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Information technology: Efficient restructuring and the productivity puzzle☆

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ABSTRACT

Labor productivity in the US has recently grown more strongly than in most European countries. It is often argued that the American productivity increase is due to the widespread introduction of new information and communication technologies (ICT). But why have the same technologies not similarly increased Europe's labor productivity? This paper provides a theoretical explanation for this productivity puzzle based on an extension of Radner's (1992) model of hierarchical information aggregation. The introduction of new ICTs enables organizations to process any given amount of information with a shorter delay. This enables organizations to restructure and solve incentive problems without risking to produce with excessive delay. Even a marginal improvement in the ICT can yield significant increases in labor productivity if – and only if – the organization is drastically restructured. Restructuring yields hierarchies with fewer layers and fewer managers, all working under incentive pay and providing first best effort. However, managers need not participate in the gains associated with the restructuring of their business firms.

1. Introduction

Over the last two decades, US labor productivity has grown more strongly than in most European countries. Many observers argue that the American productivity increase is due to the introduction of new information and communication technologies.[1] This includes the widespread use of new communication devices such as the internet, e-mail, mobile phones, and mobile computers with wireless internet access as well as new more comfortable software products for word-processing and statistical applications. However, these innovations were also used immediately by many European firms (Jorgensen and Vu, 2007). If they are the key explanation for the impressive American productivity increase, then why have not they increased European labor productivity to a comparable extent?

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[1] Oliner and Sichel (2000, p. 3) estimate that "the use of information technology and the production of computers accounted for about two-thirds of the 1 percentage point step-up in productivity growth between the first and second halves of the decade." According to Gordon (2004) the US–EU productivity gap has been largest in the IT- intensive sectors.

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The present paper provides a theoretical explanation for this productivity puzzle. It analyzes the way in which innovations in information and communication technologies affect the optimal design of organizations. The explanation for the puzzle put forward here is the following. The introduction of new IC technologies enables organizations to process any given amount of information with a shorter delay. This means that organizations can reduce the division of labor and solve incentive problems without risking to produce with excessive delay. Restructuring generates a higher surplus when the number of employees involved in a particular process is reduced. It enables the principal to better address free rider problems in team production processes. Under a proper incentive contract, the reduction of the number of employees increases equilibrium effort. Therefore, an improved IC technology enables restructured organization to produce more efficiently for a given delay.[2]

I show that even a marginal improvement of the IC technology can yield significant increases in labor productivity if the organization is restructured appropriately. Moreover, marginal changes in ICT productivity may result in a significant restructuring of organizations. Several hierarchy levels may disappear and the optimal organization employs fewer managers for each individual processing task. Note that this does not necessarily imply a reduction of the overall size of business firms. It rather means that the number of managers who work on particular projects within firms is reduced significantly.[3]

An improved IC technology without an appropriate restructuring instead yields only marginal productivity gains. Hence, there is a strong complementary between IC technology improvements and a lean organizational design. If the organization avoids restructuring then the productivity increase remains marginal. A straightforward explanation for the productivity puzzle is that European companies have been more reluctant to restructure their production process in an appropriate manner. If complementarities are not made use of, then the productivity effect of ICT improvements cannot fully be exploited.

In the model a principal hires a number of agents called managers who work on a given number of information items. Each agent has to provide effort in order to properly understand the information that he is supposed to handle. Agents have to process all items in order to realize a high output level. Unobservable additional effort on objects increases the likelihood of the good outcome. First-best effort cannot be implemented because all agents are wealth-constrained. The overall success probability of the organization is increasing in the aggregate amount of effort provided by all employees.

In the first example of Section 4, I impose a uniform sharing rule for the management team. All managers get the same share of the project's output. Under this rule most of our results can be derived quite easily. Generally, it may be optimal to provide only a subset of managers with monetary incentives and to distribute the surplus unevenly. In Section 6, I discuss the general case. Without any restrictions on the sharing rule it is optimal to provide only a fraction of the employees with incentives for extra effort. The restructuring process that follows an ICT productivity increase may then lead to a situation in which all remaining employees work under monetary incentives.

Section 7 addresses the question of why workers or managers may be willing to forgo the efficiency gains that are associated with the restructuring of their firms. Cannot they be compensated if the firm produces more efficiently? And will not new firms hire those workers who have been dismissed by others? We address these questions in a macroeconomic extension of the basic model in which capital (or the number of available projects) is fixed. In such a setup optimal restructuring can lead to an excess supply of workers which reduces labor rents. Therefore, countries in which labor is politically powerful end up with inefficient production processes that hire too many workers and artificially generate labor rents.

2. Related literature

The model in this paper analyzes the way in which innovations in information and communication technologies affect the design of organizations. The paper is related to two recent strands of the literature on organizational design. The first one imports insights from computer science into economic theory. This literature introduces a delay of information processing into economic models. It started with Radner (1992, 1993) and Radner and Van Zandt (1992). The resulting optimal "reduced tree" structure is designed for one-shot problems in which there is only one set of data to be processed, or the processing of the data is finished before another calculation task occurs. I restrict attention to this case in most of the paper. Van Zandt (1997, 1998) and Meagher et al. (2001) study the case when new data comes in before the processing of the old set is finished. Orbay (2002) adds the frequency with which new data arrives as a new dimension to the analysis of efficient hierarchies. A similar problem is addressed in Appendix A of this paper.

The paper is also closely related to the recent work by Garicano (2000); Garicano and Rossi-Hansberg (2004, 2006) on the microeconomic and distributional consequences of IT innovations. These papers address related questions in a different framework. Garicano introduces a model of hierarchical information aggregation. In this model agents may either specialize in a problem solving or in providing advice to other problem solvers. Two variables measure the quality of information

[2] A similar effect of technological innovations has most likely affected the organization of upper class households over the last century. According to Davis (2008), "servants were imperative to the functioning of middle and upper class homes in Victorian England. Without the veritable army of servants for the upper and upper-middle classes, women would not be able to live the leisured lives they had grown accustomed, and would certainly not have the time to flaunt their status with neighbor-calling and the numerous balls and social activities", but even "most lower-middle and middle-middle classes employed at least one servant, as assistance was almost a necessity in maintaining the home" (see also Roberts, 2003). Technical progress made it possible to perform many household tasks in a much shorter time span. As a consequence, the former principals now perform a much more heterogeneous set of tasks.

[3] See Earle et al. (2006) for an empirical analysis of the relationship between firm size and technology adoption.