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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 technology and another concerning ownership and boundaries of firms – and we consider if and how each 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.

JEL: P1, P5, L2, O3

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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 and corporate governance 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 most likely to gain from the new information technology?

These questions are very controversial. The theoretical literature leads to substantially contrasting hypotheses, and it is a fascinating empirical question to understand the 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 and organizational 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 may tend to fit together complementarily and to reinforce each other.

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

[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 economies.

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 organizational 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 survey data from 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 by considering some policy implications of our finding that the direction of causation running from ownership and organization form turns out to be stronger than the reverse.

2. Moving beyond the double neutrality hypothesis

In a famous passage Samuelson has argued that “[i]n a perfectly competitive economy it doesn’t really matter who hires whom....” (1957, 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 do not have any bearing on the ownership attributes of the organization (i. e. 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 (i. e. property rights are “neutral” towards technology).

This “double neutrality” assumption can only make sense in a world of zero transaction costs and symmetric information. 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. In this case, the attribution of property rights to these individuals involves the concentration of control rights in few hands and possibly in 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 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 possible "double bias" involving the relationship between rights and technology. The two biases characterizing the relationship between rights and technology may reinforce each other and bring about a multiplicity of "organizational equilibria." For instance, the concentration of ownership and control in the hands of few individuals makes it costly to employ and develop other difficult-to-monitor and specific factors. It biases the technology in the sense that it favors the concentration of the difficult-to-monitor and specific-skill characteristics in the few controlling factors. However, under this "biased technology," in a self-reinforcing circle of cumulative causation, it is convenient that control is given to these few factors because they can save the most in monitoring and specificity-insurance costs if they control the organization. In this way a particular organizational equilibrium may be 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 characterized by the employment of many difficult-to-monitor and specific skills. Under this technology, however, 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.[2]

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

3. Two Opposite Biases and the Neutrality Hypothesis

In a world of positive transaction costs, the transition to information technology and the transition to different proprietary forms may be correlated. However, one may advance two different hypotheses. On the one hand, it may be that small entrepreneurial firms and firms characterized by strong employee-participation in decision making have the most to gain from the adoption of new information technology. On the other hand, it could be the case that large firms, characterized by hierarchical decision-making structures, have the most to gain from the adoption of new information technology. It is an open issue which types of firms would adopt more quickly, and which firms the new information technology should, in the long run, favor.

[2] 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. It is an interesting empirical question – that we are examining in this paper – whether this malleability exists in reality and whether property rights have a relevant influence on technology adoption.

Analysis of these issues can be traced as far back as Coase's famous 1937 article on the nature of the firm, which predicted that "[C]hanges like the telephone and the telegraph, which tend to reduce the cost of organizing spatially, will tend to increase the size of the firm." (p. 46) Coase observed that most technological innovations caused a decrease of "both the cost of organizing 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 sets of costs" (ft. 31 p. 46) [3]. He clearly believed that in the case of telephone lines the first aspect was more relevant than the second and, therefore, the size of 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 centralized 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 centralization 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 centralized hierarchies has reduced co-ordination costs only at the significant expense of production efficiency. In this case information technology, if they equiproportionately reduce 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 transactions to have the highest incentive

[3] Similar issues have re-emerged in the technical literature dealing with IT. See, for instance, Attewell and Rule 1984, George and King 1991, Malone 1997).

to adopt new technology. In the long run, we should also expect small firms to increase their share of the market relative to large firms.

A similar conclusion may be reached when one refers to the unbundling and self-monitoring properties of the machines built using modern information technology. With information technology, new machines become more easily re-programmable and, therefore, less co-specific to other machines. Decentralized 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 also 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.[4] Again, in the long run, we should expect also that these firms that are relatively favored by information technology will increase their share of total production.

A final argument pointing in the same direction concerns the skill requirements associated with the adoption of information technology. Re-programming machines and handling the massive information that becomes available with information technology requires many skilled tasks. Thus, information technology involves workers acquiring much valuable knowledge to perform their tasks[5]. The monitoring characteristics 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

[4] 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.
[5] Krueger (1993) provides some evidence on the skilling effects of computers.

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.

There are, however, counterarguments implying that information technology is more easily adopted by and favors the economic development of large organizations. To start with, new information technology facilitates the monitoring of other agents. An Orwellian "big brother watching you" world becomes feasible – or much cheaper – and information technology may change agents who cannot be easily observed under the traditional technology into "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 indulged in long breaks and neglected the care of their trucks. Satellite control and black boxes now allow employers to get detailed information about truck drivers very cheaply. The adoption of information technology in this case is likely to be more advantageous for those firms that have large hierarchies and can greatly save on monitoring costs by adopting this technology.[6] 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-

[6] This discussion emphasizes the monitoring aspects of the "on-board computers". Baker and Hubbard (2002) point out that there may also be effects on coordination in the trucking industry.

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

owned firms are likely to be favored in the long run, and we should observe their share increasing over time.

This somewhat Orwellian argument may also be supported by the observation that information technology is likely to increase the extent of economies of scale and complementarities both in the gathering and the use of information. Economies of 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 characterized by bounded rationality or, in other words, by a bounded capacity to gather and process information. Information technology, however, can relax these constraints on bounded rationality, allowing a single individual to exploit to a larger extent the economies of scale and the complementarities that often characterize the production and the use of information. 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, if, under a regime of strong economies of scale and complementarities in the use and the production of technology, information technology raises the returns to concentrating information in few hands, it would also lead to a concentration of assets.[8]

A related argument is offered by Aoki (2000), who points out that headquarters of large firms may be better placed than smaller decentralized units in observing and responding to systemic environmental 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 relative to idiosyncratic information. In

[8] However, in general, when pronounced complementarities and economies to scale do not favor a further concentration of decision-making power, the relaxation of the bounded rationality requirements, due to IT, has the traditional effect of favoring markets over hierarchies (Williamson 1985).

particular, the decisions related to information technology standards are based on systemic information that may be better handled by the headquarters of large firms.[9]

Which of these various mechanisms, each of which has some intuitive plausibility, tends to dominate empirically? Aoki (2000) maintains that, at least in the early phases, systemic information may have a dominating influence. According to Hart (1995), Brynyolfsson (1994) and Barca (1994), however, the disintegration bias prevails: information technology tends to cause greater disintegration and forms of dispersed worker ownership.[10] By the same argument, in the short run we should expect small entrepreneurial or worker-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 2001 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 be seen only as a consequence of an "optimal" distribution of information corresponding to the state of technology. A (possibly inefficient) past distribution of 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 technology and the factors influencing adoption decisions. In particular, the pre-existence of the large organizations inherited from central planning may imply that the adoption decisions that are integration-biased may have a weight greater than those requiring disintegration, relative to the

[9] Aoki (2000), however, does not apply this argument to the issue of integration and disintegration in general but to the specific analysis of the relative efficiency of American and Japanese firms.

[10] 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 only give incentives to a few of them.

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 worker-owned (entrepreneur- or group-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. The dynamics of post-socialist economies are interesting because firms are unlikely to have their characteristics determined by some long-run optimal adjustment to the other features of the organization, which thus cannot easily be changed, independent of the other characteristics. Transition economies may therefore provide a useful setting to test both the possibilities of an "integration" or of a "disintegration" bias of new information technology as well as the null hypothesis of "double neutrality" that would stem from conventional neoclassical theory.

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) Hypotheses and econometric framework

Our hypotheses in this paper concern, first, the correlation of information technology adoption with the boundaries and ownership of the firm and, second, the direction of causality between technology adoption and organizational characteristics. The possible causal relationship running from organizational form to technology can be summarized in the following simple expression:

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

where TECH refers to the extent of information technology adoption, INTEG represents the degree of firm integration, OWN refers to some aspects of ownership of the firm (private and inside ownership), and X is a vector of other firm characteristics. Relationship (1) expresses the possible impact on decisions to adopt technology of organizational form, including the extent of integration and the ownership structure of the firm. The specific measures of these variables are discussed in the next subsection.

As discussed previously, there is also a possibility of reverse causality: the development of information technology may lead to changes in organization and ownership. These are summarized in the following expressions:

(2) INTEG = g (TECH, X)

(3) OWN = h (TECH, X)

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 start 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.[11] The ownership structure in the early transition period was determined by privatization programs designed to transfer property quickly under political constraints that again 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.[12] Does private ownership increase technology adoption, and which types of private owners are more likely to use the new information technologies? The conceptual discussion suggests a focus on insider ownership – where we distinguish ownership held by employees collectively from direct worker and managerial ownership, as described below - and we also consider foreign owners separately, as these generally represent large, integrated multinational companies that may have superior access to the latest technological advances.

Our empirical strategy is 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.

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

[12] See, e.g., the articles in Earle, Frydman, and Rapaczynski (1993) for descriptions of the initial design of privatization policies in these countries.

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 "beginning of transition" (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. In the empirical work, we generally specify period s as the year 1994 (with some variation due to data availability), while t represents 1998, so that Δ is the change between these two years. 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 ΔTECH, ΔINTEG, and ΔOWN 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 are based on in-depth surveys conducted several times during the 1990s, and they include information on technology, ownership, and boundaries of the firm. The sample covers a wide range of sectors, as shown in Table 1, with an emphasis on manufacturing industries.[13] 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 sectoral 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

[13] The samples were drawn from lists of privatized joint-stock companies.

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. Data are pooled across countries because our hypotheses in this paper do not concern cross-country differences in behavior, and, in any case, the sample sizes are too small to permit us to investigate such differences with this database.[14] As discussed in the previous section, we define the initial period *s* as the year 1994 for most variables, the transition period *t* as 1998, and the change therefore as the difference in a variable measured in each of these two years. To some extent data limitations prevent us from measuring variables earlier than 1994, but we also prefer 1994 as a starting date because it includes early transition period decisions concerning ownership, allocation of investment, and firm organization that were taken by governmental agencies. Firms were only gradually acquiring autonomous decision-making during this period, and they were being privatized, reorganized, and given financial resources by government decisions.

The size measure in our analysis 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), used as a control for the advantages of areas with strong demand conditions and better supplies of skilled workers able to work with new information technologies.

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 is the proportion of employees "who in most of their working time used personal computers,

[14] Moreover, standard tests for structural change fail to reject pooling of the data across countries. Taking the first specification reported in Table 4 as an example and testing for pooling of each pair of countries yielded F-statistics of 1.30, 0.82, and 0.67, in each case far below the critical F value for statistically significant differences.

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, as shown in Table 3, rose from .10 in 1994 and .18 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 others near 100 percent; moreover, nearly all the firms (over 90 percent of them) change their level of computerization from 1994 to 1998.

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 some additional factors. First, it is necessary to distinguish between different types of employee ownership resulting from privatization, including direct shareholding by managers and workers, separately, and collective shareholding through an "employees' organization" that exercises control rights on behalf of employee-owners. All three of these ownership types are quite common in the post-privatization transition environment, and our data permit us to measure them.[15] Second, the state has continued to keep shares in many "privatized" companies, which is important to take into account, 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. Finally, we distinguish domestic private and foreign owners, as the latter tend to be large, highly integrated multinational corporations, thus occupying the extreme position both in the extent of outside ownership and on the "make" end of the "make or buy" dimension. A confounding possibility is that foreign owners may have better information about and lower cost access to new technologies.

In our empirical strategy for estimating the effects of ownership on technology adoption, we specify dummy variables related to dominant ownership of each of these types

[15] The collective ownership form was encouraged in Hungary and Romania by privatization programs that granted special facilities (reduced prices and installment payments with negative real interest rates) to employees forming such organizations. The varieties of insider ownership in several East European economies are discussed in Earle and Estrin (1996), who point out that employee owners may have weak control rights when the institutions of private property are poorly developed.

(private versus state, insider versus outsider, individual manager versus individual worker versus collective insider, and domestic outside investor versus foreign outsider), following much of the transition literature on privatization and ownership issues (e.g., Earle and Estrin, 1996). Dominant ownership is defined as the largest type in any particular comparison, with ties broken in favor of the state, insiders, managers, and domestic investors in each of the comparisons. In estimating the effects of technology on insider and collective ownership, however, we define the variables as shares.[16] The mnemonics for all the ownership variables are again defined in Table 2, and Table 3 provides descriptive statistics.[17] 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. Also useful, from the econometric point-of-view, is that all types of ownership are significant in the data, and all vary substantially across the firms in the sample.

The level and change in vertical integration are difficult concepts to measure, so we employ two alternative variables for the level and three for the change. First, the share of externally purchased material costs in total costs (MatCost95 and MatCost98 for 1995 and 1998, respectively) shows the extent to which inputs are made or bought: more integrated firms should have a lower cost share due to purchased materials. With substantial variation across firms, the overall trend shown in Table 3 is very slightly towards more integration (from 49 to 48 percent), by this measure. Second, the number of plants (production establishments) in 1995 and 1998 (Plants95 and Plants98) proxies for the extent to which the firm combines different activities, providing an alternative measure of integration. By this measure, the extent of integration declined, but again very slightly (2.73 to 2.52, on average). Finally, the occurence of a split-up of the legal entity from 1995 to 1998 (Split in Tables 2

[16] In earlier versions of the paper, we employed variables representing ownership shares by type rather than the dummy variables for dominant ownership adopted here. The results for these variables are qualitatively very similar.

[17] The data do not permit us to measure separately the share of managers' and workers' shares held collectively, but the nature of the privatization process encouraged egalitarian distribution of shares acquired through the collective organization; thus we can assume that they are predominantly held by workers.

and 3) measures disintegration, and our data show that nearly one-fifth of the firms engaged in such a reorganization.[18]

(iii) Results

The results from estimating alternative specifications of equations (1') are shown in Table 4.[19] Sample firms that are less integrated by both our indicators – material cost intensity (MatCost95) and fewer plants (Plants95) – 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. In the first two specifications shown, each of these variables is included separately, and the estimated effect of Plants95 is statistically significant at the 5 percent level, and that of MatCost95 at the 10 percent level. When both variables are included in the same specification (the third column of results), MatCost95 increases and Plants95 loses significance, and the estimated coefficients are only slightly changed. The implied magnitudes are economically meaningful, particularly for material costs: a one standard deviation increase in MatCost95 is estimated to raise the proportion of employees who are computer-users by about 10 percentage points compared to its average initial level. Given that the mean of Tech94 is only 9 percent, this represents an implied effect of greater than doubling of computer usage for an average firm.

Overall, therefore, the data support the hypothesis of a negative impact of firm integration on information technology adoption. Size *per se*, however, appears to matter very little, as the coefficients on Ln(Emp94) are always tiny and statistically insignificant. The effect of capital intensity, while statistically significant, is estimated to be very small in magnitude.[20]

The results for the ownership variables are shown in the rightmost three columns of the table. Our analysis implies that private ownership tends to raise adoption, which is

[18] We initially intended to investigate merger activity as well, but there were too few cases in our data (9 total) to permit this analysis.
[19] Because of an inconsistent pattern of missing values across variables, which results in somewhat 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 qualitatively quite similar to those reported in Table 4.
[20] A referee suggested we estimate these equations with the sample restricted to firms that do not split up between 1994 and 1998. The results are nearly identical for MatCost95, but the effect of Plants95 is somewhat reduced.

consistent with a corporate governance interpretation, whereby new investments and innovations are more likely to be undertaken under private ownership. Interestingly, the estimated effects of DInsOwn94 and DOutOwn94 are nearly identical, although the former has greater statistical significance, implying a larger standard error and somewhat more variation among different types of outside ownership. Considering the disaggregated ownership categories, in the final column of results in the table, the analysis provides strong support for both collective inside ownership and foreign ownership in spurring computerization. The first finding is consistent with the view that incentives in closely held insider organizations are complementary with new technology adoption, while the second finding supports the notion that foreign investors bring new technologies with them.[21]

Concerning the results for the control variables, the strong relationship of adoption with location in the capital city of the country could be due to higher levels of product demand, greater availability of skilled labor, or possibly some "digital divide" between city and countryside. The positive effect of capital intensity is consistent with capital-skill complementarity or greater returns to computer usage in more capital-intensive production settings. The statistical insignificance and small magnitude of the estimated country effects imply that the control variables have accounted any cross-country variation in the unconditional mean of ΔTech.

Our estimations of equations (2') and (3'), the opposite direction of the relationships, are shown in Table 5. By contrast with the evidence of a positive effect of lower integration and greater (collective) employee ownership on technology adoption, there is comparatively weak evidence of technology effects on organization form and ownership. The estimated effects of the prior level of computerization (Tech94) on changes in total insider ownership (ΔInsOwn) and collective ownership (ΔColOwn) are estimated to be negative, which would imply the opposite correlation to those in Table 4, but the coefficients are statistically insignificant. The change in the natural logarithm of the number of plants (ΔlnPlants) is very weakly related to prior computerization, as is ΔMatCost. Only the probability of a split

[21] We have also re-estimated these equations with Plants95 and MatCost95 entered separately. The estimated coefficients were qualitatively similar to those in the Table.

(Split) between 1994 and 1998 is strongly related, and the coefficient statistically significant.[22] The data thus provide some evidence that the extent of computerization works to disintegrate firms by encouraging split-ups. 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 ΔMatCost, and ΔlnPlants.

To summarize, the results provide evidence that less integrated firms and those with more collective employee ownership tend to adopt new information technologies more readily. Evidence for the reverse relationship is much weaker, although the data do imply that information technology increases split-ups. These effects are mutually reinforcing, providing some suggestion that less integrated firms are more likely to adopt technology that will continue to lead to their further unbundling. The other hypotheses concerning reverse causation find less support, as there is no significant impact of technology on the number of plants, the extent to which material inputs are purchased externally, nor on inside and collective ownership. 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 relationship between organizational typologies and decisions on adoption of information technology. The transition setting is particularly exciting, both because the transition has thrown up new 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 yet had the time to adjust optimally to each other and freeze organizational types. The empirical results suggest both that less integrated firms are more likely to adopt information

[22] The marginal effects are shown in the probit estimation results, implying that a 10 percent increase in COMP94 implies an approximate 2.3 percent increase in the probability of a split-up in the subsequent years.

technology and that firms with more such technology tend to split up, thus becoming less integrated. Contrary to a number of theoretical arguments, the data provide no support for the hypothesis of a positive correlation of integration and information technology adoption, due either to a higher adoption rate among more integrated firms or a greater tendency towards integration among firms that are more IT-intensive. We also find that private ownership tends to encourage adoption, with the effect strongest for collective insider and foreign 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 may have some mutually reinforcing tendencies.

Perhaps the most interesting implication of our analysis stems from the finding that the relationship running from ownership, organization, and integration to IT adoption turns out to be stronger than the reverse. In the opposite case, one could have argued that, as long as modern technologies tend to diffuse widely across countries, country-specific institutional characteristics should not be very relevant. The spread of common technologies would eventually tend to bring about a growing uniformity in the ownership and organizational structures of each country. By contrast, our results support the hypothesis that the characteristics of the prevailing ownership and organizational forms may be crucial for the adoption of new technologies and, as a consequence, for economic development.

Do these results have implications for policy choices in other countries? One problem in the past is that there was relatively little that could be learnt from policies consciously aimed at improving ownership and control arrangements. It can difficult to infer lessons precisely because the intentionality in the policy design means that the choice was endogenous, and therefore causality is ambiguous. In many cases, however, such as the introduction of the public company in the U.S. (Roe 1994) and the keiretsu in Japan (Barca, Iwai, Pagano, and Trento 1999), the successful new economic institutions came about as the unintended consequences of major economic and political shocks.

We have argued that the case we study – the transition from socialism – provides a particularly useful example of unintended consequences. The ownership and organizational arrangements inherited from central planning and determined for political reasons in the very early transition years were not chosen to enhance the capability to adopt new innovative technologies. Yet we have shown that those organizational considerations carried important consequences for IT adoption. This could still be taken into account by the policy makers of countries such as some of the former Soviet Republics, or even Iraq, that are still undergoing major changes of their institutions. It could also be relevant for countries such as Italy where, after the Parmalat bankruptcy there is a growing concern about the shortcomings of "family capitalism." After all, it is not impossible to learn from what others did unintentionally. Indeed, unintentional consequences may provide an even better guide for intentional economic policy choices.

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Table 1
Distribution of Sample by Industry and Country

	N	%
Industry		
Food	39	19,4
Light industry	48	23,9
Heavy processing	28	13,9
Machines	36	17,9
Construction	23	11,4
Services	25	12,4
Other	2	1,0
Country		
Czech and Slovak Republics	42	20,9
Hungary	75	37,3
Romania	84	41,8
Total	201	100,0

Table 2
Variable Definitions

Variables measuring technology adoption	
Tech94, Tech98	Proportion of employees working with personal computers or computer-controlled machinery, 1994 and 1998
ΔTech	Tech98 - Tech94
Variables related to types of ownership	
DPrivOwn94	Dummy variable for dominant private ownership, 1994[23]
DInsOwn94	Dummy variable for dominant insider ownership, 1994
DOutOwn94	Dummy variable for dominant outsider ownership, 1994
DColOwn94	Dummy variable for dominant collective ownership, 1994
DManOwn94	Dummy variable for dominant managerial ownership (outside workers' collective), 1994
DWorkOwn94	Dummy variable for dominant worker ownership (outside workers' collective), 1994
DDomOwn94	Dummy variable for dominant domestic outsider, private ownership, 1994
DForOwn94	Dummy variable for dominant foreign ownership, 1994
InsOwn94, InsOwn98	Proportion of insider ownership, 1994 and 1998
ΔInsOwn	InsOwn98 – InsOwn94
ColOwn94, ColOwn98	Proportion of collective ownership, 1994
ΔColOwn	ColOwn98 - ColOwn94
Variables measuring firm integration/disintegration	
MatCost95, MatCost98	Proportion of material costs in total costs, 1995 and 1998
ΔMatCost	MatCost98 - MatCost95
Plants95, Plants98	Number of production establishments (plants), 1995 and 1998
ΔlnPlants	ln(Plants98) - ln(Plants95)
Split	Dummy variable referring to the occurrence of a split-up in period 1995–1998 (= 1 if yes, 0 if no)
Other variables	
Emp94 (No.)	Total employment, 1994
Assets/Rev94	Ratio of book value of production assets (plant and equipment) to sales revenues, 1994
Capital	Dummy variable for the location of the firm (= 1 if located in the capital, 0 otherwise)

[23] Dummy variables for dominant ownership refer to the type of owners holding the largest share in the company. The minimum value of dominant share occuring in the sample is 28 percent.

Table 3
Summary Statistics

	Mean	Std Dev	N
Continuous Variables			
Tech94	0.09	0.14	201
Tech98	0.16	0.16	201
InsOwn94	0.47	0.45	184
InsOwn98	0.45	0.44	196
ColOwn94	0.20	0.34	187
ColOwn98	0.14	0.30	196
MatCost95	0.49	0.22	201
MatCost98	0.48	0.22	198
Plants95 (number)	2.73	3.64	201
Plants98 (number)	2.52	3.41	201
Emp94 (number)	617.92	892.22	201
Assets/Rev94	1.57	13.39	201
Dummy Variables			
DPrivOwn94	0.83		183
DInsOwn94	0.50		183
DOutOwn94	0.33		183
DColOwn94	0.21		176
DManOwn94	0.16		176
DWorkOwn94	0.11		176
DDomOwn94	0.18		176
DForOwn94	0.15		176
Split	0.17		200
Capital	0.15		201

Table 4
Regression Results: The Effect of Organizational Variables on Information Technology Adoption

	1		2		3		4		5		6	
Independent Variables	coeff	t	coeff	T	coeff	t	coeff	t	coeff	t	coeff	t
Tech94	-0.046	-0.61	0.035	0.57	0.014	0.23	-0.015	-0.34	-0.015	-0.35	-0.018	-0.42
Ln(Plants95)			-0.011**	-2.02	-0.009	-1.61	-0.006	-1.25	-0.006	-1.21	-0.006	-1.20
MatCost95	0.040*	1.73			0.046**	2.17	0.041**	2.03	0.040**	2.01	0.033	1.56
DPrivOwn94							0.023***	2.53				
DInsOwn94									0.025***	2.70		
DManOwn94											0.020	1.28
DWorkOwn94											0.008	0.64
DColOwn94											0.027**	2.29
DOutOwn94									0.026*	1.77		
DDomOwn94											0.002	0.08
DForOwn94											0.031**	1.94
Ln(Emp94)	0.001	0.14	0.002	0.39	0.001	0.20	0.003	0.79	0.003	0.77	0.001	0.12
Assets/Rev94	0.002***	20.10	0.002***	20.79	0.002***	20.49	0.002***	25.20	0.002***	24.91	0.002***	25.12
Capital	0.035*	1.81	0.022	1.48	0.026*	1.72	0.026*	1.80	0.026*	1.76	0.025	1.50
Czech-Slovak	0.062**	2.21	0.052***	3.06	0.046**	1.99	0.012	0.67	0.010	0.46	0.023	0.88
Hungary	0.025	1.55	0.015	1.36	0.012	1.19	0.010	0.92	0.009	0.75	0.011	0.92
Constant	0.012	0.26	0.043	1.38	0.020	0.54	-0.003	-0.10	-0.003	-0.12	0.016	0.59
Adj R^2	0.24		0.31		0.30		0.45		0.46		0.47	
N	201		195		179		161		161		155	

Note: Dependent variable = ΔTech. The regressions also include controls for seven industry categories. * , ** and *** indicate 10, 5 and 1 percent levels of significance, respectively. The regressions were estimated with robust standard errors.

Table 5
Regression Results: Effect of Information Technology on the Organization

Dependent variable (Estimation method)	ΔInsOwn (OLS)		ΔColOwn (OLS)		ΔlnPlants (OLS)		ΔMatCost (OLS)		Split (probit)	
Independent variables	coeff	*t*	coeff	*t*	coeff	*t*	coeff	*t*	Marginal effect[a]	*t*
Tech94	-0.115	-1.21	-0.130	-1.45	-0.233	-0.96	-0.001	-0.02	0.231**	1.96
InsOwn94	-0.349***	-5.75							0.033	0.84
ColOwn94			-0.750***	-8.64						
Ln(Plants95)					-0.199***	-4.29			0.082***	3.45
MatCost95							-0.192***	-4.02	-0.004	-0.05
Ln(Emp94)	-0.006	-0.37	-0.021	-0.78	0.056**	2.17	-0.010	-0.79	-0.017	-0.85
Assets/Rev94	-0.001**	-2.13	-0.000	-1.03	0.001**	2.42	-0.014***	-9.98	-0.031	-1.35
Capital	-0.011	-0.22	-0.065	-1.07	0.097*	1.67	-0.006	-0.28	-0.025	-0.70
Czech-Slovak	-0.293***	-4.43	-0.112**	-2.12	-0.147**	-2.31	-0.024	-0.72	0.326**	2.43
Hungary	-0.317***	-5.81	-0.056	-0.96	-0.015	-0.28	0.051*	1.82	0.064	1.44
Constant	0.421***	3.70	0.348**	1.99	-0.128	-1.09	0.141	1.55		
Adj R^2	0.31		0.47		0.28		0.20		0.46[b]	
N	190		193		196		198		161	

Note: The regressions also include controls for seven industry categories. The regressions were estimated with robust standard errors. * , ** and *** indicate 10, 5 and 1 percent levels of significance, respectively.

[a] The marginal effect of a change in the independent variable.

[b] Pseudo R^2