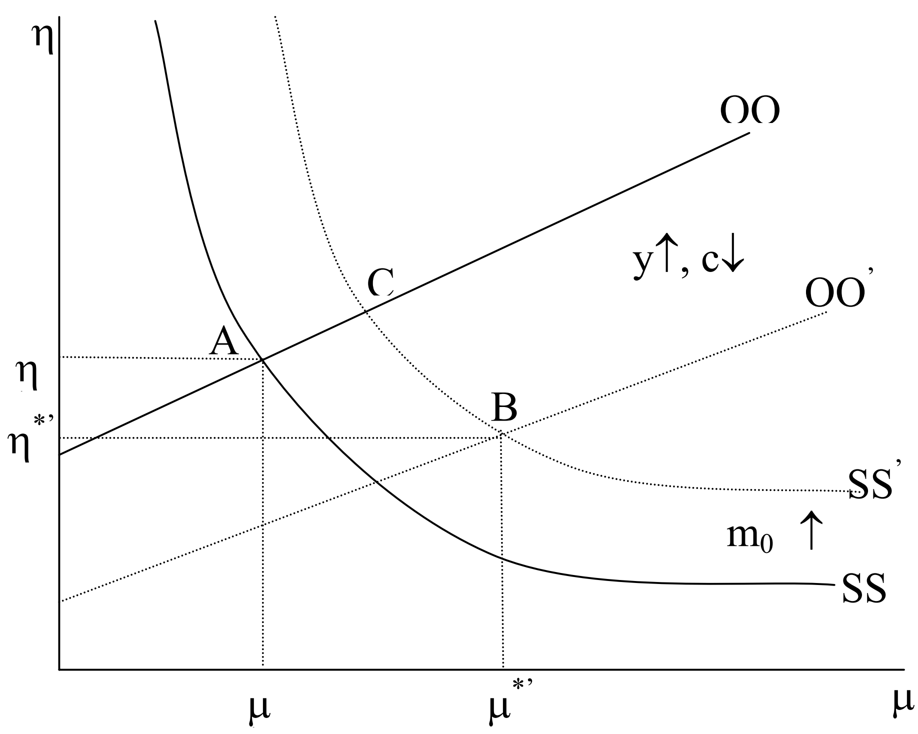

Figure 1: Match equilibria and the effects of ICT

Figure 1 shows the net effects on μ^* and η^* of changes in the exogenous parameters due to ICT. A rise in matching effectiveness of m_o shifts out the SS curve and raises both μ and η

to the equilibrium C. But together with the rise in y and fall in c the net effects are a large rise in μ and fall in η at the new equilibrium B.

These effects of ICT are heightened if we explicitly allow for the workers' choice of training and the firms' choice of technology.

3.Choice of Technology and Education Levels

We now assume that there are two types of investment, in the pre-market period, which can raise output per worker. The assumption of no credit constraints implies these can be financed. At a cost υ the firm can acquire a new ICT machine τ. If the firm acquires the new machine, τ takes the value of 1 and is zero otherwise. The worker can choose to undergo h units of training, from the interval $[0, \bar{h}]$ at a cost c(h), in the period before coming into the market. Since we assume utility is transferable between workers and firms, we can focus on the total surplus. The firm may finance pre-market period training since long-term complete contracting between the firm and the worker is feasible. In case of separation the worker would make a transfer payment to the firm, therefore it does not matter who incurs the cost of training. These transfer payments do not affect the marginal incentive to invest in training. The assumptions make it possible to focus on and analyze the effect of education and technology on distance work. Output is produced in the market period. Only workers with initial training further increase their human capital through learning by doing, at the rate γ(h) on the base, which is some function k of h. Thus for an employment interval t_E human capital accumulation becomes,

$$h = k(h)e^{\gamma(h)t_E} \tag{5}$$

Output per worker now becomes,

$$a(h,\tau) = y + \alpha(\tau, h) \tag{6}$$

$$\alpha > 0 \quad if \;\; \tau = 1$$

This implies strict complementarity between the acquisition of new technology and human capital. One adds to output only in the presence of the other. The cost function is:

$$C = c(h) + \nu\tau \tag{7}$$

Standard concavity assumptions (Appendix, A21) ensure that equilibrium exists, since there are diminishing returns to education and the present discounted value of a match is bounded.

Since training and technology raise y and therefore the match surplus and wages, they have a self-reinforcing aspect. The more they are adopted, the higher the returns to adopting them. From Figure 1 we know that a rise in y has a relatively greater impact on μ and therefore w. Now it is clear that both τ and h raise y. ICT would increase the workers' own returns from training. The expansion in availability of relatively low-wage workers will encourage the further adoption of technology that makes it possible to utilize them (Acemoglu, 1997). The assumptions ensure the existence of a unique determinate equilibrium, which maximizes welfare. But under slight, realistic modifications, multiple equilibria and inefficiencies could occur due to a number of causes.

First, training could rise with the flow probability of a successful search, μ, since the expected benefits from education rise. A rise in μ now has two effects on entry of firms. It raises wage and therefore lowers entry, but it raises the level of workers' training and therefore raises entry. The OO curve becomes non-linear with an initial downward sloping segment, giving rise to multiple stable equilibria[4] at low and at high μ. There is a possibility of being trapped in a low-level equilibrium steady state, where the level of private investment will be less than socially optimal. A policy induced rise in m_o and upward shift in the SS curve will shift the system to the high level equilibrium with optimal investment.

To consider multiple equilibria arising from the adoption of technology, suppose a match can be destroyed in the market period, which follows the training period, with probability s. For simplicity, the entry birth rate β is now fixed at zero, and there is an exogenous per period probability of separation s. In steady state separations equal matches:

$$m_o M(O, S) = sE \tag{8}$$

[4] Such equilibria are explicitly derived in Liang et. al. (1995).

If search and opportunities are not changing, new matches available must equal separations from the existing employed. After a separation, there is a probability that technology and training will not occur together in the new match. Now consider workers and firms making an investment decision.

Result 3: *If there is a positive probability of separation $0 < s < 1$, then private parties may not recover the full returns to their investment, so that multiple equilibria exist and underinvestment may occur. If a critical mass adopt all adopt, below that no one adopts.*

Proof: From the definitions above, the total surplus (TS) available to the firm and the worker in period 2, after the shock, is:

$$TS = (1-s)(y+\alpha(..))+s\psi(y+\alpha(..))-(1+r)C \tag{9}$$

Since investment raises productivity we assume $\alpha(..) > (1+r)C$. With probability $(1-s)$ there is no separation and the pair captures the full return on their investment made at cost C, in the first period. But, after separation due to a match specific shock, each firm and worker has to find a new pair. Under random matching, the probability of a good match, which equals the proportion of the population investing and training, is ψ. Therefore the new match surplus will be only $\psi(y+\alpha(..))$ with probability *s*. If the proportion investing, $\psi\rightarrow 1$ all will find it profitable to undertake investment since TS is $y+\alpha(..) -(1+r)C > 0$. But if $\psi\rightarrow 0$ the private returns to investment are only $(1-s)(y+\alpha(..)-(1+r)C$, this can be negative if *s* high, so that no one will invest. If s is close to 1, TS is $- (1+r)C$, no one investing is the unique equilibrium. If $s = 0$, TS is $y+\alpha(..) -(1+r)C > 0$, everyone investing is the unique equilibrium. Therefore $0 < s < 1$ is necessary and sufficient for multiple equilibria to exist. All agents investing is an equilibrium, but so is no one investing. Given s, $(1-s)(y+\alpha(..))+s\psi^*(y+\alpha(..)) = (1+r)C$, determines the critical value ψ^*. If $\psi > \psi^*$, $\psi\rightarrow 1$.

Government policy can contribute to raising ψ above ψ^*. Underinvestment in training can also arise if the firm is able to extract the entire match surplus, because of network effects, and the wage offer falls. This is explored through an example in the next section.

4. Networks and Extraction of Surplus

So far we have considered the distribution of the match surplus between two contracting parties, one in region A and the other in B. We now bring in a second region A firm as a simple way of capturing the effect of networks on match surplus. Since the density of interactions is much higher in the developed region A, agents in the region A have power to leverage their networks. This allows them to extract more of the match surplus. When third parties are involved, region B agents may be forced to enter into transactions that give them negative utility. In the simple example[5] illustrating this process below, the dominant region A firm is able to obtain the surplus from the region B worker's transaction with a second region A firm by making the second firm stop interacting with the distance worker unless the latter agrees to a bargain favoring the dominant firm. ICT, by increasing region B's participation in networks, will remove this cause of surplus extraction. Therefore new technologies and the outsourcing they make possible have the potential to mitigate long entrenched global inequalities.

A II

		C	D
A I	C	e, e	0, f
	D	f, 0	g, g

Figure 2: A co-ordination game between region A firms

[5] Basu (2000), chapter 6, analyzes the effect of third party transactions on coercion in the context of interlinked rural markets.

There are two Region A firms, AI and AII, of which AI is the bigger. They have a number of business transactions with each other. If both adopt business plan or strategy C returns to both are higher than if one or both of them follow strategy D. That is, they play a co-ordination game with strategic complementarities. In Figure 2, which gives the payoffs, AI's payoffs are written first. Since $e > g > f > 0$, there are two Nash equilibria in this game: (C, C) and (D, D). Both AI and AII enter into transactions with a Region B firm (B). AII stands to gain S^{AII} from the transaction and B would gain S^{BII}. If they do not transact together these values would be zero.

The bigger firm, AI, has the first move. It offers a wage W and employment E, pair (W, E) to B for the job. In the next period of the game B can accept or reject this take it or leave it offer. In the third period B and AII decide on their trade and in the final period AI and AII carry out their transaction.

Result 4: *Network effects and strategic interactions can leave the Region B firm at its no trade level of profits, and it can even make a loss on its transactions with a Region A firm.*

Proof: AI threatens AII with strategy D, if AII trades with B in the case of B refusing AI's offer. The threat is effective in stopping AII trading with B if $e-g > S^{AII}$. When the inequality holds, AII loses more from the reduction in its transaction with AI, than it gains from trading with B. The threat is a credible one for AI to make only if its loss on playing D with AII is less than its potential gain from trade with B. This requires $\Pi(W^*, E^*) > e-g$. That is, AI's profits from its interaction with B, $\Pi(W^*, E^*)$, exceed AI's loss in playing D rather than C with AII, e-g.

AI maximizes its profits, subject to B's participation constraint. That is, the sum of B's gains from transactions with AI and AII, where *c* is the cost B incurs, per unit of employment E, must not be negative for B to be willing to participate in the transactions:

$$\underset{W,E}{Max} \quad \Pi(W,E) = y(E) - WE$$

$$\text{subject to } WE - cE + S^{BII} \geq 0 \tag{10}$$

AI maximizes its profits when the participation constraint holds with equality, so that WE - cE = $-S^{BII}$. This condition determines its equilibrium offer (W*, E*) to B. Thus, the payoffs will be such that B will earn zero, AII will earn S^{AII}+ e, and AI will earn, Π(W*, E*) + e. AI extracts the entire surplus from B, including what B earns from its transaction with AII.

Since AI's credible threat lies off the equilibrium path it would not be observed in actual play. It will only be implicit. The general point is that future trades, including those between sellers and other buyers, matter when network effects are present; therefore strategic, dynamic effects occur (Farrell and Klemperer, 2002). AI is able to extract some of B's surplus from B's interaction with third parties, as long as AI has more interactions with these other parties than B has.

ICT will increase S^{AII} and raise it above e – g, so that AII would not want to endanger its interaction with B; then AI's threat will no longer be effective and the surplus extraction fails. As the density of B's interactions rise, it will have alternatives to both AI and AII. By making entry of new firms easier it will reduce the hold of AI on both B and AII, which arise from its premier position in the network. B's exit options and bargaining power improves.

The source of AI's advantage is partly greater information. It knows more about the markets and other firms. Equivalently B does not know firms other than AI and AII or finds the transaction costs of contacting them very high. ICT lowers the cost of acquiring information. The Internet[6] lowers these costs but, unlike a monopolistic firm, does not require to be compensated for doing so, partly because adding content advertises those contents, and partly because it is not owned by anyone. AI, in contrast, extracts a rent for the information it provides or the trade it allows, and gives B the least consistent with B's

[6] Open standards are a key feature to realize these benefits. As Mansell (2001) points out electronic EDI systems allowed Northern firms to exchange standardized information using proprietary software platforms and create closed networks.

participation. Research has discovered, however, that the Internet only benefits those job searchers who are otherwise qualified (Kuhn, 2003); since costs of search are low, the proportion of inadequate candidates using it is more. Therefore some independent certification and initial physical contact are also important to enter networks.

Apart from information about trading partners, knowledge of international standards is necessary for region B to raise the quality of its output sufficiently to access new markets. ICT helps acquire this information also but open standards are essential for these benefits to accrue fully. This issue is explored further in drawing together the conclusions for policy in the next section.

5. Policy Conclusions

In the models, a rise in the efficiency of the matching process benefits both firms and workers. The entry of new distant workers increases the scale, improves matching, and again benefits both. Under free entry of firms more workers would induce entry of more firms and expand the level of activity. An improvement in ICT improves matching. It also raises per worker productivity, and reduces the cost of entry of new firms, both of which raise equilibrium wage offers to workers. Therefore encouraging the spread of ICT, access and bandwidth, should be a key policy objective.

Since region A firms obtain the major share of the match surplus and make large transient profits, a low tax on them can be used to help establish a specific welfare fund to upskill and redeploy region A workers that loose jobs temporarily. Firms will factor in some of the losses to workers, but unlike with a ban, will still be able to outsource if cost savings are very high[7]. Cheap education and training facilities in Region A will also prevent adverse effects on low skill workers there of the kind Feenstra and Hanson (1995) document. De Long (2002) argues that a major reason for the rapid rise in inequality in America in the last decade has been the decline in the quality of primary education and the affordability of secondary education. Here there is clearly a role for government policy.

A rise in the efficiency of the matching process, affects both search and opportunities equally, but a rise in per worker productivity, and fall in the cost of entry of new firms increase opportunities and reduce searching workers. Therefore they benefit workers relatively more than they benefit firms. They increase the flow probability that a searching worker locates an opportunity relative to the flow probability that an opportunity locates a worker. Therefore the workers get a larger share of the match surplus. Free competitive entry of firms reduces excess profits to zero. Policy conclusion: giving a larger weight to technology and training, and ensuring competitive entry will tend to reduce inequality within and across countries over time.

Moreover, the enhanced matching model shows that training and technology have a self-reinforcing aspect. The more they are adopted, the higher the returns to adopting them. Training choice responds positively to a rise in the flow probability of a match, and to firms' adoption of better technology. Returns to the technology and learning by doing, in turn, improve with training. But these effects imply the flow probability of a match rises with training so that multiple equilibria are possible. In that case, the level of private investment may be less than socially optimal. Well-designed public intervention can trigger large changes. The rise in productivity would benefit both regions. Any one country imposing a ban on outsourcing would loose out in the benefits from technology and training.

There are strong incentives for training in conditions where opportunities are expanding. Strict quality standards can strengthen these incentives[8]. Such quality standards will ensure

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[7] An interesting example of outsourcing that did not lead to job loss, was when Dabur an Indian Pharma company outsourced its IT and other system maintenance to Accenture, an American company, in 2004. Accenture employed some Dabur employees to do the job.

[8] Such quality standards are automatic for traded goods and by demonstration extend to others. NASSCOM (2002) argues that high quality is the reason for India's success in software exports. Mansell (2001), "....producer firms are required to meet new quality, time-to-delivery, or other standards introduced by buyers

that employers will be willing to expand education and training facilities to shift workers above the threshold. The availability of labour skills, in turn, can induce firms to adopt new technology in a beneficial feedback cycle.

Workers from region B benefit not only from the rise in wages, but also in so far as these technologies allow them to participate in distant markets. As their exit options improve such workers would get a better bargain. Thus despite more flexibility in labour markets workers bargaining power could improve. Unions should focus more on training, insurance and access activities.

In transactions between region A and B firms or individuals, a source of the formers' advantage is more information and deeper networks. This is one explanation for the low share of region B in the match surplus. ICT has the potential to improve Region B's access to networks, and create new networks, thus reducing the disadvantages of uneven access. Institutional support is required, however, for the initial access. Industry bodies, governments, or international institutions can encourage new specialized networks. ICT lowers the cost of acquiring information both about potential trading partners and about standards of acceptable products. Knowledge of the latter is vital for the Region B to access new markets.

Open standards are essential for the above effects. When network effects dominate it pays to expand the market. Therefore far-seeing policies should lock-in the large new populations into the networks, even at the cost of some minor current concessions on openness and market access. Conversion costs of common standards should be lowered. There is a result that when standardization conversion costs are small relative to network effects all regions gain from accepting common standards (Gandal and Shy, 2001).

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in the industrialized countries (pp.290)." Such standards are impossible to achieve with illiterate and subsistence labour.

The spread of open standards in the ICT industry gives valuable lessons, to apply to different kinds of networks. Open standards enhance competition and innovation. But are especially valuable when they apply to inputs, and where innovation occurs in small steps through a series of contributors. Such interoperability turns competitors into complementors. It has been argued that international patent rights (IPRs) should be limited to facilitate interoperability between competing products. When there are network effects, consumers value compatibility and IPRs by turning the initial choices of a small user group into *de-facto* standards, may confer monopoly rights without any significant innovation. There should be only limited copyright protection for interfaces when a firm improves an interface, to allow products of different manufacturers to work together in a computer system. Reproduction and translation of copyright code is essential for this (Gandal, 2002).

Network externality can imply rapid death for small local networks unless compatibility is built in. Small new entrants need to negotiate for survival, to keep options open, to think strategically and combine with those who would gain. They must be willing to learn the language before contributing to it, be willing to engage in a range of activities and move slowly up to higher value added products.

Standards help specialists who want to compete globally, but incompatibility helps sustain local protection. In markets where incompatibility is a strategic choice regulation is required. Inefficient firms with large installed bases may insist on incompatibility to deter rivals who would be much more effective with compatibility. With strategic pressure markets may lock into inefficient standards. Therefore measures to enhance the role of public and quasi-public standard development organizations and their speed and conflict resolution capabilities are of great value.

Under network externalities competition policy has to consider dynamic aspects. It may be necessary to give concessions initially in order to make a market, and such concessions may not be aimed at destroying competition. Therefore policies that improve one's product need to be distinguished from those that block a competitor. Open standards can help prevent the latter. Competition policy should give rivals rights such as reverse engineering that allow them to insist on compatibility, notwithstanding patent rights (Farrell and Klemperer, 2002).

ICT itself has many benefits for labour; but inducing more innovation and learning through economic incentives can multiply the benefits many times.

Appendix

The matching model

A worker can be either searching (S) or employed (E). A firm can have an opportunity that is filled (F) or existing (O). There are asset values associated with each of these states. Thus the "return" on the asset value of being employed (V_E) is a dividend of wages (*w*) per unit time.

$$r\,V_E = w$$

Or V_E is the present discounted value of income accruing to the worker from the match. Similarly the return to the firm of a filled opportunity is its share of the match surplus. That is output (*y*) minus wages,

$$r\,\Pi_F = y - w$$

The asset value of continued search or keeping an opportunity unfilled respectively, comes from the value of a match subtracted from the value of continued searching,

$$r\,V_s = \mu(V_E - V_s)$$

$$r\,\Pi_o = \eta(\Pi_F - \Pi_o)$$

Rearranging gives the four asset values as:

$$V_E = w / r \qquad \text{A1}$$

$$\Pi_F = (y - w) / r \qquad \text{A2}$$

$$V_s = (\mu / \mu + r)V_E \qquad \text{A3}$$

$$\Pi_o = (\eta / \eta + r)\Pi_F \qquad \text{A4}$$

The match must determine a wage, but because labour is heterogeneous a replacement cannot be found instantly, so there is a range of wages between the demand and supply price of labour, which makes each party better off than they would have been without the match. If there is symmetric Nash bargaining the surplus is shared equally, so that,

$$V_E - V_S = \Pi_F - \Pi_O \geq 0 \qquad \text{A5}$$

The unique wage offer function determined by substituting Eqs. A1 to A4 in Eq. A5 is:

$$w = \{y(\mu + r)\} / \{2r + \eta + \mu\} \qquad \text{A6}$$

Firms and workers take η and μ as parametric in making decisions, although they are endogenously determined in the equilibrium. If $\eta = \mu$ Eq.A6 implies that *y* would be split between the two. If $\mu > \eta$ workers find new opportunities faster than firms can find people, so more than half the surplus goes to the worker. Differentiating A6 tells us how the wage offer varies with the parameters:

$$\delta w/\delta\eta<0, \quad \delta w/\delta\mu>0, \quad \delta w/\delta y>0 \qquad \text{A7}$$

In the case of the more general Nash bargain where ϕ is the share of the match surplus (*MS*) going to the worker:

$$V_E - V_S = w/(\mu + r) = \phi MS \quad and \quad \Pi_F - \Pi_O = (1-\phi)MS \qquad \text{A8}$$

Solving for *w* in this case:

$$w = \{\phi(\mu + r)y\} / \{r + \eta(1-\phi) + \mu\phi\} \qquad \text{A9}$$

And then differentiating A9 gives similar partial derivatives, with the new result that the wage offer rises with the workers share of the match surplus:

$$\delta w/\delta y > 0, \quad \delta w/\delta\phi > 0, \quad \delta w/\delta\mu > 0, \quad \delta w/\delta\eta < 0 \qquad \text{A10}$$

The free entry condition closes the model, ensuring that Π_o is driven down to *c*. Substituting this in A8 and then solving for *w*:

$$w = \{\phi(y - rc)\} / \{r - 2\phi r - \mu\phi\} \qquad \text{A11}$$

The derivatives remain unchanged, only the negative effect on the wage offer of η is now replaced with the negative effect of *c* from Eq. A11.

$$\delta w/\delta y > 0, \quad \delta w/\delta\phi > 0, \quad \delta w/\delta\mu > 0, \quad \delta w/\delta c < 0 \qquad \text{A12}$$

Substituting A1 to A3 in A5 and imposing $\Pi_o = c$ gives:

$$w = \{(\mu + r)/(2r + \mu)\}\{y - rc\} \qquad \text{A13}$$

This is the case of free entry and equal share of the match surplus. The derivatives are the same as (15) except that ϕ drops out. Result 1 gives a summary:

Result 1: *Comparative static results from the wage offer function:*

$$\delta w/\delta\eta<0, \quad \delta w/\delta y > 0, \quad \delta w/\delta\phi > 0, \quad \delta w/\delta\mu > 0, \quad \delta w/\delta c < 0 \qquad \text{A14}$$

In the steady-state equilibrium the free entry condition and the matching technology determine μ^* and η^*. These then determine w^* from Eq. A12, and S^* and O^* from Eqns. A15.1 and A15.2 which imply that $S^* = \beta/\mu^*$ and $O^* = \beta/\eta^*$. The steady state is defined as[9]:

*Definition*1: Steady-state equilibrium is a wage function $w(y, c, \mu, \phi)$ and a quadruple (μ^*, η^*, S^*, O^*) satisfying the conditions:

(i) $V_E^* - V_S^* = \phi\, MS \text{ and } \Pi_F^* - c = (1-\phi)MS$ (Nash Bargain)

(ii) $\Pi_o^* = c$ (free entry)

(iii) $\mu^* S^* = \eta^* O^* = m_0\, M(S^*, O^*)$ A15.1

$\mu^* S^* = \beta$ (steady-state) A15.2

The implicit function OO is defined as:

$$\eta = \eta^{oo}(\mu; y, c) \quad with \quad \delta\eta^{oo}/\delta\mu > 0, \quad \delta\eta^{oo}/\delta y < 0, \quad \delta\eta^{oo}/\delta c > 0 \qquad \text{A16}$$

Substituting A2 and A13 in A4 and imposing free entry gives a specific function, which clearly satisfies the derivatives in A16.

$$\eta = \{(2r+\mu)c\}/(y - rc)$$

Since a rise in μ raises wages, fewer firms enter, opportunities fall, and therefore η (= m/O) rises. A rise in *y* or fall in *c* makes entry more attractive thus raising entry and lowering η, the rate at which opportunities locate a worker.

[9] Laing et.al. (1995) obtain similar results in an application of the matching model to study endogenous growth and training decisions.

The implicit function SS is defined as:

$$\eta = \eta^{ss}(\mu; m_o) \quad with \quad \delta\eta^{ss} / \delta\mu < 0, \quad \delta\eta^{ss} / \delta m_o > 0, \qquad \text{A17}$$

Since m = m_o O M (S/O, 1), η = m/O, and S/O= η/μ, therefore η = m_o M(η/ μ,1), is the required implicit function. The Inada conditions satisfied by the matching technology M imply that the derived implicit function is convex to the origin, with asymptotes that approach the two axes.

Result 2: *The effects of changes in m_o, y and c on unique steady-state values of (i) μ*, η*, (ii) S^* O^* and, (iii) w^* are:*

(i) $$d\mu^* / dm_0 > 0, \quad d\mu^* / dy > 0, \quad d\mu^* / dc < 0$$

$$d\eta^* / dm_0 > 0, \quad d\eta^* / dy < 0, \quad d\eta^* / dc > 0 \text{ (for matching rates } \mu^*, \eta^*) \qquad \text{A18}$$

(ii) $$dS^* / dm_o < 0, \qquad dS^* / dy < 0, \qquad dS^* / dc > 0$$

$$dO^* / dm_0 < 0, \qquad dO^* / dy > 0, \qquad dO^* / dc < 0 \text{ (for } S^*, O^*) \qquad \text{A19}$$

(iii) $$dw^* / dm_o > 0, \qquad dw^* / dy > 0, \qquad dw^* / dc < 0 \text{ (for equilibrium wages, } w^*) \qquad \text{A20}$$

Proof: Given the shapes of the SS and OO curves a unique equilibrium exists and determines a pair (μ^*, η^*) satisfying (ii) and (iii) of definition 1. To prove the comparative static results:

(i) For matching rates:

Totally differentiating the steady-state equilibrium conditions:

$$\mu^* - \eta^{oo}\left(\mu^*; y, c\right) = 0$$

$$\mu^* - \eta^{ss}\left(\mu^*; m_0\right) = 0$$

Letting λ stand for y, c, and m_o:

$$\frac{d\eta^*}{d\lambda} - \frac{\delta\eta^{oo}}{\delta\mu}\frac{d\mu^*}{d\lambda} = \frac{\delta\eta^{oo}}{\delta\lambda}$$

$$\frac{d\eta^*}{d\lambda} - \frac{\delta\eta^{ss}}{\delta\mu}\frac{d\mu^*}{d\lambda} = \frac{\delta\eta^{ss}}{\delta\lambda}$$

Writing in matrix form

$$\begin{bmatrix} 1 & -\dfrac{\delta\eta^{oo}}{\delta\mu} \\ 1 & -\dfrac{\delta\eta^{ss}}{\delta\mu} \end{bmatrix} \begin{bmatrix} \dfrac{d\eta^*}{d\lambda} \\ \dfrac{d\mu^*}{d\lambda} \end{bmatrix} = \begin{bmatrix} \dfrac{\delta\eta^{oo}}{\delta\lambda} \\ \dfrac{\delta\eta^{ss}}{\delta\lambda} \end{bmatrix}$$

$$\begin{bmatrix} 1 & -\dfrac{\delta\eta^{oo}}{\delta\mu} \\ 1 & -\dfrac{\delta\eta^{ss}}{\delta\mu} \end{bmatrix} = \det$$

From A16 and A17 the determinant, det > 0.

Using Cramer's rule

$$\frac{d\eta^*}{d\lambda} = \frac{\begin{bmatrix} \dfrac{\delta\eta^{oo}}{\delta\lambda} & -\dfrac{\delta\eta^{oo}}{\delta\mu} \\ \dfrac{\delta\eta^{ss}}{\delta\lambda} & -\dfrac{\delta\eta^{ss}}{\delta\mu} \end{bmatrix}}{\det}$$

$$\frac{d\mu^*}{d\lambda} = \frac{\begin{bmatrix} 1 & \dfrac{\delta\eta^{oo}}{\delta\lambda} \\ 1 & \dfrac{\delta\eta^{ss}}{\delta\lambda} \end{bmatrix}}{\det}$$

The signs of the derivative follow using A16 and A17 and substituting for λ.

(ii) For steady-state opportunities O^* and searching workers S^*: From definition 1, $S^* = ß/\mu$, therefore the sign of $dS^*/d\lambda$ will be the negative of the sign of $d\mu^*/d\lambda$ which was derived in (i) above.

From definition 1, $O^* = ß/\eta$, therefore the sign of $dO^*/d\lambda$ will be the negative of the sign of $d\eta^*/d\lambda$, which was derived in (i) above.

(iii) For equilibrium wages: Totally differentiating the wage offer function A13 with respect to λ gives:

$$dw^* / d\lambda = \delta w^* / \delta\lambda + (\delta w^* / \delta\mu^*)\,(d\mu^* / d\lambda)$$

Substituting the signs obtained in Result 1 and in part (i) of Result 2, gives the required signs.

Concavity assumptions:

1. The function $k : R_+ \rightarrow [0,1]$ is strictly increasing, differentiable, and concave with $\lim_{h\rightarrow 0} k(h) > 0$ and $\lim_{h\rightarrow \bar{h}} k(\bar{h}) \leq 1$

2. The function $c(h) : R_+ \rightarrow [0,1]$ is strictly increasing, differentiable, and convex s.t $\lim_{h\rightarrow 0} c(h) = 0$ and $\lim_{h\rightarrow \bar{h}} c(\bar{h}) = \infty$

3. The rate of growth of human capital $\gamma : R_+ \rightarrow R_+$ is strictly increasing, differentiable, strictly concave with $\lim_{h\rightarrow \bar{h}} \gamma(h) < \zeta$.

4. The function $a : R_+^2 \rightarrow R$ is strictly concave in *h*. (A21)

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