Sources of Knowledge and Other Factors that Generate Multifactor Productivity Improvements: Evolving Debate in Different Theories of Productivity

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ABSTRACT

Advances in scientific knowledge have long been regarded as a significant determinant of multifactor productivity growth. Most empirical studies that analyses the impact of knowledge on productivity focus on different measures of research and development (R&D) as sources of productivity improvements. In fact, searching for determinants of productivity also brings competing theoretical models that might be important for productivity improvements. Therefore, the purpose of this paper is to fill this gap by providing an overview of key topics in the literature on productivity determining factors. It is argued that all types of R&D are significant determinants of productivity growth across nations. In the case of competing theories of productivity such factors as human capital, exports and imports, inflows and outflows of foreign direct investment, and government infrastructure stock have been mentioned as productivity determining factors. Among these determinants of productivity, while only human capital seems to have consistent and positive impact on productivity, other determinants have conflicting effects upon productivity.

Key Words: knowledge creation, productivity, competing theories of productivity, types of R&D

Çoklu Faktör Verimliliğinin İlerlemesini Oluşturan Bilgi Kaynakları ve Diğer Faktörler: Farklı Verimlilik Teorilerinde Gelişen Tartışmalar

ÖZET

Bilimsel bilgideki gelişmeler uzun zamandır çoklu faktör verimliliğindeki büyümenin önemli bir belirleyicisi olarak kabul edilmektedir. Bilginin verimlilik üzerindeki etkilerini analiz eden pek çok ampirik çalışmalar, verimliliği iyileştirmenin kaynakları olarak farklı araştırma ve geliştirme (AR-GE) ölçüleri üzerinde odaklanmışlardır. Aslında, verimlilik artışının belirleyici faktörler araştırılırken, rekabetçi teorik modellerin de verimlilik artışında önemli olabileceği iddia edilmektedir. Daha önceki çalışmaların ilgili faktörleri ayrı ayrı incelemesi sebebiyle, bu çalışmanın amacı literatürdeki verimliliği belirleyen faktörleri bir arada inceleyerek, anahtar konular hakkında genel bir bakış sağlıyarak, bu konudaki boşluğu gidermektir. İncelemer sonucunda, bütün AR-GE çeşitlerinin ülkelerin verimliliğinin büyümesinde önemli faktörler olduğu belirlenmiştir. Rekabetçi verimlilik teorileri olarakta beşeri sermaye, ihracat ve ithalat, bir ülkede yapılan doğrudan yabancı yatırımlar ve ülkelerin yurtdışında yaptığı doğrudan yatırımlar, ve devletin gerçekleştirdiği altyapı yatırımları verimliliği belirleyen faktörler olarak gösterilmiştir. Verimliliğin bu belirleyicileri arasında, sadece beşeri sermayenin verimlilik üzerinde tutarlı ve olumlu etkisi varken, diğer faktörlerin verimlilik üzerindeki etkileri çelişkilidir.

Anahtar Kelimeler: bilimsel bilgi oluşturma, verimlilik, AR-GE çeşitleri, rekabetçi verimlilik teorileri

INTRODUCTION

Standard growth accounting exercises provide a breakdown of observed economic growth into components associated with changes in factor inputs and a Solow residual that reflects technological progress and other elements. Generally, the accounting exercise is viewed as a preliminary step for the analysis of fundamental determinants of economic growth. The final step involves the relations of factor growth rates, factor shares, and technological change (the residual) to elements such as government policies, household preferences, natural resources, initial level of physical and human capital, and so on. The growth-accounting exercise can be particularly useful if the fundamental determinants that matter for factor growth rates are substantially independent from those that matter for technological change.

Early on, Solow (1956, 1957) estimated percentage changes in the value of technological change or the residual using aggregate U.S. data between 1909 and 1949. His analysis showed that more than 87 percent of the growth in the U.S. economy could not be explained by the growth in capital and labor, and therefore, the residual or unexpected portion of growth must be attributable to something else. Solow argued that what was captured in his residual calculation may reflect technology advance over time, or what is also called total factor productivity[1] (TFP) growth; more precisely multifactor productivity (MFP).

Other researchers, using alternative framework of analysis, independently reached similar conclusions as Slow. For instance, the unexplained portion of the growth was explained more carefully as a measure of our ignorance by Abramovitz (1956). Implication for these analyses meant that even though economists were able to calculate unexplained growth, but they were not able to suggest a full explanation for what caused it. Different from Solow, however, Abramovitz argued that improvements in education and increases in research and development (R&D) might be the cause of growth experience not explained by capital and labor.

[1] Rest of the study multifactor productivity, total factor productivity, and productivity is used interchangeably.

Recent theories of endogenous growth allow for a sharper perspective on this residual. Specifically, the residual can be clearly interpreted within settings that allow for increasing returns and spillovers or in the models in which technological progress is generated by purposeful research. These interpretations provide direction for explaining the residual in terms of research and development expenditures (R&D), public policies, and other factors. In "idea" models of Romer (1990), Grossman and Helpman (1991), and Aghion and Howitt (1992), new products or processes (ideas) spring from research and development (R&D) expenditures. The new products increase productivity once they are embodied in nonlabor inputs such as higher quality or more specialized capital and intermediate goods. Therefore, increases in productivity are considered one of the main elements of economic growth.

The purpose of this article is to fill the gap by providing an overview of key topics in the literature on the MFP determining factors of nations since most empirical studies that investigate determinants of MFP focus on various measures of R&D, and seldom allow for the other determinants of productivity that emerge from theoretical models. Revealing such determinants of productivity may inform us about the relevance of competing theoretical models. In addition, identification of key drivers of MFP may be better for policy makers. In search of productivity determining factors, in the first section sources of knowledge that generated through different types of R&D will be discussed. These are business R&D, government R&D, university R&D and foreign R&D. The second section discussed the absorbing capacity of any nation through foreign relations with the rest of the world, such as exporting, importing and foreign direct investment inflows and outflows. Advantage of facilitating technology transfer a country should invest in human capital and infrastructure domestically. Thus, third section reviews the ideas related to facilitating technology transfers. Finally, fourth section concludes and discusses some future research opportunities.

1. Sources of Knowledge

Research and development (R&D) is considered as a significant source of technical change. *Frascati Manual* (OECD, 1993) defines R&D as "comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge to devise new applications" (p. 29). R&D is not the only source of new technology. Other activities such as education and learning by doing are important sources of productivity growth in modern, industrial economies. Moreover, education and learning by doing can increase economic performance through an improved ability to absorb new knowledge coming out of domestic and foreign R&D.

Even though the connection between R&D and innovation is complex and nonlinear, it is obvious that significant improvements in scientific knowledge or technology cannot occur without work being undertaken in a systematic basis, and R&D is a good indicator of this broader phenomenon. However, there are different kinds of R&D and its impact on productivity may work through different ways. It is important to consider these different types of R&D in order to capture the links between R&D and productivity. Both business sector and public sector (government laboratories and higher education institutions) can perform R&D. Another significant source of domestic technical knowledge improvements can be aroused as a result of R&D performed outside the country. In what follows, we briefly examine the potential impact of these different kinds of R&D.

1.1. Business R&D Expenditures

Research and Development performed by business generates new goods and services, in higher quality of output and in new production processes. These are sources of productivity growth at the firm level and at the macroeconomic level. The influence of business R&D on productivity has been analyzed in voluminous empirical studies, performed at the all aggregation levels—business units, firm, industry and country levels—and for many countries (particularly the United States). In view of the accumulating evidence from these studies, a consensus in the literature is that business R&D contributes to domestic productivity[2]. These studies estimate elasticity of output with respect to business R&D varying from 10 percent to 30 percent[3]. Generally differences in econometric specifications, data sources, number of economic units, measurements methods for R&D and economic performance, aggregation level, and periods of studies are the reasons for this large variation in the estimated output elasticities.

One of the earliest large-scale econometric studies is presented by Lichtenberg and Siegel (1991). They study productivity growth for over two thousand US firms over the period 1972 to 1985, running regressions of the form:

growth in total factor productivity = a + b (R&D expenditure / output) + random shocks

where the regression coefficient b is an estimate of the direct marginal product of R&D and the net rate of return on R&D investment is given by (b – the depreciation rate of productive knowledge). They do not attempt to capture productivity benefits that might spill over to other firms, so their estimates are for private returns that might understate the value of the full social returns. Lichtenberg and Siegel show that gross rate of return on company-funded R&D is around 35 percent.

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[2] However, there are a few exceptions to this consensus. Panel studies on firm and industry level data (Griliches and Lichtenberg, 1984,; Jaffe, 1986; Bernstein, 1988) report that R&D elasticities are often statistically insignificant.

[3] See a survey of literature by Nadiri (1993).

In another microeconomic study of the returns to business R&D, Bernstein and Nadiri (1991) use the cost function, instead of production function, approach to measure returns to business R&D capital for six manufacturing industries in the United States for the period 1957-86. Their approach is more sophisticated than that of Lichtenberg and Siegel (1991) in several respects: i) they allow for process improvements to reduce costs of production and for product innovation to raise the profit margin on sales; ii) they estimate the stock of R&D knowledge that has been accumulated over a long time period, rather than using just the current flow of R&D effort, so taking into account likely delays between the R&D activity and its translation into productive innovations; and iii) they estimate several different spillover effects between industries.

Estimation of a system of cost and price functions allows Bernstein and Nadiri (1991) to estimate both private and social rates of return to R&D, where the social rate of return takes account of the spillover benefits (or costs) to other industries[4]. While their estimated private return to business R&D for the manufacturing industries ranges between 21 percent and 28 percent, social returns to business R&D estimates are varies between 21 percent to 86 percent. Higher social returns show that spillover effects of business R&D—captured by the difference between social and private returns—are positive for all but one industry.

Hall and Mairesse (1995) to analyze R&D performance of companies use individual French manufacturing firms' data for the period 1980-1987. Using a production function approach they find that the estimated coefficient of R&D capital is uniformly positive. In addition to finding statistically significant effect of business R&D on output, Hall and Mairesse more importantly raise the issue that the rate of return method of estimating the productivity of R&D by using the R&D investment intensity ratios can give misleading results. Authors argue that the net rate of returns to R&D should be higher than the gross returns to R&D. Using the R&D investment intensity ratio they find the opposite results. Thus, it is better to measure R&D capital stock instead of R&D flow variables. On the other hand, calculating R&D capital stock requires appropriate depreciation ratio, which is rather difficult to determine.

In summary, business sector investment in R&D is important in generating new technological knowledge. There is a large body of micro-econometric evidence from studies across a variety of OECD countries that rates of return are substantially higher at the level of industries, with gross rates

[4] Their estimates are net of depreciation, which they assume—based on the estimates from Hulten and Wykoff (1981)—to be ten percent per year for R&D capital.

of return of up to 40% or more suggesting that there are significant knowledge spillovers between firms and between industries.

1.2. Government R&D expenditures

Government and university R&D have a direct effect on scientific, basic knowledge and on public admissions. In many cases the impact of government research on productivity is not measured, either it is indirect or because its results are not accounted in existing measures of GDP (health related research improves the length and quality of life, which are not taken into account in GDP measures.

Much of the available literature in this subject concentrates on examining either the effects of public basic research on the innovative activities of firm (see among others Jaffe, 1989; Mansfield, 1991; Robson, 1993; Narin, Hamilton and Olivastro, 1997; Arundel and Geuna, 2004) or the contribution of scientific research to productivity growth. For example, Adams (1990) shows that fundamental stocks of knowledge proxied by accumulated academic scientific papers, significantly contribute to productivity growth in the United States industries. Another study is examined the military innovations in Canada (Poole and Bernard, 1992). They find evidence that a defense-related stock of innovation has a negative and significant effect on the multifactor productivity of four industries for the period 1961-1985. Furthermore, Nadiri and Mamuneas (1994) formally include the stock of public R&D, along with the stock of public infrastructure, as a determinant of the cost structure of the United States manufacturing activities. Their results suggest that public R&D capital has significant productive effects and is associated with a substantial "social" rate of return. On the other hand, in its panel data analysis of 10 OECD countries, Park (1995) finds that public R&D loses its significant effect on productivity growth when business R&D is included among the explanatory variables.

There are a few empirical studies on the factors determining the productivity benefits of research carried out in government labs. Adams, Chiang and Jensen (2000) shows that Cooperative Research and Development Agreements (CRADA) are the primary channel by which the United States federal government laboratories increase the patenting and R&D of industrial laboratories. Authors argue that without CRADA patenting of new innovations does not change much and only federally funded R&D increases. Adams et al's findings are interpreted as the fact that CRADAs are legal agreements between government labs and firms to work together on joint research, and such cooperation creates knowledge spillovers. In other words, as a result of limited collaboration between government scientists and those of industrial firm social returns of government laboratories R&D will be low.

1.3. Universities and Multifactor Productivity

Changes in the economic, social and knowledge environment provide opportunities to new or improved products. Research knowledge of university is increasingly considered as providing a significant number of opportunities to develop new or improved product. There are growing number of studies on the opportunities of knowledge transfer undertaken by universities and university researchers. In recognition of this fact, governments throughout the industrialized world have launched numerous initiatives since the 1970s to link universities to industrial innovation more closely.

The three major forms of mechanism through which universities and university researchers transfer knowledge are the diffusion of research knowledge through conferences and scientific publications, the training of a skilled labor force, and the commercialization of knowledge. The first two-knowledge transfer mechanism related the Mertonian open science argument has been the main objective of the United State universities for centuries. On the other hand, the third source of diffusion of research knowledge through commercialization of knowledge has become very significant over the past quarter-century. The commercialization of knowledge can itself be considered under many alternative mechanisms, notably through consulting activities, research contracts with industry, patenting and spin-off formation.

We witnessed a dramatic increase in patenting and licensing activities of publicly funded research by American universities (Jensen and Thursby, 2001; Sampat, 2006). This rise has contributed to some of the highest-profile debates in science and technology policy today. The issue of what aspects of academic research should be public – and what private – lies at the heart of each of these debates. In recent years, according to Dietz amd Bozeman (2005); and Sampat (2006) we have seen a dramatic growth in the "private parts" of academic research, i.e. those that are disseminated via patents and licenses rather than simply placed in public domain. These changes have been praised as a new model of academic research, one that facilitates economic and social returns from universities. On the other hand, these have criticized as dramatic changes in the commercialization of academic research as representing a socially inefficient "privatization" of academic research and as a threat to the nature of science itself.

Previous studies (see among others, Jensen and Thursby 2001; Dietz and Bozeman, 2005; Adams, Black, Clemmons, and Stephan 2005; Sampat, 2006; and Adams and Clemons 2008) have examined how this change in the diffusion of university knowledge affects the output of publicly funded university research in specific industries. In addition, these studies analyzed the various channels through which universities contribute to innovation and economic growth. Nevertheless, contribution of commercialization of knowledge through universities on multifactor productivity of total economy is open empirical question. Especially, considering latest changes in the decomposition of federal research and development expenditures, shifts of federal government' funds from industry to universities, it is important to understand economic impact of this changing composition of federal funds for the discussion of science and technology policy. For example, share of industries that receive government funds stayed behind for the first time that of universities in 2000. with the availability of data for the United States starting from 1953 until 2000, average share of R&D performed in industry and funded by government was 27.5%. during this period universities received in average nearly 10% of government's funds. However, for 2000-2006 period, while average share of government funds universities received increased to nearly 12%, industry's share declined to 7%[5].

Tighter constraints on public funding have also influenced the universities throughout the OECD. A number of OECD member countries has been facing declined in their share of growth of public funding by higher education (OECD, 2002). In the United States, Cohen et al. (1998) note that federal research funding per full-time academic researcher declined by 9.4 percent in real terms during 1979-1991. Financial support from state governments for operating budgets of U.S. public universities declined from nearly 46 per cent of total revenues in 1980 to slightly more than 40 percent in 1999 (Slaughter and Leslie 1997: Table 3.2), while the share of federal funds in the United States public university operating budgets decline from 12.8 to 10 per cent during the same period (the share of operating revenues derived from tuition and fees raise from 12.9 to 15 per cent). The United Kingdom government also decreased its institutional funding universities during the 1980s and 1990s (OECD, 2002).

Faced with slower growth in overall public funding, increased competition for research funding, and continuing cost pressures within their operating budgets during the past two decades, at least some universities have become more aggressive and "entrepreneurial" in seeking new sources of funding. University presidents have promoted the regional and national economic benefits flowing from academic research. They have also sought closer links with industry as a means of expanding academic research support. Both internal and external factors therefore have led many nations' universities to promote stronger linkages with industry as a means of publicizing and/or strengthening their contributions to innovation and economic growth.

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[5] Author's calculation. Data received from National Science Foundation, Division of Science Resources Statistics. 2008. *Academic Research and Development Expenditures: Fiscal Year 2007*. Detailed Statistical Tables NSF 09-303. Arlington, VA. Available at http://www.nsf.gov/statistics/nsf09303/.

The economically important "outputs" of university research have come in different forms, varying over time and across industries[6]. They include, among others: technological and scientific information[7] (that can increase the efficiency of applied R&D in industry by guiding research towards more fruitful departures), equipment and instrumentation[8] (used by firms in their or their research production process), skills or human capital (embodied in student and faculty members), networks of scientific and technological capabilities (which facilitate the diffusion of new knowledge), and prototypes for new products and processes.

In addition to changing patterns of funding behavior for academic work discussed above, Slaughter and Leslie (1997) argue that globalization changed the nature of corporate competition, putting a premium on products and processes derived from scientific innovation: "As the economy globalizes, the business or corporate sector in industrialized countries pushed the state to devote more resources to the enhancement and management of innovation so that corporations and nations in which they were headquartered could compete more successfully in world markets" (p.7). Increased demand on industry's side, together with the decreases in the supply of federal funding, thus put market-like pressures on faculty members and their institutions to shift focus in their pursuit of support for research. Not surprisingly, then, the market-oriented behaviors of faculty and universities have become the key components of what Slaughter and Leslie describe as "academic capitalism".

Another change in the context of university research has been the evolution of legislation that has enabled the capitalization of knowledge, by which Etzkowitz, Webster and Healey signify "the translation of knowledge into commercial property in the literal sense of capitalizing on one's intellectual (scientific) assets", as well as "the way in which society at large draws on, uses, and exploits its universities, government funded research labs, so on to build the innovative capacity of the future" (1998, p.9). Slaughter and Leslie (1997) review some of the most relevant federal legislation in the United States, of which the Bayh-Dole Act of 1980 is arguably one of the most significant (see also Etzkowitz and Stevens, 1998). This act allowed universities to patent the results of research that the federal government had funded, thereby earning royalties by licensing innovations to private corporations. Thus even as the federal government was reducing direct support for academic research, it was removing obstacles to universities' ability to profit from research. Such a development was not without controversy: "Some in Congress argued that

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[6] This list draws from Cohen et al. (1998).

[7] David, Mowery, and Steinmueller (1992) and Nelson (1982) discuss the economic importance of the "informational" outputs of university research.

[8] See discussion of Rosenberg and Nelson (1994) about universities as being a source of innovation in scientific instruments.

granting private companies the rights to publicly funded research amounted to an enormous giveaway to corporations: others pronounced the act a visionary example of industrial policy that would help America compete in the fast moving information age" (Press and Washburn, 2000, p. 41). Bowie claims that the second argument won out because of "the growing threat of international economic competition and ... the perceived decline in research and development capabilities of American Industry" (1994, p. 14). The Bayh-Dole Act's effect has been significant. Before its passage, universities were producing approximately 250 patents per year (Press and Washburn, 2000), and as 1978, the government owned title to over 28,000 patents, of which fewer than 4% had been licensed (Etzkowitz and Stevens, 1998). On the other hand, in 1998 alone, universities produced over 4,800 patent applications (Press and Washburn, 2000).

Since empirical studies considers university R&D as a part of public R&D, returns to R&D that performed in the universities are measured by publications' received patents, and citations. Compare to European counterparts U.S. universities generate significant scientific knowledge. For instance, Nickell and Van Reenen (2001) reports that even though the United Kingdom has a relatively strong science base build around an ensemble of university-related research institutes; nation has been having difficulties translating the science base into innovation and industrial performance. The authors argue that due to constraints researchers faces while they are doing consulting work, their commercial payoffs from their research efforts are limited.

Unique characteristics of U.S. academic environment are emphasized by Pisano (2002). Especially, the "flexibility" of the U.S. academic system and other make it relatively straightforward for leading academic scientists to become deeply involve with commercial firms, thus facilitating the formation of successful start-up companies. The willingness to exploit the results of academic research commercially distinguishes the United States environment that of either Japan or Europe. Mobility of academic scientists into commercial venture is difficult in the later regions where academic scientists are essentially civil servants operating on a rigid and hierarchical system. While Pisano's comments are directed at the biotechnology sector, they would seem to be generalized to other areas of technology.

1.4 Foreign R&D

The knowledge generated in other countries is another source of new technology for any national economy. There are many ways for technology to cross border. Companies can buy patents, licenses or know-how from foreign firms. They can observe competition (e.g. reverse engineering), they can hire foreign scientists and engineers, they can interact with foreign competitors who invested in their country (foreign direct investment), read the scientific and technological literature, or have direct contacts with foreign engineers in conferences or fairs. The effect of foreign-produced knowledge on a country's productivity may depend on the capacity of the recipient country to digest such knowledge, to make efficient use of it, which requires a sufficient technological activity of its own. This is traditionally named as "absorptive capacity".

Generally macroeconomic studies are used to calculate the spillover benefits of foreign R&D. This is done by regressing multifactor productivity on a stock of domestic R&D and stock of foreign R&D. One of the first macroeconomic studies was conducted by Coe and Helpman (1995) who calculated the stock of domestic R&D (aggregating public and private) using the perpetual inventory method with an assumed depreciation rate of either 5 percent or 15 percent. They estimated pooled cointegration regression on total factor productivity data for 22 OECD countries over 20 years (1971-90). Their results give elasticities of total factor productivity with respect to domestic capital stocks that are higher for the G7 countries than for the smaller OECD economies. Furthermore, foreign R&D incorporated into trade flows has a significant impact on total factor productivity growth.

Park (1995) also searches for evidence of knowledge spillovers comes from foreign countries. Using a panel data set of ten OECD countries for the period 1973-1987, Park finds that domestic private research is a significant determinant of both domestic and foreign productivity growth. Park's paper differs from Coe and Helpman (1995) in constructing the weights that calculates the spillover of foreign R&D. He uses functional composition of public and private research to measure the weights for technological neighbors. The empirical results support the idea that there are international technological spillovers.

In contrast to previous papers findings of significant and positive foreign R&D spillovers, Luintel and Khan (2004) argue that studies using groups of countries in a panel framework are not considering the possibility of heterogeneity of knowledge diffusion across countries. The authors model knowledge spillovers dynamics at the country level for G10 countries during 1965-1999. They regress multifactor productivity on domestic R&D stock and foreign R&D stock using the Johansen VAR approach and Fully Modified Ordinary Least Square (FMOLS) estimator, concluded that foreign R&D emanates significantly negative spillover for the United States while rest of the countries in the paper received positive spillovers from the foreign countries' domestic R&D investments.

In general, foreign R&D is another source of knowledge creation. However, pooling panel data ignores the specific country dynamics, and Luintel and Khan (2004) results suggest that knowledge spillovers may not be positive for the technology leader.

2. Absorbing knowledge

There is widespread evidence that the rate of technology transfer between countries depends on the policies and activities of the recipient country. Two schools of though are strongly represented in the empirical literature on international technology flows. The first considers international trade and foreign direct investment to be the mechanisms that transfers the technology across nations. The second is related the absorptive capacity of the domestic economy that receives the technological knowledge. This model considers the domestic investment in education, research and infrastructure.

2.1. International Trade and Absorbing Knowledge

There is more than one reason why international trade should increase the scope for cross-country knowledge spillovers. First of all, by engaging in the competitive market place of international trade, local companies learn more to use the state-of the-art techniques and to produce goods that local consumers are willing to pay for. In addition, when local consumers start buying modern high-quality imported foreign goods they start to demand the same quality from local firms, which then are pressured into modernizing. In other words, international trade enhances innovations by increasing product market competition. Finally, international trade allows a country to produce a specialized range of goods on a larger scale to meet a global demand while relying on imports to satisfy the local demand for other products. Therefore, international trade fosters innovations by allowing potential innovators, both in higher- and lover- income countries, to take advantage of economies of scale. That is, with large-scale production, firms more quickly acquire specialized knowledge of how to reduce production costs, and they also have more incentives to generate and implement cost-reducing innovations.

2.1.1. Exports and Multifactor Productivity

Following the theoretical discussion above, a growing body of empirical studies has reported the superior performance characteristics of exporting plants and firms relative to non-exporters. Employment, shipments, wages, productivity and capital intensity are all higher at exporters at any given moment. At any point in time exporters produce more than twice as much output and are 12%-19% more productive (Bernard and Jensen, 1999). In their paper, Bernard and Jensen examine the relationship between exporting and firm performance. Their study focuses on two key issues: do good firms become exporters and so exporters outperform non-exporters. To tackle these issues, Bernard and Jensen consider the structure and performance of a company before, during, and after exporting, taking extreme care to avoid confusing correlated outcomes, e.g. exporters are more productive, with casual relationships, e.g. exporting increases productivity. Authors use the firm/plant level data from the Longitudinal Research Database of the Bureau of the Census for the period 1984-1992. Regress dependent variables such as total employments, shipments, value-added per worker, total factor productivity, average wage on export dummy that represents whether the current status of the firm is exporter or not, a vector of four digit (SIC) industry dummies, and a vector of U.S. state dummies. Bernard and Jensen estimate that the average percentage difference between exporters and non-exporters in the same industry and state are positive and significant for every firm/plant in all years. In choosing among the competing explanations for the excellent performance characteristics of exporters at any point in time, Bernard and Jensen conclude that success and new products lead to exporting, and that exporting is associated with growth in plant size. On the other hand, the lack of productivity gains suggests that firms entering the export market are unlikely to substantially raise their productivity, even if they export continuously. Thus, their results conflict with the theory that exporting is productivity enhancing. However, exporting does provide expanded market opportunities for the most productive firms in a sector. As these plants expanded the overall economy may grow as resources are relocated from less productive to more productive activities. Potential benefits may be located in terms of the number of jobs and, through higher plant survival rates, the stability of jobs.

There are at least two important theoretical reasons why exporting might improve firm performance: serving a larger market might allow a firm to take advantage of any economies of scale in production or to provide some reductions in domestic variations in demand; and firms active on foreign markets are exposed to more intense competition and must improve faster than firms who sell their products domestically only. Looking at the reverse direction, it is expected that success leads to exports because there exists additional costs of selling goods in foreign markets, and, therefore, large, more productive and more innovative firms will be more likely to export because they can recover these extra costs more easily. Wagner (2002) uses a matching approach to look at the casual effects of starting to export on firm performance in the German economy. The empirical study is base upon an unbalanced panel of plans built from the cross section data collected in regular surveys in Germany between 1978 and 1989. Econometric estimates reveal economically and statistically significant positive effects on two indicators of plant performance, growth of employment and wages, and weaker evidence for a positive effect on labor productivity.

Delgado *et al* (2002) also investigates the relationship between total factor productivity differences of exporting and non-exporting firms using a sample of Spanish manufacturing firms over the period 1991-1996. Furthermore, two complementary explanations for the greater productivity of exporting firms: (1) the market selection hypothesis and (2) the learning hypothesis are analyzed in this paper. Non-parametric tests are applied to compare the cumulative distribution functions of multifactor productivity for different groups of firms such as, exporters, non-exporters, entering exporters and existing exporters. Their results show that exporting firms have higher levels of multifactor productivity compare to non-exporting firms. They also report that companies that finally become exporters have higher productivity than non-exporters in the period prior to their entry to export markets. Same conclusion also applies the companies that exit the export market. The continuing exporters' ex-ante productivity distribution is higher than those of exporters that leave the export markets.

Greenaway and Kneeler (2007) applies the idea of how multifactor productivity of companies affected by entry to, participation in and existing from export markets to behavior of manufacturing firms that involves in export markets in the United Kingdom during the time period 1988-2002. Their data set contains of information on 11,225 firms yielding a total of 78,606 observations. By using ordinary least square estimator, Greenaway and Kneeler test the difference growth in total factor productivity between new exporters and non-exporters, controlling for fixed firm, time and industry effects as well as total factor productivity, employment and wages. Their estimates show that growth of productivity is higher for companies around 4.1 percent in the year of entry to export markets than in the period before, after controlling for productivity growth in companies that did not enter the export market.

2.1.2 Imports and multifactor productivity

Imports are conduits of technology diffusion. Grossman and Helpman (1991) by embedding the endogenous growth theories in multi-sector, multi country general-equilibrium analyzed the effect of imports in intermediate as well as final goods on long-run growth. Technology diffuses in this framework through being embodied in intermediate inputs: if R&D expenditures create new intermediate goods which are different (the horizontally differentiated input model) or better (the quality ladder model) from those already existing, and if these are exported to other economies, then the importing countries are implicitly utilizing the technology from abroad. Moreover, if the importing country pays less than the intermediate good's full marginal product, then international trade in these intermediate goods triggers productivity increases in the importing country.

Even before the introduction of the endogenous growth theories, a voluminous literature had developed that connected domestic R&D expenditures to multifactor productivity growth. The specific contribution of the new growth and trade theories lies in the testable hypotheses one can derive with regard to trade and openness. Coe and Helpman (1995) derives and tests two implications of these models. The first is related to the composition of imports: ceteris paribus, if one country imports primarily from other countries that have accumulated high levels of technological knowledge, then country should exhibit higher productivity levels than if it would import primarily from countries than if it would import primarily from countries with comparatively low levels of technological knowledge. This is also known as import composition effect. The second effect is related to the overall import share of a country: for a given composition of imports, a country should benefit more from foreign R&D creating innovative intermediate goods, the higher is the country's overall import share (overall import share effect). More precisely, their idea is to evaluate the indirect benefits arising from imports of goods and services that embody the technological knowledge of trade partners.

At the center of the study by Coe and Helpman is what the authors call the "foreign stock of knowledge" of a given country. This variable is constructed as a weighted sum of the cumulative R&D expenditures of the country's trading partners where the weights are given by the bilateral import shares[9]. According to Coe and Helpman, their analysis "underlies the importance of the interaction between international trade and foreign R&D" (p. 860). They conclude their paper by reporting, "not only does a country's total factor productivity depend on its own R&D capital stock, but, as suggested by theory, it also depends on the R&D capital stock of its trade partners." (p. 875).

There is evidence that imports are a significant channel of technology diffusion. On the other hand, the evidence for benefits associated with exporting is weaker.

There are some reasons to remain skeptical as well. Firs, the analysis of Keller (1998) has shown that the imports shares in the construction of the foreign R&D variable are not, in fact, essential to obtain results of Coe and Helpman (1995). Keller (1998) uses randomly created shares in place of the actual bilateral import shares to create the counterfactual foreign knowledge stock. Using this alternative foreign R&D variable yields similarly high coefficients and levels of explanation variation as the regressions using imports data.

A number of authors have made progress by examining the international R&D spillover regression further. Xu and Wang (1999) report that technology diffusion in recent trade and growth models is specifically related to differentiated capital goods trade. This is in contrast to the trade data Coe and Helpman (1995) use to construct to their import shares (from overall trade). According to Xu and Wang (1999) this distinction is important: the capital goods-foreign R&D variable accounts for about 10 percent more of the variation in productivity than does Coe and Helpman's analysis. They also

[9] This is analogous to the domestic R&D-Total Factor Productivity literature as initially proposed by Griliches (1979). In this line of studies, authors have often tried to capture the degree to which productivity in one industry depends on in another by computing weighted sums of outside R&D, where the weights are, for instance, input-output coefficients.

conclude that this variable performs better than Keller's (1998) counterfactual variable.

Overall, the evidence points to a significant role for imports in international technology diffusion. However, the various stands of the literature leave still some questions open, and we do not have yet a firm estimate of the quantitative importance of imports for international technology diffusion.

2.2. Foreign Direct Investment and Multifactor Productivity

Another channel for cross-country technology transfer is *foreign direct investment* (FDI). FDI enables local workers to benefit from the know-how of foreign companies and to learn through practical experience how to become efficient managers and entrepreneurs; it enables local companies to learn by observing at close range how a successful company competes in the global economy. FDI is a plausible channel from a theoretical standpoint, because an influential theory argues that firm-specific technology is transferred across international borders by sharing technology among multinational parents and subsidiaries (Markusen, 2002). There are a number of models showing how multinational corporations might generate technological learning externalities for domestic firms, for example through labor training and turnover (Fosfuri *et al*, 2001) or through the provision of high-quality intermediate inputs (Rodriguez-Clare, 1996).

"Industrial organization" approach to foreign investment in manufacturing suggest that multinationals can compete locally with more informed domestic firms because multinationals possess non-tangible productive assets, such as technological know-how, marketing and managing skills, export conducts, coordinated relationships with suppliers and customers, and reputation. Since these assets are almost always gained through experience, they cannot be easily licensed to host country firms, but can be transferred at a reasonable cost to subsidiaries that located in the host country (Teece, 1977). If multinationals do indeed possess such non-tangible assets, then one would expect that foreign ownership to increase a firm's productivity.

In addition, domestically owned firms might benefit from the presence of foreign firms or participating in joint ventures may accumulate knowledge, which is valued outside the firm. As experienced workers leave the foreign firms, this human capital becomes available to domestic firms, raising their measured productivity. Similarly, some firm-specific knowledge of the foreign owners might "spill over" to domestic industry as domestic firms are exposed to new products, production and marketing techniques, or receive technical support from upstream or downstream foreign firms. Foreign firms may also act as a stable source of demands for inputs in an industry, which can benefit upstream domestic firms by allowing them to train and maintain relationship with experienced employees. In all these cases, foreign presence would raise the productivity of domestically owned firms.

On the other hand, productivity of domestically owned firms can be reduced as a result of foreign presence of corporations. If imperfectly competitive firms face fixed costs of production, a foreign firm with lower marginal costs will have an incentive to increase production relative to its domestic competitor. In this environment, entering foreign firms producing for the local market can draw demand from domestic firms, causing them to cut production. The productivity of domestic firms would fall as they spread their fixed costs over a small market, forcing them back up their average cost curves. If the productivity decline from this demand effect is large enough, net domestic productivity might decline even if the multinational transfers technology or its firm-specific asset to domestic firms.

The potential transfers of knowledge associated with inward FDI have two directions. In the case of offshore production, the host country may benefit from technological externalities emanating from foreign companies. On the other hand, if foreign companies intend to copy or to source to source the domestic knowledge base, their home country is more likely to benefit from potential spillovers.

Dunning (1994) has argued that even though inward FDI may decrease indigenous innovative capacity, outward FDI is likely to have an unambiguously positive effect on productivity ("where foreign.production adds to domestic production, the R&D base of the investing company is strengthened—whatever the nationality of the firm" (p. 81)).

Evidence regarding the FDI is mixed. Using a cross-country framework, Lichtenberg and van Pottelsberghe de la Potterie (2001) found that inward FDI flows did not carry knowledge spillovers among the United States, Japan, and eleven European countries during the period 1971-1990. In other words, inward FDI flows do not seem to contribute to the improvement (or to the reduction) of the technological base of the host countries.

Another study by Xu (2000) using the U.S. Bureau of Economic Analysis' comparable data on U.S. outward FDI into forty countries between 1966 and 1994 finds significant evidence that there is a positive relationship between FDI and productivity growth, which stronger in the developed countries compared to developing countries. Xu finds that the overall effects of technology spillovers through U.S. multinational enterprises (MNEs) affiliates and R&D spillovers increases annual multifactor productivity growth rate of developed countries by 1.34 percentage points during the sample period. In addition, 40 percent of the increase in annual multifactor productivity growth comes from the technology transfer of the US MNEs affiliates. Thus, his results suggest that MNEs are almost as important as international trade a conduit for spillovers among developed countries.

Due to concerns of aggregation bias at the manufacturing level because of heterogeneity across sectors and across firms, Keller and Yeaple (2003) use firm level data to analyze whether FDI leads to significant productivity gains for domestic firms. Their study is based on data on an unbalanced sample of manufacturing firms in the United States from Standard and Poor's *Compustat* database. In addition, using total of 1,115 U.S.-owned firms that were active between years 1987 and 1996 and examining the relationship between firms' total factor productivity growth and the changes in the degree of foreign activity through imports and FDI. The size of FDI spillovers is economically important and it is estimated that they accounted for about 14 percent of productivity growth of U.S. firms.

3. Facilitating Technology Transfers: Education and Infrastructure

To take advantage of technological progress generated elsewhere, a country must invest in education and in local public goods such as infrastructure.

3.1. Education

Barro and Sala-i-Martin (1995), using a large sample of countries between 1965 and 1985, regressed the average growth rate on several macroeconomic variables, including educational attainment, and public spending on education as a fraction of GDP. They conclude that educational attainment (measured by average years of schooling) is significantly correlated with subsequent growth, however if we decompose the aggregate measure of educational attainment the impact of primary education remains largely insignificant. Barro and Sala-i-Martin also report that public spending on education also has a significantly positive effect on growth.

Another study applies econometric estimation to explain variation in 20-year growth rates during 1965-1985 on a cross section of 78 countries (Benhabib and Spiegel, 1994). In their preferred model, technological progress is the sum of two components: an exogenous component, as in the neo-classical model; and a semi-endogenous component, related to the rate of absorption of technology from the technological leading country, captured by an interactive term between the productivity gap and the level of human capital. Benhabib and Spiegel shows that the interactive term is statistically important.

Dowrick and Rogers (2002) conclude broadly similar results. This paper is different from that of Benhabib and Spiegel (1994) because they use a panel growth data instead, and this enables authors to control for country-specific growth effects. Dowrick and Rogers also use an instrumental variable estimator to control for reverse causation between growth and the explanatory variables. They confirm the finding that the level of human capital speeds up technological catch-up, especially amongst the middle-income and richer countries.

Finally, Frantzen (2000) argues that both human capital's level and its increase rate are important for explaining productivity growth. In addition, Frantzen finishes his paper saying 'there is explicit evidence of significant interaction between the level of human capital and the catch-up process" (p. 73).

3.2 Infrastructure and the Economy

The main concern of the infrastructure policies is improvements in the quality of life issues. During the 1980s, however, sufficiency of the stock of infrastructure has been increasingly questioned and analyzed. The final report to the President and Congress of the National Council on Public Works Improvement (1988) emphasizes the significance of infrastructure to economy:

> The quality of a nation's infrastructure is a critical index of its economic vitality. Reliable transportation, clear water, and safe disposal of waste are basic elements of a civilized society and a productive economy. Their absence or failure or failure introduces an intolerable dimension of risk and hardship to everyday life, and a major obstacle to growth and competitiveness (p. 1).

Measures of infrastructure and their potential contribution to macro economy are analyzed in Arrow and Kurz (1970), and in Aschauer and Greenwood (1985). These authors expand on the standard neoclassical production function, expressed in labor-intensive form, to include the public stock of infrastructure capital. In other words, measures of infrastructure enter directly as factors of production in private sector production function. In these models, multifactor productivity and economic growth are increased through cost reductions and/or improved specialization as a result of the "size" and "quality" of the public infrastructure. From an economic standpoint infrastructure capital consists of large capital-intensive natural monopolies such as highways, other transportation facilities, water and sewer lines, and communication systems. Most of these systems are owned publicly and represent the tangible capital stock owned by the public sector[10].

A clear implication of including public capital in the private production technology is that it may play a direct role in promoting private sector productivity. Even though a great number of empirical studies have accumulated, the evidence is far from the conclusive. Some empirical evidence suggests that the public capital stock is an important factor of production in the

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[10] Gramlich (2004) defines this as narrow public sector ownership of the stock of infrastructure capital.

aggregate production technology. Time series evidence is presented for the post-World War II period (1949-1985) in the United States that a "core infrastructure" of streets and highways, mass transit, airports, water and sewer systems, and electrical and gas facilities bears a substantially positive and statistically significant relationship to both labor and multifactor productivity (Aschauer, 1989a). In the same study Aschauer attributes productivity slowdown of the United States during the 1970s and first half of the 1980s to under-investment in infrastructure. In another study, Munnell (1990) estimates similarly strong results for the significance of infrastructure investment in private sector production by adjusting the standard U.S. Bureau of Labor Statistics (BLS) measure of labor input to account for changes in the age/sex composition of the labor force and updating the sample period to 1987. Munnell also calculates adjusted measures of multifactor productivity growth and reports that after accounting for changes in the quality of the labor force and for changes in the growth rate of the core infrastructure capital stock, the decline in multifactor productivity growth during the 1970s and 1980s relative to the 1950s and 1960s is "much more in line with expectations" and that "much of the drop in published multifactor productivity numbers may reflect the omission of public capital from the calculations of inputs rather than a decline in technological innovation (p. 19)."

In line with the previous studies, Aschauer (1989b) applies the cross-country data for the group of seven countries (the United State, Canada, France, Italy, Japan, United Kingdom and West Germany) over the period 1965 and 1985 and shows that after controlling for employment growth and private investment, public nonmilitary investment yields an important and positive relationship with growth in gross domestic product per employed person.

While these studies use neoclassical production function approach to estimate the impact of infrastructure capital on multifactor productivity, other empirical studies apply a dual cost function approach for different countries. The cost structure of an industry would be affected by public capital services in two ways. First, a larger quantity (or better quality) of public capital services will shift the cost per unit of output downward in an industry if the industry receives any benefit from improved or larger public capital services. Second, firms will adjust their demand for labor, intermediate inputs, and physical capital stock if public sector capital services are either substitutes or complements of the factors of production in the private sector. That is, the impacts of public sector services may not be neutral with respect to private sector input decisions.

Berndt and Hansson (1992) uses such a dual cost function approach to analyze the contribution of public infrastructure capital to private sector output and productivity growth in Swedish economy from 1960 to 1988. Authors conclude that private production costs decreases as a result of rises in public infrastructure capital. Berndt and Hanson also compare the growth of multifactor productivity for optimal level of public infrastructure capital whit that of actually realized in the private sector for two different periods between 1960-1973 and 1974-1988. It is reported that assuming private sector long-run equilibrium multifactor productivity growth slowdown would be reduced by 6.1 percent if the public infrastructure capital had been at optimal level.

Nadiri and Mamuneas (1994) analyze the impacts of publicly financed infrastructure and R&D capitals on the cost structure and productivity performance of twelve two-digit U.S. manufacturing industries for the period 1956-1986. They also use duality theory in which the cost function and input demand equations are simultaneously estimated when private production externalities are present in order to measure the effects of public infrastructure capital on industry input demand for labor, materials and capital. Their results similar to studies discussed above also suggest that there are significant productive effects from public infrastructure capital. Even thought the impact of public infrastructure capital on the cost structure varies across industries, it is concluded that an increase in the size or the quality of public infrastructure capital shifts the cost function downward in the industries considered. Moreover, the factor demand in each industry is also influenced by the public infrastructure capital.

The papers discussed above argue that the public capital stock has significant and positive impact upon private sector output and productivity. Most of this literature suggests that a decline in the growth of the public capital stock since the early 1970s caused a "productivity slowdown" in the private sector lowering profitability and investment. A policy implication of these studies is that unless reductions of public infrastructure capital are reversed the nation's standard of living will be further threatened. On the other hand, Tatom (1991) claims that these studies that concludes a positive and significant impact of public infrastructure capital on private sector output and productivity have arisen as a result of spurious estimates. According to Tatom, most of these empirical studies have ignored a trend or broken trends in productivity, as well as the statistically significant effect of energy price changes. By accounting for these two factors and using production faction approach for the period 1948-1998 for the United States private business sector, Tatom finds that the conventional estimates of the elasticity of output with respect to public infrastructure capital is declined from about 30 to 40 percent to about 13 percent. Author also suggests that studies that find a statistically significant public infrastructure capital effect use equation estimates that include nonstationary variables. Therefore, these estimates are likely to be spurious. After addressing all these issues using a first-differenced estimate of the production function, Tatom concludes that the hypothesis of changes in public infrastructure capital will influence the private sector output can be rejected.

Following Tatom's critique about the omitted variables in affecting productivity and problems with the econometrical framework, Holtz-Eakin (1994) estimates production functions including more explanatory variables such as time effects and state/region effects in addition to labor, private capital, and public capital inputs for the state and local governments for the 48 states in the United States over the years 1969 to 1986. After using different estimation techniques such as OLS, GLS and IV, he concludes that "the best estimate of the elasticity of private output or productivity with respect to state and local government capital is essentially zero (p. 20)." Thus, his estimates shows that, contrary to popular belief, public sector capital is not affecting private sector productivity after controlling for unobserved, state-specific characteristics in the production function estimates.

Finally, Evans and Karras (1994) investigate productivity of government activities by estimating aggregate production functions for private nonagricultural gross state products. In addition to traditional inputs, labor and private capital, their production function is extended using government infrastructure capital and current government services. The sample consists of a panel data for the 48 contiguous U.S. states in each year for the period 1970-1986. The types of infrastructure capital they use in their estimations are net stock of highway capital, net stock of water and sewer capital, and net stock of other infrastructure capitals. Current educational services, current highway services, current police and fire services are the examples of the current government services they use as an input in the production function. Their estimates show that only government educational services are productive; however all other government activities taken into consideration are *not* productive. In contrast to other studies those conclude no relationship between government infrastructure capital and productivity, Evans and Karras shows that the productivity of government infrastructure capital is significantly negative.

4. Conclusion

Main purpose of this paper was to survey the landscape of topics that are related to determining factors of multifactor productivity. This survey is based on the theoretical and empirical perspectives, all within the context of generating knowledge and how to absorb created knowledge both domestically and from abroad. Since, it is argued that other competing theories of productivity may be important in explaining productivity differences, whether studies that are just using the different kinds of R&D to explain productivity or using competing theories of productivity such as imports and exports of goods, foreign direct investment, public infrastructure capital stock, and human capital stock may be important factors that changes in these factors might alter the domestic multifactor productivity, policymakers may be missing such information that would be significant to each specific nation.

After discussing the theoretical and empirical studies above we decided to re-examine multifactor productivity relationship with types of knowledge stock together with proposed by other competing economic theories of productivity should be examined empirically in a dynamic equilibrium framework for nations. Such empirical research will be in our research agenda for the future. With such dynamic-panel-model, focusing only on R&D may lead to omitted variables problems. In such case, the estimated parameters will become biased and their implications will be unreliable. Thus, a future research should tackle these omitted variable issues.

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