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Information Technology, Organizational Form and Transition to the Market

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Abstract - The paper reviews theories of information technology adoption and organizational form and applies them to an empirical analysis of firm choices and characteristics in four transition economies: the Czech Republic, Hungary, Romania, and Slovakia. We argue that these economies have gone through two major structural changes — one concerning "new technology" and another concerning ownership and boundaries of firms — and we consider if and how each one of the two structural changes has affected the other. We test the impact of firm size, integration and ownership on the extent of new information technology adoption (measured by growth in the fraction of employees using personal computers or computer-controlled machinery), and the impact of information technology on changes in the boundaries and the ownership structure of enterprises, drawing upon a sample survey of 330 firms.

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1. Introduction

What kinds of firms are more likely to adopt modern information technology? Are we more likely to find information technology in large, integrated firms or in smaller, more focussed entities? Which property rights arrangements are more likely to favor the adoption of new technology? Are firms owned by employees more or less likely to adopt than firms owned by outside investors? And which kinds of firms are likely to be advantaged by the new information technology?

These questions are still very controversial. The theoretical literature leads to substantially contrasting hypotheses, and it is a fascinating empirical question to understand the real nature of the adoption process of new information technologies. The empirical question is particularly interesting in the case of the transition economies. Because of the fact that applied technology was particularly underdeveloped under socialism, transition can be seen as a twofold process: a transition to new proprietary forms plus a transition to a new type of technology, where the new information technologies are perhaps the fundamental aspect of the "technological transition." These two types of structural changes are far from being independent and the theoretical literature offers several reasons for which one type of transition can influence the other and vice versa.[1] But these mutual influences may be difficult to disentangle, particularly in a world of positive transaction costs where property rights and technology tend to fit together complementarily and to reinforce each other in a similar manner to natural species in evolutionary biology.[2] Similarly to natural species, organizational species may be defined by the characteristics of one of many possible local maxima; once organizations have reached one of these local

[1] The interdependence between ownership relations and technology is considered in Pagano (1993) and Pagano and Rowthorn (1994). The analysis of this interdependence is seen by Aoki (2001) as an early example of "institutional complementarities". According to Aoki (2000), because of a different structure of institutional complementarities, informational technology has had a remarkable impact on the relative performance of the American and Japanese economy.

[2] Recent debates in theoretical biology relate both speciation and the stability of incumbent species to the epistatic relations among genes: natural selection may have a stabilizing effect on incumbent species and new species are more likely to emerge in allopatric conditions where the pressure of competition is weaker. On the relevance of the speciation debates for evolutionary economic theory see Pagano (2001a).

peaks, the nature of technology and the features of property rights reinforce each other so that it is impossible to determine which one of them was the initial driving force that pushed the organization to that particular local peak.

Post-socialist Eastern Europe offers the possibility to test some hypotheses suggested by the theories in a setting where we can sidestep this "chicken-and-egg" problem in analyzing the relationship of technology adoption and organizational form. Our overall empirical strategy is to exploit the situation created by the rapid processes of liberalization and privatization in societies where technology and organization had been determined by central planners. We argue that this situation decouples the processes generating the key variables and provides some exogenous variation that is useful leverage in analyzing their causal influences.

The paper is structured in the following way. In the next section we discuss why it is useful to challenge the "neo-classical" "double neutrality hypothesis" according to which technology and firm organization do not influence each other. In section 3 we consider the different ways in which information technology and organisational arrangements can influence each other and we point out that predicting a change in a certain direction is tantamount to assuming that a certain set of causation flows prevails on the other. In the fourth section we draw upon recent survey data on enterprises in four transition economies to test the relationships among technology adoption decisions, firm size, integration, and ownership that are suggested by the theoretical considerations. Section 5 concludes.

2. Moving beyond the double neutrality hypothesis

In a famous passage Samuelson has argued that "In a perfectly competitive economy it doesn't really matter who hires whom...." (1975 p. 894). Samuelson's statement can be understood as a "double neutrality" that makes sense within the framework of standard neoclassical theory. On the one hand, the nature and the combinations of the factors that are employed in the firm does not have any bearing on the ownership attributes of the organization - that is technology is "neutral"

towards property rights. On the other hand, the different property rights arrangements do not bias the combinations of the factors that are employed nor their nature - that is property rights are "neutral" towards technology.[3]

This "double neutrality" assumption can only make sense in a world of zero transaction costs and symmetric information. In this case it is possible to write complete contracts that make it irrelevant who controls the firm, and technology is "neutral" in the sense that alternative technologies do not imply that owners of various factors can run the firm at different costs. At the same time, in a world of zero transaction costs and complete contracts, property rights systems are also "neutral" in the sense that they do not bias technology in a particular direction. Complete contracts make it irrelevant that the agency costs of owners are, in any case, cancelled by the facts that their objective are aligned with that of organization - a circumstance that does not hold for the non-owning factors. Thus different owners will not try to substitute away expensive non-owning factors characterised by high-agency-costs and technological choice will not be biased by the nature of property rights.

Removing the artificial assumption of complete contracts and zero transaction costs implies the collapse of the "double neutrality" that characterises the relationship between technology and ownership in standard neoclassical theory. In a world of positive transaction costs, technology can bias both the level of decentralization of property rights and their allocation to the owners of particular factors. Suppose that, because of new technology, numerous individuals have to accumulate specific and "hidden" information. In this case efficiency can be improved by giving strong incentives to these numerous individuals. The attribution of control rights to a large number of individuals can be achieved by the decentralization of production to smaller firms and/or by the attribution of stronger rights to the workers of large firms. The situation is radically different when new technology implies that few individuals should accumulate much specific and difficult to monitor human and physical capital.

[3] In the terms of evolutionary biology, the Samuelsonian statement implies that in neo-classical theory there are no "epistatic interactions" between the nature of the technology adopted and the allocation of property rights.

In this case the attribution of property rights to these individuals involves the concentration of control rights in few and possibly hierarchical firms.

However, causation can also flow in the opposite direction. The pre-existing distribution of ownership and control rights can bias the type of technology that is adopted and/or the speed by which it is adopted. When control and ownership rights are concentrated in the hands of few individuals, this may inhibit the adoption of new technologies that imply that other individuals should accumulate specific and difficult to monitor skills. By contrast when the distribution of ownership and control rights is already dispersed among small and/or non-hierarchical firms the adoption of these technologies meets fewer obstacles and it is likely to be much faster.

Thus, the abandonment of the assumption of zero transaction costs and of complete contracts implies the replacement of Samuelson's "double neutrality assumption" by a "double bias" involving the relationship between rights and technology. The two biases, characterising the relation between rights and technology, are likely to reinforce each other and cause the existence of a multiplicity of "organizational equilibria." For instance the concentration of ownership and control in the hands of few individuals makes it very costly to employ and develop other difficult to monitor and specific factors. It favours a technology which is biased in the sense of concentrating all the hidden information and specific skills in the hands of the few controlling factors. However, under this technology, in a self-reinforcing circle of cumulative causation, it is convenient that control is given to the concentrated control of these few owning factor. In this way a particular organizational equilibrium is able to sustain itself.

An alternative organizational equilibrium could have been possible, however. Suppose that a pronounced dispersion of ownership and control among many owners had initially prevailed. Under this distribution of property rights it would have been relatively cheap to choose a technology characterised by the employment of many difficult to monitor and specific skills. However under this technology the initial distribution of property rights would have been viable. Thus, via the associated

alternative technology, an initial distribution of property rights characterized by a pronounced dispersion of ownership and control could also have become a self-sustaining organizational equilibrium[4].

An assessment of the impact of information technology must necessarily deal with two complex issues. In the first place, information technology has several and somewhat contrasting implications on the distribution of property rights. In the second place, while some aspects of information technology can favour some property rights arrangements, the existence of some types of distribution of rights can, in turn, favour the adoption of (some particular aspects) of information technology.[5] Both issues are behind the hypotheses that we are going to formulate about the possible correlation between the transition to information technology and the transition to different ownership arrangements.

3. Six hypotheses on information technology and property rights

The validity of the double neutrality hypothesis that characterises neoclassical theory is itself an empirical issue that we will later examine. However, in this section we describe in more detail several possible ways in which neutrality may be violated. We consider six possible reasons why the transition to information technology and the transition to different proprietary forms may be correlated. The first three reasons suggest that small entrepreneurial firms (or firms characterised by strong employee-participation in decision making) have the most to gain from the adoption of new information technology. Such firms should more readily adopt, and the availability of new information technology is also likely to bring about an increase of the relative share of this type of firms. By contrast, the latter three reasons imply that large firms, characterized by hierarchical decision-making structures, should have

4 The multiplicity of organizational equilibria is shown in Pagano (1993) and Pagano and Rowthorn (1994). In the latter paper it is also shown that the size of the set of agency costs for which the case of multiple equilibria arise increases with the value of the elasticity of substitution among factors that is with the degree of "malleability" of technology by property rights.

5 This problem of joint determination is related to the very nature of the "epistatic interactions" defining organizational equilibria.

the most to gain from the adoption of new information technology; they should adopt more quickly, and the new information technology should, in the long run, favour the diffusion of this type of firms.

(i) The "inverted" Coasian effect

In his famous 1937 article on the nature of the firm Coase predicted that "[C]hanges like the telephone and the telegraph, which tend to reduce the cost of organising spatially, will tend to increase the size of the firm." (p. 46) Coase observed how most technological innovations caused a decrease of "both the cost of organising and the costs of using the price system" and "whether the invention tends to make firms larger or smaller will depend on the relative effect of these two set of costs" (ft. 31 p. 46). He clearly believed that in the case of telephone lines the first aspect was more relevant than the second and, therefore, the size of the firms would tend to increase with what was at that time the "new information technology". His hypothesis was that the cost reducing impact of this technology was greater on firms' hierarchies (where many hierarchical instructions could have been given very fast and relatively cheaply by phone) than on markets (where also many transactions could have been carried out at a lower cost by phone).

However, unlike the Coasian case of the telephone and telegraph lines, the more recent novelties in information technology are sometimes claimed to reduce the cost of decentralised co-ordination occurring in the market more than the cost of centralised co-ordination within firms. The impact of information technology on the development of electronic markets, where many agents interact with other agents, may be greater than its impact on the development of electronic hierarchies where a centralisation and a simplification of these interactions has already been carried out (Malone, Yates, Benjamin 1994). The shift to market relations is especially likely to occur when the introduction of centralised hierarchies has reduced co-ordination costs only at the significant expense of production efficiency. In this case information technology, reducing equiproportionately the relative impact of all types of co-

ordination costs, may imply that total costs (the sum of co-ordination and production costs) become relatively lower under market arrangements (because the absolute reduction may be greater for market than for hierarchical coordination). If this hypothesis is valid we should expect small firms relying relatively more on market transaction to have the highest incentive to adopt new technology. In the long run we should also expect small firms to increase their share of the market relatively to large firms.

(ii) Unbundling machines effect

With information technology, new machines become more easily re-programmable and, therefore, less co-specific to other machines. Decentralised ownership in this case does not cause any hold-up problem and allows an efficient flexible re-allocation of machines to their changing best uses. This is particularly advantageous for small firms which can then cooperate with other firms without incurring the traditional hold-up problems (Williamson 1985, Hart 1995). Moreover information technology may make it less expensive to check cases of equipment misuse, although the increased complexity of tasks may make such monitoring harder. If the first effect predominates, this should make it relatively cheaper to arrange rental contracts or financial support for worker-owned firms (Alchian and Demsetz 1972). The overall effect should be that small entrepreneurial firms with relatively little start-up capital should find it particularly convenient to adopt new information technology.[6] Again in the long run we should expect also that these firms that are relatively favoured by information technology should increase their share of total production.

(iii) Workers' skill effect

Re-programming machines and handling the massive information that becomes available with information technology requires many skilled tasks. Thus, information

6 Start-up firms may suffer from liquidity problems for other reasons, however. If they face higher costs of capital than do older firms and if the older technology is cheaper, then this effect may be reversed.

technology involves that workers must acquire a lot a valuable knowledge to perform their tasks. The monitoring characteristic of their work become more similar to those features of artistic and professional work mentioned by Alchian and Demsetz (1972) than to those of the easily observable assembly line workers, and the Hayek (1935) problem of transmitting hidden information becomes more acute. Moreover, relative to assembly line workers who could be easily re-allocated to other tasks, their ability may become more specific to the problems involved by some production activities. Because of the changes in the monitoring and specificity characteristics of their jobs, workers should be given high-powered incentives for their daily effort and adequate safeguards for their investment in specific human capital. Both things may be more cheaply provided within small firms where a large number of worker-entrepreneurs have high powered incentives. For these reasons we should expect that these firms should be the first ones to adopt new information technology and, in the long run, these firms should expand their share of the economy.

(iv) "Big brother watching you" effect

New information technology facilitates the monitoring of the other agents. An Orwellian "big brother watching you" world becomes feasible or much cheaper and, because of information technology, agents who cannot be easily observed under the traditional technology become "easy to monitor factors". In this case asymmetric information can be re-distributed and concentrated and some features of the traditional Fordist model can be extended beyond its traditional boundaries. Among the numerous possible examples, one is particularly striking: truck drivers were considered hard-to-monitor workers who, in absence of self-employment and truck ownership, would have taken long breaks and little care of their trucks. Satellite control and black boxes now allow employers to get detailed information very cheaply about truck drivers. Contrary to the other effects of information technology that we have examined above, in this case, the adoption of information technology is likely to be more advantageous for those firms that have large hierarchies and can

greatly save on monitoring costs by adopting this technology. Such monitoring may be less beneficial in firms with substantial employee ownership, however, if incentives tied to cash flow rights mitigate shirking problems[7]. If this is the main feature of information technology we should also expect that large, non-employee-owned firms are likely to be favoured in the long run and we should observe their share increasing over time.

(v) Information complementarities effect

Information technology is likely to increase the extent of economies to scale and complementarities both in the gathering and the use of information. Economies to scale and complementarities have always characterized these two processes. Each piece of information is more useful and often makes sense only in the context of other information. Moreover each piece of information can be used many times without additional costs. These characteristics of information can make the concentration of much information in one or few persons very productive. Each individual is characterised by bounded rationality or, in other words, by a bounded capacity to gather and process information. However, information technology can relax these constraints on bounded rationality allowing a single individual to exploit to a larger extent the economies to scale and the complementarities that characterise information. As long as this occurs the ownership of assets should follow a similar pattern. Asset owners who do not hold the information relevant for their best use should bargain with the individuals who hold this information. Thus, in the world of incomplete contracts considered by Hart (1995) and Brynyolfsson (1994), these agents would have a lower incentive to invest than the agents who control both the physical assets and the relevant information. In other words, information technology, making convenient the concentration of information in few hands, would also lead to a concentration of assets .

[7] This aspect of information technology is considered by Colombo and Delmastro (1999) in a careful study of the Italian metalworking industry. According to them information technology has increased the monitoring and coordination of top managers of large plants that have adopted a leaner kind of organization which implies a reduction of the number of hierarchical layers and an increase of subordinates for manager.

(vi) Systemic information effect

Aoki (2000) points out that headquarters of large firms may be better placed than smaller decentralized units to handle systemic environmental parameters that is on parameters that have a simultaneous effect on the costs and returns of the activities of all task units. By contrast, the latter have an obvious comparative advantage to handle the idiosyncratic environment. At least, in its early phases, information technology may increase the importance of systemic information relatively to idiosyncratic information. In particular the decisions related to information the information technology standards are based on systemic information that is better handled by the headquarters of large firms.[8]

Aoki (2000) maintains that, in early phases, (vi) may have a dominating influence. According to Hart (1995), Brynyolfsson (1994) and Barca (1994) the first set of effects (i, ii, iii) prevails over the effects (iv) and (v) and, therefore, information technology tends to cause greater disintegration and forms of dispersed worker ownership.[9] By the same argument, in the short run we should expect small entrepreneurial or workers owned firms to be more likely to adopt information technology. However, this conclusion is dubious for two reasons. In the first place we have seen that, in principle, information technology can push the distribution of information and of the physical assets both towards greater decentralization and towards greater centralization (see also Pagano 2001b and Zuboff 1988). When we consider the case of countries different from the United States, the impact of information technology is ambiguous (Carnoy 1997). Secondly, the distribution of assets cannot only be seen as a consequence of an "optimal" distribution of information corresponding to the state of technology. A (possibly inefficient) past distribution of

8 However Aoki (2000) does not apply this argument to the issue of integration and disintegration but to the specific analysis of the relative efficiency of American and Japanese firms.

9 Moreover, according to Barca (1995), information technology tends to make ownership a less efficient incentive system because, while many individuals need high powered incentives, ownership can give incentives only to few of them.

assets may influence the distribution of information and make it more convenient to apply information technology in a particular direction. In other words, the history of an economy can influence adoption decisions in the short run and the overall property rights structure of the economy in the long run.

These issues concerning the historical path of an economy are particularly relevant for transition economies where the different distribution of power that characterized the socialist economies before 1989 may have substantially influenced the initial distribution of information and the relative convenience of adoption decisions. In particular the pre-existence of the large organizations inherited from central planning may imply that the adoption decisions that are due to effects (iv) and (v) may have a weight greater than those due to effects (i), (ii), and (iii), relative to the pattern in western economies. Moreover, the theories developed in the market economy setting tend to assume that the various dimensions of organizational form – size, integration, ownership structure – tend to be highly correlated: in the simplest case, for instance, firms are either small, homogeneous, focused, and employee-owned on the one hand, or large, heterogeneous, vertically integrated, hierarchical, and investor-owned on the other.

Transition, however, has created a situation where various combinations of these attributes co-exist within particular firms. These "hybrids" may prove superior or inferior to existing "organizational species," and how they evolve may teach us something about which factors have a greater tendency to persist and thus about the nature of the path dependence in the co-evolution of technology and organization. The dynamics of post-socialist economies are interesting because firms are unlikely to have the frozen organizational type of many western organizations where each characteristic has had the time to become optimally adjusted to the other features of the firm. [10] For

[10] In evolutionary biology Kauffman (1993) points out that epistatic interactions may freeze part of the genotype so that it fails to adapt to the environment. These epistatic interactions are analogous to the complementarities that, in our framework, exist between rights and technology and may freeze the characteristics of the organizational species of the firm.

this reason, post-socialist firms may sometimes move more easily towards the highest new peaks.[11]

4. Empirical analysis of technology and organization in transition

The economic transition underway in Central and Eastern Europe provides an interesting setting for testing the empirical relationships between technology adoption and organizational form (ownership and integration) implied by the foregoing conceptual discussion. In this section, we report estimates of such relationships, exploiting the quasi-experimental nature of the economic transition and drawing upon panel data from a sample survey of some 330 enterprises in the Czech Republic, Hungary, Romania, and Slovakia. We begin by presenting our econometric framework, including a discussion of identification problems that arise in the standard market economy setting and that we argue may be mitigated in our analysis of transition economies. Next we describe our data set, and finally report estimation results.

(i) Econometric framework

The hypotheses discussed in the previous section can be summarized in three relationships:

(1) TECH = f (INTEG, OWN, X)

(2) INTEG = g (TECH, X)

(3) OWN = h (TECH, X)

where TECH refers to some measure of information technology adoption, INTEG represents a measure of integration, OWN refers to a measure of employee ownership of the firm, and X is a vector of other firm characteristics. Relationship (1) expresses the possible impact on decisions to adopt technology of organizational variables such as size, extent of integration, and ownership structure of the firm. Relationships (2) and

[11] However, the "marginal efficiency," expressed in a movement in the right direction from the bottom of a fitness valley, should not be confused with the "overall efficiency" of the actual position measured by the altitude occupied by the firm. Even when they do not tend to move towards the highest peak, Western firms are likely to show a much higher level of efficiency. Indeed, the two things may be related: a firm at a local peak may be less likely to change in the right direction than a firm in a fitness valley that requires no effort to melt the ice around a peak.

(3) focus on the possibility of reverse causality: the development of information technology may lead to changes in organization and ownership.

Clearly, a number of other factors may also be correlated with all three of the variables, thus it is necessary to control for a vector of X variables, including capital intensity and sector. But the chief problem in identifying the relationships among technology adoption, firm size and integration, and employee ownership is that these variables are themselves likely to be jointly determined, and therefore that the lines of causality may be difficult to assess. For instance, adoption may be greater in smaller, less integrated firms with substantial employee ownership, but the presence of the technology may itself encourage disintegration and the development of profit-sharing and employee participation. This would imply that the residual in the empirical equation that is the counterpart to (1) would be correlated with the independent variables. To take another example, firms may be more likely to be started-up as cooperatives in niches where capital requirements and therefore minimum efficient scales are low and information technology has either high or low productivity, depending on the relative importance of the hypotheses outlined above. Technology, integration, and ownership could all be endogenous, rendering it difficult to test any particular hypothesis about their relationships. In the long-run, when ownership and the boundaries and technologies of firms have been optimally adjusted, one might observe no relationship among these factors whatsoever.

The transition context may be helpful for disentangling the relationships, however, because each of the variables may be treated as approximately exogenous at the beginning of the transition situation. Under the socialist system, the technology used by a firm and its size and degree of integration were determined by central planners, with rather little attention to the mechanisms discussed in Section 3 above.[12] The ownership structure in the early transition period was determined by privatization programs designed to transfer property quickly under political constraints that again

[12] Kornai (1992), for instance, discusses the determination of technology, integration, and firm size under central planning.

admitted little concern for the possibility of optimal combinations of technology, integration, and ownership. In particular, politically driven insider privatization led to workers becoming dominant owners of large, integrated, capital-intensive, hierarchically organized manufacturing firms.[13]

Our empirical strategy is therefore to examine the change over some period in each dependent variable as a function of the level of the independent variable(s) measured prior to the period. For this purpose, information on individual firms is essential as inferences drawn from aggregate sectoral data could be confounded by essential technological differences. Finally, assuming linear relationships, our estimating equations take the following form:

(1') $\Delta TECH_{ti} = \alpha_0 TECH_{si} + \alpha_1 INTEG_{si} + \alpha_2 OWN_{si} + \alpha_3 X_i + \varepsilon_i$,

(2') $\Delta INTEG_{ti} = \beta_0 INTEG_{si} + \beta_1 TECH_{si} + \beta_2 X_i + \upsilon_i$, and

(3') $\Delta OWN_{ti} = \gamma_0 OWN_{si} + \gamma_1 TECH_{si} + \gamma_2 X_i + \omega_i$,

where Δ refers to a change in the level of the corresponding variable, *t* is the "transition time period," *s* is the "socialist or early post-socialist time" (with $s < t$), *i* indexes firms, X is a vector of control variables (including a constant term), and ε, υ, and ω represent the effects of unobservables. The parameters α_0, β_0, and γ_0 capture the effect of the inherited levels of the dependent variables. Our claim is that the parameters of interest (α_1, α_2, β_1, and γ_1) are identified because the processes determining the level of TECH, INTEG, and OWN at time *s* – central planning and the immediate post-socialist policies – are different from the processes determining TECH, INTEG, and OWN by time *t* – the impact of transition to the market.

(ii) Data and measures

To test the relationships, we draw upon panel data from a sample survey of enterprises in the Czech Republic, Hungary, Romania, and Slovakia. The data, described more fully in Earle *et al* (1999), are based on in-depth surveys conducted several times during the 1990s, and include information on technology, ownership,

[13] See, e.g., the articles in Earle *et al* (1993) for description of the design of privatization policies.

and boundaries of the firm. The sample covers a wide range of sectors, as shown in Table 1, with an emphasis on manufacturing industries. Because production functions differ across sectors, it is essential to control for sector when examining the relationships among the variables of interest, but it should be pointed out that the estimated effects combine those of a number of other factors, including product market structure, size, and location. We pool the Czech and Slovak samples because of the small size of the usable Slovak data set (11 firms) and because the origins and policy environment are most similar between these two countries.

Table 2 provides variable definitions and Table 3 shows descriptive statistics for employment size, capital intensity, geographic location, and our measures of the dependent variables. The size measure is employment in 1994 (Emp94), and the table shows that most firms in the sample are medium size. Capital intensity is captured by the ratio of the book value of plant and equipment to revenue in 1994 (Assets/Rev94), and the geographic variable is location in the capital city of the country (Capital).

Measuring technology adoption is difficult, because of the several types of technologies that could be considered and the essentially qualitative nature of many forms of technological improvement. The problem is particularly severe in a sample covering a diverse range of industries, although even a narrowly defined sector may have several types of new technologies from which to choose. The measure of TECH we employ in this paper, and which is shown in Table 3, is the proportion of employees "who in most of their working time used personal computers, information technology or computer controlled machinery in their work," as stated in the survey question (which is also accompanied by an instruction not to include "computers working with the old card-based technology"). The mean of this variable across all firms rose from .02 in 1989 to .1 in 1994 and .17 in 1998, showing rapid spreading of the new technologies. The firms show significant variance in the extent of adoption, with some close to zero and other near 100 percent in each of the countries.

The theoretical arguments about technology and ownership usually focus on issues of employee ownership and participation, where the implicit comparison is

generally with the publicly traded, investor-owned corporation. In the transition context, one must take into account two additional factors. First, in a situation where the institutions of private property are poorly developed, employee owners may have weak control rights in transition economies (see, e.g., Earle and Estrin , 1996, for a discussion). Second, there is an important role for continued state ownership in many companies, as the state may behave differently compared to either insiders or outside investors, and state ownership may have different complementarities with technology and other aspects of organization.

Table 3 includes measures of the percentage of shares held both by inside owners (InsOwn) and private outside owners (OutOwn) of all types (foreign, domestic, individual, etc.), while the residual category is the state. All the firms in the sample were 100 percent state-owned in 1990 but nearly all had been privatized by 1995, and the residual state shareholding was low by 1998. The insider-outsider mix varies considerably, however, with the highest rate of employee ownership in Romania, the lowest in the Czech Republic and Slovakia, and Hungary in the middle. As discussed above, the ownership structures in 1994 were the outcome to a considerable extent of politically driven privatization policies, and much less so of the conventional market forces that would imply joint determination of the variables.

The share of material costs in total costs (MatCost95 and MatCost98 for 1995 and 1998, respectively) is employed as one measure of the extent of vertical integration. The Czech and Slovak firms appear to be the least integrated (material costs account for about 60 percent of all costs, while they are only about 40 percent in the Hungarian and Romanian sample). The overall trend is slightly towards more integration (from 49 to 47 percent), by this measure. We also use the number of production establishments in 1995 and 1998 (ProdEstab95 and ProdEstab98) as a proxy for the extent of integration. By this measure, the extent of integration slightly declined.

BoundChange measures the proportion of 1994 employment lost as the result of a split-up or gained as a result of a merger during the 1995-98 period, while Split

and Merger are the corresponding dummy variables. Nearly a quarter of the Czech-Slovak and Hungarian firms split-up during this period, but the proportion was only half as great in Romania. Mergers were as common as split-ups in Hungary, and in magnitude of employment change apparently outweighed the split-ups in size, but mergers were few in the Czech and Slovak Republics and non-existent in Romania.

(iii) Results

The results from estimating alternative specifications of equations (1'), (2') and (3') are shown in Table 4.[14] Less integrated firms, as measured by both our indicators, material cost intensity (MatCost95) and fewer production establishments (ProdEstab95), are more likely to adopt information technology (that is, to increase the fraction of employees working with computers, ΔTech) between 1994 and 1998 in these data. The estimated effect of the MatCost95 measure is statistically significant by conventional criteria (at the 5% level, with a one-tailed test), but the effect of ProdEstab95 is not precisely estimated. Thus, the data support the hypothesis of a negative association between technology adoption and firm integration, consistent with effects (i) and (ii) in Section 3, above, and indeed they suggest that technology may reduce integration.

On the other hand, technology adoption is strongly related to capital intensity (Assets/Rev94), which could be consistent with effect (iv) if the presence of more capital increases the return to monitoring workers. The estimated coefficient on the size variable, Ln(Emp94), is tiny and statistically insignificant, so there is little support for effects (v) and (vi). The results for the ownership variables imply that privately owned firms, whether inside- or outside-dominated, are also more likely to adopt, with no difference between them; this is consistent with a corporate governance interpretation, whereby new investments and innovations are more likely

[14] Because of an inconsistent pattern of missing values across variables, which results in slightly different samples for each equation, we also re-estimated all equations with a common sample, obtained by imputing missing values at their sample means; the estimates were quite similar to those reported in Table 4.

to be undertaken under private ownership, and it does not support the implication of effect (iii) that worker ownership might lead to greater adoption (relative to outside ownership).[15] The strong relationship of adoption with location in the capital city of the country is probably indicating higher levels of product demand, while the statistically insignificance and small magnitude of the estimated country effects implies that the control variables (including industry controls) have accounted for the cross-country variation.

Looking at the opposite direction of the relationships, insider ownership changes (ΔInsOwn) are estimated to be negatively related to prior level of computerization. This result implies that computerization tends to reduce worker ownership and again contradicts effect (iii), but the coefficient on Tech94 is imprecisely estimated, preventing us from drawing firm conclusions. The change in the number of plants (ProdEstab) is weakly related to prior computerization, while the probability of a split (Split) between 1994 and 1998 is more strongly related, and statistically significant.[16] The data thus provide some evidence that the extent of computerization works to dis-integrate firms, reducing the number of plants and encouraging splitups. Other dependent variables yield results that are consistent in their direction, although the results are not statistically significantly different from zero: the estimated coefficients on Tech94 are negative in the equations for BoundChange, ΔMatCost, and Merger.

Thus, the data provide some evidence that disintegration may be encouraged by information technologies, a result that is consistent with the inverted Coasian and unbundling machines effects discussed in section 3, above, and it appears to be inconsistent with the workers' skills, big brother and information context effects, as well as the neoclassical neutrality of technology with respect to firm organization.

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[15] We also estimated a version of this equation in which outside ownership is disaggregated into several categories; in this specification, the strongest impact is estimated to arise from foreign ownership (with a coefficient of .033 and a t-value of 1.84).

[16] The marginal effects are shown in the probit estimation results, implying that a 10 percent increase in COMP94 implies an approximate 3 percent increase in the probability of a splitup in the subsequent years.

The data also provide some evidence of reverse causation, from lower levels of integration towards technology adoption. These effects are mutually reinforcing, suggesting that less integrated firms are more likely to adopt technology that will continue to lead to their further unbundling. The weak relationship of technology with firm ownership may possibly reflect the lack of control rights usually associated with employee ownership in the post-privatization environment of Eastern Europe. In any event, the evidence strongly contradicts the hypothesis of neoclassical neutrality with respect to the association of technology and integration of firms.

5. Conclusion

Economic theory implies several alternative hypotheses about the relation between "organizational species" (Pagano 2001a) and decisions on adoption of information technology. The transition setting is particularly exciting, both because the transition has thrown up new hybrid organizational forms and because the pre- and early transition processes generating technology and organizations creates some exogenous variation in these variables, thus generating a "quasi-experiment" that helps us to sort out the lines of causality (Meyer 1995).

Our analysis exploits this situation in which property rights and technology have not had yet the time to adjust optimally to each other and freeze organizational types. The empirical results suggest that both that less integrated firms are more likely to adopt information technology and that firms with more of such technology tend to become less integrated. We also find that private ownership tends to encourage adoption, although the effect is equally strong for private outside as for private inside ownership. These findings are inconsistent with the neoclassical neutrality of technology and organization, and they are consistent with the idea that technology adoption and lower firm integration tend to be mutually reinforcing.

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Table 1
Distribution of Firms by Branch

	Czech and Slovak Republics		Hungary		Romania		All	
	N	%	N	%	N	%	N	%
Food	19	13.57	28	28.57	18	18.37	65	19.35
Light industry	28	20.00	23	23.47	20	20.41	71	21.13
Heavy processing	30	21.43	26	26.53	5	5.10	61	18.15
Machines	46	32.86	19	19.39	0	0.00	65	19.35
Construction	9	6.43	1	1.02	28	28.57	38	11.31
Services	4	2.86	0	0.00	27	27.55	31	9.23
Other	4	2.86	1	1.02	0	0.00	5	1.49
Total	140	100.00	98	100.00	98	100.00	336	100.00

Table 2
Variable Definitions

Continuous Variables	
Tech94, Tech98	Proportion of employees working with personal computers, information technology or computer-controlled machinery, 1994 and 1998.
ΔTech	Change in the proportion of employees working with personal computers, information technology or computer controlled machinery, between 1994 and 1998 (Tech98 – Tech94).
InsOwn94, InsOwn98	Proportion of insider ownership in 1994 and 1998.
ΔInsOwn	Change in the proportion of insider ownership, between 1994 and 1998 (InsOwn98 - InsOwn94).
OutOwn94	Proportion of outsider ownership in 1994.
MatCost95, MatCost98	Proportion of material costs in total costs, 1994 and 1998.
ΔMatCost	Change in the proportion of material costs in total costs, between 1995 and 1998 (MatCost98 – MatCost95).
ProdEstab95, ProdEstab98 (No.)	Number of production establishments (plants), 1995 and 1998.
ΔlnProdEst	Change in the logarithm of the number of production establishments, between 1995 and 1998 [ln(ProdEstab98) – ln(ProdEstab94)].
BoundChange	Ratio to 1994 employment of employees lost as a result of split-up or gained as a result of merger during 1995-1998.
Emp94 (No.)	Total employment, 1994.
Assets/Rev94	Ratio of book value of production assets (plant and equipment) to sales revenues, 1994.
Dummy Variables	
Split	Occurrence of a split-up in period 1995 – 1998 (= 1 if yes, 0 if no).
Merger	Occurrence of a merger in period 1995 – 1998 (= 1 if yes, 0 if no).
Capital	Location of the firm, = 1 if located in the capital, 0 otherwise.

Table 3
Descriptive Statistics

	Czech and Slovak Republics			Hungary			Romania			All		
	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N	Mean	Std Dev	N
Continuous Variables												
Tech94	0.15	0.12	88	0.10	0.13	87	0.06	0.14	94	0.10	0.13	269
Tech98	0.27	0.19	87	0.17	0.15	85	0.10	0.15	94	0.18	0.18	266
InsOwn94	0.12	0.29	80	0.39	0.40	94	0.68	0.43	97	0.41	0.44	271
InsOwn98	0.07	0.21	85	0.30	0.39	87	0.73	0.36	96	0.38	0.43	268
OutOwn94	0.67	0.39	78	0.48	0.42	98	0.04	0.09	96	0.38	0.42	272
MatCost95	0.48	0.18	55	0.60	0.16	82	0.40	0.26	86	0.50	0.22	223
MatCost98	0.43	0.20	67	0.59	0.15	79	0.40	0.25	87	0.47	0.22	233
ProdEstab95 (No.)	2.13	2.94	93	2.47	2.42	87	3.24	4.31	97	2.62	3.38	277
ProdEstab98 (No.)	1.61	2.13	93	2.38	2.29	85	3.14	4.39	97	2.39	3.21	275
BoundChange	-0.07	0.23	85	0.12	1.10	82	0.02	0.12	97	0.02	0.63	264
Emp94 (No.)	663.72	913.86	134	566.79	504.82	98	615.79	1216.83	98	620.70	922.46	330
Assets/Rev94	3.57	21.85	75	0.39	0.32	76	0.55	0.83	84	1.46	12.38	235
Dummy Variables												
Split	0.22		93	0.23		84	0.11		97	0.18	0.39	274
Merger	0.04		92	0.23		84	0.00		97	0.08	0.28	273
Capital	0.11		140	0.14		98	0.21		98	0.15	0.36	336

Table 4
Regression Results

Dependent variable	**ΔTech**		**ΔInsOwn**		**ΔlnProdEst**		**ΔMatCost**		**BoundChange**		**Split**		**Merger**	
(Estimation method)	(OLS)		(OLS)		(OLS)		(OLS)		(OLS)		(probit)		(probit)	
Independent Variables	coeff	t	coeff	t	coeff	t	coeff	t	coeff	t	marg effect	t	marg effect	t
Tech94	-0.022	-0.57	-0.115	-0.79	-0.233	-1.32	-0.001	-0.01	-0.091	-0.94	0.259	1.73	-0.002	-1.03
InsOwn94	0.019	1.59	-0.349	-6.83										
OutOwn94	0.019	1.26												
Ln(ProdEstab95)	-0.006	-1.09			-0.199	-7.58								
MatCost95	0.042	1.75					-0.192	-4.54						
Ln(Emp94)	0.003	0.68	-0.006	-0.26	0.056	2.42	-0.010	-1.10	0.018	1.37	0.057	2.26	0.000	2.44
Assets/Rev94	0.002	7.88	-0.001	-0.54	0.001	0.57	-0.010	-2.33	0.001	0.59	-0.019	-0.71	-0.000	-0.89
Capital	0.027	2.24	-0.011	-0.21	0.097	1.59	-0.006	-0.25	-0.009	-0.25	-0.038	-0.59	0.000	0.35
Czech-Slovak	0.015	0.85	-0.293	-3.83	-0.147	-2.24	-0.024	-0.84	-0.861	-2.11	0.126	1.47	0.762	4.13
Hungary	0.012	1.00	-0.317	-5.85	-0.015	-0.27	0.051	2.13	-0.007	-0.19	0.109	1.49	0.710	5.43
Constant	-0.002	-0.07	0.421	2.94	-0.128	-0.95	0.141	2.45	-0.094	-1.14				
Adj R^2	0.39		0.26		0.23		0.14		0.09		0.13		0.27	
N	161		190		196		198		213		217		164	

Note: The regressions also include controls for 7 industry categories. "Marg effect" refers to marginal effect of a change in the independent variable.