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ABSTRACT

Together but Apart: ICT and Productivity Growth in Israel*

There is widespread agreement about the important role played by Information and Communication Technologies (ICTs) in the US productivity revival and in the evolving US-EU productivity gap. In Israel, the ICT sector grew very rapidly during the 1990s and became a hotbed of innovation and technological advance by worldwide standards. Yet, Israel's overall productivity growth remained sluggish, with traditional sectors both in manufacturing and services seemingly unable to benefit from the success of the ICT sector. The main goal of this paper is to shed light on these twin developments. We use newly constructed data on industry-level ICT investments between 1990 and 2003 and estimate production functions for manufacturing industries augmented to include ICT capital. We find a significant elasticity of value-added with respect to ICT capital, which increases considerably with the technological sophistication of the industry. We also find that ICT capital deepening is the most important factor contributing to value added growth in manufacturing during 1995-2000, before the burst of the dot.com bubble. Because most ICT capital is concentrated in high tech industries, growth in manufacturing has been mostly confined to the high-tech sector. Facilitating the adoption of ICT in traditional industries is therefore crucial to achieving economy-wide growth. The Israeli experience described here - although restricted to the manufacturing sector - provides a useful example of the benefits and limitations associated with a growth strategy centred on a local ICT producing sector, however successful it might be.

JEL Classification: O3 and O4
Keywords: GPT, ICT and productivity growth

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1. Introduction

The Israeli high tech sector had a remarkable history of extremely rapid growth during the 1990s. About 30 percent of Israel's business sector GDP growth during this period is attributable to growth of the high tech sector (CBS, 2003). This success story was preceded by a steady "incubation" period prodded by substantial support from the government, primarily in the form of R&D grants. The burst of the "dot.com bubble" in 2000/01 brought this process to an abrupt end, and posed serious questions about the viability of an economy-wide growth strategy based on the drive of a single sector.

Indeed, a closer look at the economic performance of the non high tech sectors reveals that the Israeli economy may be suffering from serious ailments which were largely concealed during the boom years of the 1990s. While the high tech producing sector was booming, drawing high-skilled workers, foreign capital and receiving generous government support, most of the traditional sectors of the economy were stagnating; their productivity growth declining. The picture that emerges is one of a *"dual economy"* in the making.

The problem with this picture is that such disparities across sectors cannot support the growth of the whole economy over time. The notion of one sector serving as the "locomotive" that pulls the rest of the economy is simply wrong; there are virtually no examples of such cases in economic history. For an economy to experience sustained growth most of the sectors have to grow in tandem and the productivity gains, which underlie growth, have to be widespread and pervasive. This in turn is made possible by the emergence and spread of "General Purpose Technologies" (GPTs). A fast growing GPT-producing sector is not, however, enough to guarantee sustained growth. It is the adoption of the GPT by a widening range of sectors and the complementary innovations and investments that the GPT prompts in the adopting sectors that are the main forces underlying economy-wide growth.

Given the tremendous surge of the Israeli high tech sector, and its innovativeness, the Israeli economy seemed to have been ideally positioned to take advantage of the leading GPT of our era, namely Information and Communications Technologies (ICT). However, several key features of the ICT sector in Israel prevented the local GPT from operating the way it should. First, the ICT sector in Israel is overwhelmingly export-oriented (over 70% of its output is exported). Thus, the fact that Israel has a thriving and innovative (local) GPT sector does not necessarily imply that the rest of the economy benefits from it in the sense of fast and pervasive adoption of the GPT by other sectors with the concomitant dynamic efficiency gains. Indeed, the non-ICT sectors in Israel are not actively engaged in innovative activities nor are they fast at adopting the latest ICT products and services. Second, government policy in Israel explicitly supports product innovation rather than process innovation, thus unwittingly creating a bias against the service sectors (which constitute most of the economy!), as well as against many other sectors that are process-oriented such as chemicals or construction. Third, funding by venture capital funds encouraged start-ups to aim at a short-run strategy of maximizing expected stock market value *abroad*, thus cashing in, and parting from, the intellectual property created.[1]

By contrast, recent empirical evidence suggests that the pronounced productivity growth experienced by the US economy since the second half of the 1990s took place

[1] Government support to R&D is predicated mostly on the notion that there are extensive spillovers to R&D, and hence that firms may under-invest in innovation. An important question is ***who*** benefits from these spillovers – do they go primarily to other firms in the same sector, or to other sectors as well? It would seem that in Israel these spillovers may have occurred mostly ***within*** and not ***across*** sectors and, moreover, the wider benefits may have spilled over from Israel to foreign economies.

across a relatively wide range of sectors, particularly in intensive *users* of ICT.[2] The prototypical case is retail where one single chain, Wal-Mart, experienced tremendous growth based on the widespread adoption of ICT and concomitant changes in organization, driving the whole retail sector to impressive productivity gains, and indeed having even a noticeable macroeconomic effect.

The goal of this paper is to take a first look at the role played by ICT in Israel's growth experience. Such a study has not been previously conducted because Israel does not systematically collect data on investments in ICT by firms. A large part of this research project was therefore devoted to use indirect sources to put together, for the first time, a data series on ICT investment by industry of use. We use these data to characterize the uneven use of ICT in the Israeli economy and to estimate its effects on productivity in the manufacturing sector. The empirical analysis is conducted at the industry level because, as mentioned above, there are no ICT data at the level of the firm. The paper aims at providing a better understanding of the effects of ICT production and use on growth as well as of the limitations accompanying a growth strategy centered on a local ICT producing sector, however successful.

The structure of the rest of the paper is as follows. Section 2 expands on the concept of GPT. Section 3 reviews the empirical literature on the effects of ICT on productivity. Section 4 briefly describes the evolution of the ICT sector in Israel and of productivity growth across sectors since the beginning of the 1990s. Section 5 presents the newly developed ICT investments series for Israel, its sources, definition and a short descriptive analysis. Section 6 presents econometric estimates of the effect and contribution of ICT capital to productivity in the Israeli manufacturing sector. Conclusions close the paper.

[2] See, for example, Stiroh (2002b), Jorgenson (2001) and Oliner and Sichel (2002).

2. ICT as a General Purpose Technology

In recent history, one can identify only a handful of "General Purpose Technologies" (GPTs) that played a critical role in fostering economic growth over the long run. GPTs drive long run growth through its diffusion to different sectors of the economy. These sectors, in turn, use the GPTs to advance their own technologies. This technological change in the adopting sectors feeds back to the GPT-producing sector providing additional incentives for further advances in the GPT itself. This feedback between originating and using sectors underlies the growth power of the GPTs. Classic examples are the steam engine in the 19th century and electricity in the first half of the 20th century. [3]

The preeminent GPT of our era is undoubtedly Information and Communication Technology (ICT). In the last two decades, the very term "innovation" has been usually associated with technological advances in ICT. The advent of the personal computer, Internet, cellular phones, digitalization of words, voice and images, etc., which have benefited from the rapid advance in microprocessor technology, have revolutionized the way we produce, consume and make use of our leisure time.

The way a GPT fosters economy-wide growth is not simply by continuing innovation in the GPT-producing sector itself. The ICT-producing sector is bound to be small relative to the economy as a whole and, no matter how fast it innovates and grows, it can never pull an entire economy on its own. Rather, the key feature of a GPT is that a wide and ever expanding range of other sectors adopt the advancing GPT. This leads to improvements in their own production technologies thereby leading to economy-wide growth. The often used analogy of the ICT-producing sector as a "locomotive" pulling the whole economy forward is wrong and misleading: if the rest of

[3] See Bresnahan and Trajtenberg (1995) and Helpman and Trajtenberg (1998).

the economy fails to adopt the ICT, or fails to make complementary innovations in the adopting sectors, economy-wide growth will not materialize.

This is not always easy to accomplish. Because the adoption of GPTs usually requires changes in work methods and in production technologies, it often involves significant adjustments costs associated with changes in organizational structure and with the retraining of employees. Furthermore, in order to gain network externalities and spillover effects from the GPT, a sufficient critical mass of GPT capital is required. We know from past experience that it takes some time for the economy-wide effects of a GPT to leave their imprint on the aggregate growth statistics. For example, David (1990) studied the evolution of the electric dynamo. The dynamo was first used in the early 20th century but had a broad and significant productivity impact only after 1920.

This characterization of a GPT, in conjunction with the increase in trade due to globalization, may wrongly suggest that the development of a *local* ICT-producing sector is redundant. On the contrary, a vibrant local ICT- producing sector plays an important role in the process of growth because of the concomitant development of local technological skills, managerial expertise, and world class standards in ICT. A successful local ICT-producing sector also requires a significant opening up of the economy which, by itself, encourages inflows of capital, expands trade and, in general, is a policy change believed to be productivity-enhancing. Thus, the spillovers of a thriving local ICT-producing sector may play a crucial role in prompting the rest of the economy to follow suit. The point, however, is that the existence of a local ICT-producing sector by itself may not be enough to generate sustained and widespread growth, or such growth may take too long to materialize. Government intervention may be required to incentivate the adoption of ICT by non high tech users.

3. Literature Review

During the last twenty years, economists have examined the link between the IT revolution and productivity gains. Until 1995, productivity growth in the US remained sluggish despite the evolving computer revolution. This puzzle, commonly referred to as "Solow's paradox", ended only with the acceleration in productivity growth that started in 1995.[4] During the last decade, a consensus has emerged that ICT is a driving force behind the resurgence of US productivity growth (Jorgenson and Stiroh (2000) and Oliner and Sichel (2000)).

The impact of ICT on productivity is believed to occur through three main channels. First, the rapidly declining prices of ICT products -- driven by rapid and accelerating technological progress (particularly in the manufacturing of semiconductors) -- triggered high growth in ICT investments. These investments represent an increase of ICT *usage*, and the associated ICT capital-deepening increases productivity (Jorgenson, 2001). Second, the very rapid productivity growth in the ICT-*producing* industries accounts for a substantial amount of the overall productivity acceleration (Jorgenson, Ho and Stiroh, 2003). Third, ICT capital as a form of GPT increases productivity by enabling more efficient organizational forms, networking externalities and spillover effects.

Empirical research examining the productivity revival in the US decomposed the observed productivity growth into its various channels. The consensus appears to be that a major portion of the productivity acceleration came from the two first components:

[4] This is consistent with that view that the effects of a GPTs are felt only after a (sometimes considerably) period of time. This lag may be a result of unrealistic expectations derived from a relatively very small share of ICT capital in the US economy at the beginning of the 1990s (Oliner and Sichel, 1994). It may also be a result of severe measurement problems and of the relatively small and inaccurate samples used in early studies.

ICT capital deepening and TFP growth in the ICT-producing industries.[5] The third component – changes in organizational forms prompted by the adoption of ICT and spillover effects- is more difficult to estimate and the magnitude of this effect is still somewhat unclear (Stiroh, 2002a).

More detailed, industry-level, decompositions of aggregate labor productivity growth confirm that virtually all the acceleration in aggregate productivity growth is traced to industries which either produce ICT or use ICT most intensively.[6] Furthermore, studies by Bosworth and Triplett (2003) and Jorgenson, Ho and Stiroh (2004) show that the biggest contributors to aggregate ICT capital-deepening are a limited number of services industries, particularly trade, finance and business services, which were traditionally considered low-productivity growth sectors. In a dissenting view, Gordon (1999, 2000) argues that the majority of the recent productivity acceleration is due to cyclical forces and the remainder is concentrated only in industries engaged in the production of ICT and other durable goods.

In contrast to the US experience, the link between the ICT revolution and productivity growth in European economies is still not entirely understood. After WWII, it took Europe fifty years to catch up with the productivity level in the US. But, as of 1995, Europe has begun to fall behind the US in its productivity level. Recent research finds that ICT plays a significant role in explaining this expanding EU-US productivity gap. Europe's lagging growth might be caused by a smaller ICT producing sector,[7] lower ICT investment rates,[8] a less productive usage of ICT or a combination of all these factors.[9]

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[5] See, for example, Oliner and Sichel (2002) and Jorgenson, Ho and Stiroh (2003).

[6] See, for example, Stiroh (2002b), Jorgenson (2001) and Oliner and Sichel (2002).

[7] For further details see, for example, Colecchia and Schreyer (2001) and Daveri (2002).

Industry-level decompositions examining the EU-US productivity divergence find that, much of the EU failure to achieve labor productivity acceleration can be traced to the role played by key ICT-using industries. These industries, mainly services industries such as retail, wholesale and finance, played a very significant role in the US productivity resurgence but such role eluded them in most European countries.[10] There are several explanations for this. First, it appears that US firms enjoy some general environmental advantages that enable them to utilize, in better and faster ways, the new technologies. These advantages may include more competitive markets, less stringent regulations in product and labor markets, better access to capital markets, better infrastructure, superior experience with supporting ICT technologies, more qualified workers, larger market size, and other factors.[11] A second explanation is that US firms have internal organization structures ("organizational capital") that are more suitable to a better exploitation of ICT. For example, US firms are believed to have better managers and to be more decentralized or have flatter hierarchies than its European counterparts.[12, 13]

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[8] For example, Colecchia and Schreyer (2002) and van Ark, Melka, Mulder, Timmer and Ypma (2002) had found significant ICT investments gaps.

[9] Timmer and van Ark (2005) find that higher ICT capital contributions and more TFP growth originating from ICT-producing industries almost explain the entire US advantage in labor productivity over Europe since 1995.

[10] See, for example, Inklaar, O'Mahony and Timmer (2003), O'Mahony and van Ark (2003) and van Ark, Inklaar and McGuckin (2003).

[11] For further details see Gordon (2004) and Timmer and Van Ark (2005)

[12] Bresnahan, Brynjolfsson and Hitt (2002) argue that the internal organization form plays an important role in generating returns to ICT. Furthermore, as a possible proof of the US organization's superiority, Bloom, Sadun and Van Reenen (2006) find a stronger association between productivity and IT for US-owned establishments located in UK than for UK domestic establishments.

[13] Errors in measurement can potentially also explain the difference between the US and the EU. There is a wide literature discussing measurement issues associated with the expanding usage of intangible assets, e.g., software, and the difficulties of creating hedonic prices for ICT products. Even tough these

The overall poor productivity performance in the EU during the last decade masks a large variance across European countries. While labor productivity growth rates declined in most of the largest countries such as France, Germany, Italy, the UK and Spain, it did accelerate in many of the smaller countries such as Greece, Ireland, Austria and Sweden. Focusing on ICT, the data point to a significant variance in ICT investments rates. In 2004, the share of ICT investment out of GDP varied between 1.1 percent in Ireland to 3.7 percent in Finland (Table 1). Note that the share of ICT investment in the US in 2004 was larger than the share of any individual EU country and about twice the average share across EU countries. Table 2 shows that the share of the ICT-producing sector out of GDP is larger in the US than in most European countries, and that it also varies significantly across EU members.

Timmer and van Ark (2005) examine the role of each of the ICT-induced growth channels. They find that differences in the contribution of ICT capital deepening and in TFP growth among ICT-producing industries almost fully explain the labor productivity growth gap between the EU and the US. In contrast, non-ICT sources of growth are the major driver of divergent labor productivity growth within Europe.

To summarize, the empirical literature suggests that ICT played a very significant role in the US productivity resurgence. ICT affects overall productivity through rapid technological change in the ICT-producing sector and through increasing ICT use by other sectors. Furthermore, ICT was also found to be an important contributor to the divergence in the productivity growth path between the EU and the US.

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measurement issues may have a significant affect on empirical studies (especially for industry-level comparisons as in Schreyer, 2002), O'Mahony and Van Ark (2003) still find a significant difference between the US and the EU after comparing the same industries and adjusting the data by similar methods.

4. The ICT Sector and Productivity Performance in Israel

"*Israel is a high tech superpower*", Bill Gates, 2005

The development of an innovative and highly successful ICT-producing sector in Israel constitutes an interesting case that exemplifies both the potential and the limitations of the ICT-producing sector as a lever for economic growth. Israel has little natural resources but has plenty of highly skilled manpower as well as scientific and technological prowess. The government's main policy challenge is to mobilize these assets for economic growth. It did so by initiating, and running, a long-term, dynamic program of governmental support for commercial R&D. By all accounts, these programs were crucial in laying down the foundations not only of the ICT-producing sector but also of a sprawling venture capital (VC) industry in Israel. [14]

Since the first, government-backed, VC firm made its appearance in Israel in the early 1990s, the venture capital market in Israel has boomed. In the last decade there were more than 80 VC firms in operation that raised more than 14 billion dollars. Actual VC-backed investments reached a world-record 2.7 percent of GDP in 2000 (Avnimelech and Teubal, 2005). Governmental policy, together with favorable contributing factors such as the training of young cadres of ICT specialists by the defense sector and the immigration of highly skilled and educated labor force from the former Soviet Union, managed to unleash the potential embedded in Israel's abundant human capital. Consider the following facts about the growth of the ICT-producing sector and VC industry in Israel since the early 1990s:

[14] See Trajtenberg (2001, 2002) for a description of Israel's innovation policy and performance and Lach (2002) for a critical evaluation of R&D grants in Israel.

- The ICT sector grew over the 1990s at an average annual rate of 16 percent and between 1997 and 2005 it grew at an annual rate of over 7 percent.
- The ICT sector represented 8 percent of the business sector GDP in 1990 and reached 16 percent in 2005 (CBS, 2002).
- It is estimated that the ICT sector contributed a third of the growth in the business sector's GDP between 1990 and 2002 (CBS, 2003).
- ICT exports grew over the 1990s by a factor of 6, reaching 13.5 billion US dollars by 2005, and accounting for more than 25 percent of total exports.
- Israeli original innovations include major breakthrough such as: disk-on-key, cardiac stents, a pill camera for gastro imaging, instant messenger (ICQ), voice mail etc.
- There are over 4,000 high tech companies operating in Israel out of which 2,500 are start-up companies. This makes Israel into the largest concentration of start-up companies outside the United States.
- Israel is the third largest country, after the US and Canada, in terms of number of firms in NASDAQ.

For all the staggering successes of the ICT-producing sector in Israel, the rest of the economy, however, did not do so well. Non-ICT-producing sectors experienced very sluggish growth during the last decade. During 1997-2005, while the ICT sector grew at an annual rate of over 7 percent, the rest of the business sector grew at an annual rate of just 2.5 percent. The rest of the business sector does not show much innovative activity either. Even tough Israel is ranked number one in the world in terms of the share of R&D expenditures in GDP (4.5 percent in 2003), the non-ICT sectors are not significantly engaged in R&D activities. The share of the ICT sector out of total business R&D expenditure was 89 percent in Israel in 2003 compared to 36 percent in the US and 24 percent in the UK (see Table 2).

Labor productivity in the Israeli business sector grew at an average rate of 1.15 percent per year during 1986-2004. This growth rate is much smaller than in most OECD countries. Moreover, the productivity performance of the Israeli economy deteriorated during the 1990s (Figure 1). In contrast, the US experienced an acceleration in productivity growth during the 1990s, particularly during 1995-2000, which is widely believed to be associated with the ICT investment boom.

Part of the reason for the sluggish growth in labor productivity surely has to do with the increase in the number of workers due to the massive immigration from the Former Soviet Union (FSU), which started in 1990. The immigration wave was very significant - 200,000 immigrants arrived during 1990, representing 4 percent of the population. During 1991 the flow of immigrants declined to about 150,000 and stabilized at around 65,000 until 1995.[15] By and large the FSU immigrants were highly educated and skilled but their assimilation into the local economy was not costless. There is evidence that the imported skills brought by the immigrants were not properly rewarded in the local labor markets (Flug et al., 1997). To some extent, the Israeli economy succeeded in absorbing a large influx of workers - unemployment actually declined from 9.6 percent in 1990 to 6.8 percent in 1995 - but it may have paid an efficiency cost in terms of assigning the newly-arrived workers to low-skilled, low-productivity jobs.

Massive immigration, however, cannot be the complete story beyond the productivity slowdown in Israel because other countries, such as the UK, Germany,

[15] Overall, more than a million immigrants (mostly from the Former Soviet Union) arrived in Israel between 1990 and 2001, representing over 16% of the 2001 population.

Italy, Portugal and Spain, also experienced a labor productivity growth slowdown after 1995 (Timmer, Ypma and van Ark, 2003; Daveri, 2002).

Although less obvious, this productivity growth deterioration also occurred in the manufacturing sector. In this sector, labor productivity growth before 1990 was higher than after 1990, but growth accelerated in the second half of the decade (Table 3). It follows that what drives the decline in business sector labor productivity growth during 1995-2000 is the poor productivity performance of the non-manufacturing business sector. Indeed, the picture that emerges here is one where productivity growth is focused in the manufacturing sector and whatever drives productivity growth in this sector is not affecting other sectors of the economy.

Furthermore, productivity growth has been also very uneven within the manufacturing sector and was significantly biased towards high technology industries. Table 4 shows the value added and value-added per hour across different manufacturing industries grouped by their technological sophistication between the years 1995 and 2002. The high tech industries are more productive in terms of value–added per hour than industries in the other two groups and, until 2000, also increased their productivity at a much rapid pace. The high tech industries also suffered the most from the burst of the dot.com bubble.

The Israeli economy offers a fascinating illustration of extraordinary successes in the high tech sector (of which the ICT-producing sector is its main component) along mediocre growth performance in the rest of the economy. A long term strategy of governmental support of commercial R&D, which levered the potential of a highly skilled labor force, facilitated the ICT successes. Yet, the diffusion and adoption of ICT technologies across other sectors of the economy has not yet materialized. The benefits from the ICT sector eluded the rest of the economy, thus giving rise to a "dual economy" in the making.

Understanding these seemingly contradictory outcomes may provide valuable insights about the different effects of ICT on economic performance. This is important not only for assessing the Israeli experience but also, more generally, for gaining an understanding of the limitations accompanying a growth strategy centered only on growth in the ICT-producing sector and the risks associated with narrowly targeted innovation policies.[16] A "dual economy" growth strategy is problematic not only from a normative perspective but also because it may dramatically affect the growth potential of the economy by restricting the future pool of skilled labor and by laying the basis for frictions and tensions that are detrimental to growth.

5. The ICT Data in Israel

It is quite surprising that for all the successes of the ICT-producing sector, Israel does not have an official data series on investment in ICT. This Section summarizes our construction of such data from administrative sources.[17] These data permit a first analysis of ICT usage in the Israeli economy and a first econometric estimation of the contribution of ICT to productivity growth in Israel (see Section 6).

Definitions and Sources

Various definitions of ICT products and services have been used in the literature. These definitions range from very narrow ones - including only computers and peripheral equipment - to more expansive ones covering, in addition, communication

[16] See Trajtenberg (2006) for a thorough discussion of Israeli innovation policies, their effect on the "dual economy" and government policy.

[17] All technical details and a more complete analysis of the data are in Shiff (2007).

and other information equipment. The definition of ICT employed in this study is based on the definition employed by the OECD (2000) and also used by the Israeli Central Bureau of Statistics (CBS). Table 5 shows the industries whose products or services are classified as ICT according to the OECD using the International Standard Industrial Classification (ISIC) scheme (and its mapping to the SIC scheme used by the CBS).[18] Note that this is a very broad definition of ICT because it includes industries producing various types of measuring and testing instruments as well as industrial control equipment (SIC 340 and 342), which are sometimes excluded from ICT definitions.[19] In addition, the Research and Development industry (SIC 73) is included in the Israeli ICT definition (but not in the OECD definition) because Israel has an intensive start-up activity in ICT and most of the start-up firms belong to SIC 73. SIC 73 includes the research centers of multinational companies active in the ICT field (e.g., IBM, Microsoft and Motorola).

Not all of the ICT sector's products and services are defined as investments. For example, products such as insulated cable and wire (SIC 3120 and 3121) and semiconductors (SIC 3210) are inputs into the production process. These are intermediate goods and are not considered an investment. This is also true for computer services except for software (SIC 72 except SIC 721 and 725), which are mostly expenditures related to the use of computers. In the last column of Table 5, the industries whose ICT products are classified as investment in ICT are marked with a √.

ICT investment products are either imported or produced domestically. The data on imports arrive to the CBS directly from the Customs Authority. Each imported

[18] All references in the paper are to the SIC used by the Israeli CBS. Details appear in the CBS Industry Classification (2003).

[19] International comparisons based on the Groningen Growth and Development Center data exclude these industries. When necessary we adjusted the ICT definition for Israel to make it as similar as possible to the definition used by international data sources. See footnote 24.

investment product is classified into one of 7 product types based on 3-digit SICs (SICs 300, 301, 320, 330, 332, 340 and 342). The CBS assigns imports of each type of ICT product to a 2-digit industry-of-use based on customs records and other information.[20] Data on domestic ICT production are obtained from the CBS's annual Manufacturing Surveys and are only assigned to 1-digit industries-of-use. We reassigned the domestic production from 1-digit to 2-digit industry-of-use using imported ICT shares. The software investments data is constructed differently from the other ICT assets and is classified into 'own account software', 'custom software' and 'packaged software'. Because there is currently no detailed industry-level specification for the software investments, the industry-level analysis described here will exclude software investments.

All the ICT investment series are converted to 2000 prices. The Israeli CBS does not compute its own quality adjusted price indexes (hedonic prices), but the data have some indirect hedonic features because the CBS relies on the US hedonic price indexes for the imported ICT assets price indexes.[21]

In Israel, the Customs Authority for imports, and the Manufacturing Surveys for domestic production, are the *only* sources of official data on ICT investments currently available. Specifically, there are no direct, firm-level, data on ICT investments. The annual Manufacturing Surveys do collect data on investment by type (equipment, structures, etc.) but do not isolate their ICT components. [22]

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[20] For details on this procedure as well as on the conversion of the nominal flows to real 2000 prices see Shiff (2007).

[21] Alternatively, one could estimate the local hedonic data series based on the US hedonic price indexes (i.e., the "harmonized prices" methodology described by Schreyer, 2000). For a demonstration on the Israeli data and a short discussion about its implications see Shiff (2007).

[22] In the 2001 Survey of Trade, Services, Transport and Communications firms in the service sector there is a preliminary and limited attempt to isolate investments in computers and software from other office equipment.

ICT Investment

The steep decline in ICT prices together with a growing scope in the applications of ICT has encouraged investments in ICT to a varying extent in all developed countries. The lack of official ICT data prevented us from examining this issue in Israel. The newly constructed ICT data is therefore an important first step for investigating the pattern of ICT investment in Israel and compare it to other countries.

Table 1 presents an international comparison of the share of ICT investment in GDP. Between 1990 - the first year ICT data are available - and 2000 - the year the dot.com bubble burst, Israel has been steadily increasing its share of GDP devoted to investment in ICT. The share of ICT investment almost doubled over this period from 1.7 percent of GDP in 1990 to 3.1 percent in 2000. This is indeed a remarkable achievement but hardly surprising because of Israel's low initial ICT investment share in comparison to other OECD countries. Ireland, whose share was 0.62 percent in 1990, increased its ICT investment share almost fourfold over the same period. On the other hand, the GDP share of ICT investment in Spain and Italy (not shown) was almost stagnant during the decade.

Between 1990 and 2000 the level of ICT investment increased at an average annual rate of 9.6 percent, which is slightly higher than the non-residential investment growth rate (Table 6). As a result, the share of ICT in non-residential investment (column 3) did not change much during the period, hovering around 23 percent.[23] At the same time GDP increased at an average annual rate of 5.3 percent implying a 49 percent

[23] Except for a few years during the first half of the decade when non-residential investment increased considerably. Between 1992 and 1996, non-residential investment increased by 61 percent due to the massive immigration from the Former Soviet Union.

increase in the GDP share of ICT investment.[24] At the end of 2000 Israel entered a recession phase as a result of the worldwide high tech slowdown and the beginning of the Al-Aqsa intifada. Total investment as well as ICT investment steadily declined after 2001.

The composition of ICT investment is biased towards software. Software accounts for 34 to 46 percent of ICT investment depending on the year.[25] There seems to be an upward trending in the share of software but a longer time period is required to provide a definite characterization. A comparison of the software share across countries is instructive. Excluding the instrument and control equipment industries (SIC 340 and 342) from ICT to make the shares comparable, we find that since 1990 Israel directed about half of its ICT investments to software. This is a much higher share than in other European countries where the average software share reached a maximum of 45 percent in 2003. Thus, ICT investment in Israel was software-intensive. This is an interesting characteristic of the ICT investment in Israel. It may reflect the rapid pace at which Israel augments the capabilities of ICT hardware and may have implications towards the productivity effects of ICT investments.[26]

Actually, the type of ICT investment who has been increasing the fastest is, not surprisingly, computers and electronic components, at an average annual rate of almost 9 percent during 1990-2003, while software increased by 7 percent per year. Instrument and control equipment did not increased much during the period and their share in ICT investment declined steadily from 29 percent in 1990 to only 13 percent in 2003.

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[24] The 85 percent increase in the GDP share of ICT investment observed in Table 1 is due to the more restricted definition of ICT used in the international comparisons (excluding SIC 320, 340 and 342).

[25] The real figure on software investments may be even higher because of problems in monitoring some of the prepackaged software purchases done online or through user licenses.

[26] Regretfully, we will not be able to estimate the effect of software on productivity because there is no allocation of investments in software to using industries.

The distribution of ICT investments also changed quite dramatically during the 1990s. Table 7 shows that the Manufacturing and the Transportation/Communications sectors increased their share of ICT investment on account of Trade and Services. The share of the latter sector declined by 30 percentage points during 1990-2003, even tough the size of the sector (in employment terms) increased during the same period. In fact, the flow of ICT investments in this sector in 2003 was lower than that in 1990. This downward trend should be kept in mind when analyzing the productivity growth in this sector.

Another "dual-economy" characteristic of the Israeli economy is that in 2002 over 60 percent of the ICT capital was located in the ICT sector itself (compared to about 40 percent in the US).[27] This implies that ICT capital per worker was 7 times larger in the ICT sector compared to other sectors. Because of the important role played by ICT capital in generating productivity growth (especially in some services industries in the US), this difference in ICT capital per worker will be part of the explanation of the poor productivity performance in Israel. [28] This issue is taken up Section 6.

Data Construction

The ICT capital data series, for each of the ICT investments product, was constructed using the ICT investments series and the Perpetual Inventory Method (PIM)

[27] Based on BEA data, excluding software capital (there is no industry-level software capital data for Israel).

[28] Usually ICT-intensive industries, such as finance and trade, show relatively low ICT investments shares in the Israeli data. This may be due to a general measurement error that occurs in the assignation of the "indirect" ICT imports data (imports done by traders) to industries of use. This assignation is based, in part, on an old survey where finance and trade are underrepresented. The finance industry is likely to be severely affected by this error due to changes in its dependency on ICT products. Note that these industries (trade and finance) are excluded from the econometric estimation in Section 6 which uses data on the manufacturing sector only.

with constant geometric deprecation rates. For example, the capital stock for asset x in period t is: $K_{X,t}=\sum_{j=0}^{\infty}(1-\delta_X)^j I_{X,t-j}=(1-\delta_X)K_{X,t-1}+I_{X,t}$, where $I_{X,t}$ is gross investment in period t (in constant prices), $K_{X,t}$ is gross capital stock (in constant prices) and δ_X is the asset's constant depreciation rate.

The initial capital stock (for 1990), was constructed under the assumption that the pre-sample investment growth rate was equal to the average growth rate in the first 5 years of the sample (between 1990 and 1994). Thus, following Hall and Mairesse (1995), the initial capital stock ($K_{X,1}$) is:

$$K_{X,1}=I_{X0}+(1-\delta_X)I_{X,-1}+(1-\delta_X)^2 I_{X,-2}+....=\sum_{j=0}^{\infty}(1-\delta_X)^j I_{X,-j}=I_{X,0}\sum_{j=0}^{\infty}\left[\frac{1-\delta_X}{1+g_X}\right]^j$$

Or - $K_{X,1}=\frac{I_{X,1}}{g_X+\delta_X}$, where $I_{X,1}$ is the investments rate in asset x in the first year of the sample (1990) and g_X is the average growth rate of investments in asset x between 1990 and 1994.

The depreciation rates for each ICT asset are based on the U.S. Bureau of Economic Analysis (BEA) depreciation rates, after matching each of the ICT assets in the Israeli data to a parallel asset in the BEA data.[29] Even tough the depreciation rates may differ between the US and Israel, abundant previous research in other countries used US depreciation rates and there currently is no compelling evidence that this may have caused significant and consistent biases.

The non-ICT capital was constructed using the ICT capital data. The total capital stock by industry was constructed by the Bank of Israel and is currently available only

[29] These depreciation rates are described in Jorgenson and Stiroh (2000) and in Moulton, Parker and Seskin (1999). The matching of assets was done using conversion tables from the Israeli SIC to ISIC and from ISIC to NAICS, and by manually matching the assets' descriptions.

for manufacturing industries. The econometric analysis is therefore limited to the manufacturing sector. Other industry-level data for the manufacturing sector were taken from the CBS annual manufacturing surveys. Taking account of differences in aggregation levels across the different series leaves us with data on 18 manufacturing industries for the period 1990-2002 (see Shiff (2007) for details).

6. The Contribution of ICT to Growth

The contribution of ICT to productivity growth is derived from estimates of the elasticity of output with respect to ICT capital. This elasticity is estimated from a standard Cobb-Douglas production function augmented to include two types of capital: ICT capital (K_{IT}) and non-ICT capital (K_O):

$$Y = AK_{IT}^{\alpha_{IT}} K_O^{\alpha_O} H^{\alpha_H} e^u$$

where Y is value-added and H are hours worked.[30]

The estimated equation is

$$\ln Y_{it} = \ln A_{it} + \alpha_{IT} \ln K_{IT,it} + \alpha_O \ln K_{O,it} + \alpha_H \ln H_{it} + u_{it}$$

where *i=1,…,18* is the industry index and *t=1995,…,2002* is the year index. Data for the 1990-1994 period are used to construct the stocks of capital.

We assume that

$$\ln A_{it} = \lambda_0 + \lambda_i + \lambda_t$$

Preliminary tests indicate that the presence of the industry effect is not sufficient to capture all the serial correlation in output. We therefore assume that u_{it} follows an AR(1) process with heteroskedastic variance

[30] We also estimated versions of this equation with gross product (and intermediate materials) and the results are qualitatively similar.

$$u_{it} = \rho u_{it-1} + \varepsilon_{it}$$

where ε_{it} is *i.i.d* within and across industries with variance σ_i^2. More complex forms of serial correlation are unwarranted because of the small number of observations. The model is estimated by Prais-Winstein FGLS assuming an AR(1) process for u_{it}.

Table 8 shows the estimates of the production function parameters using the CBS definition of ICT capital. In column (1) we do not distinguish between types of capital and obtain insignificant estimates of capital elasticity. In Column (2) we split capital into its ICT and non-ICT components and obtain a significant elasticity for ICT capital but not for non-ICT capital. Moreover, the ICT capital's elasticity is an order of magnitude larger than the non-ICT capital elasticity. Column (3) presents OLS estimates that ignore the serial correlation (but correct for heteroskedasticity) to verify that the point estimates are similar to the FGLS estimates.

We grouped the 18 industries into 3 groups according to their level of technological sophistication as in Table 4 and, in column (4), we allow the ICT elasticity to vary by group.[31] The substantive finding here is that the ICT elasticity increases with the technological level. The ICT capital elasticity is much larger in the high tech sector (0.68) than it the low tech sector (0.05). These estimates, especially those for the high tech sector, may be biased upwards if more productive firms invest in ICT capital but it is doubtful that correcting for this endogeneity bias can reverse the conclusion that ICT capital appears to be more productive in more high tech

[31] The *high tech* group includes: Chemicals, Electronics, Machinery and Transportation. The *medium tech* group includes: Metal, Metal Products, Mineral, Mining, Rubber and Plastic and Others. The *low tech* group includes: Clothing, Food, Leather, Paper, Printing, Textile and Wood.

industries.[32] This result is not driven by the presence of ICT producing industries in the high tech sector. Gordon (1999) argued that the ICT revolution increased productivity mostly in the ICT-producing industries and nowhere else. When the electronics industry is excluded from the regression, in column (5), the result that the high tech sector has a larger ICT elasticity is preserved. This means that ICT-using industries in the medium and high tech sectors are also making productive use of ICT capital.

Note that omitting interaction terms between ICT capital and technological level decreases the estimate of other capital from 0.14 to 0.05. This is to be expected when ICT and other capital are negatively correlated within the high tech sector and when the level of other capital is lower, on average, in the high tech sector than in the rest of the economy.[33] Thus, ignoring the heterogeneity in the elasticity of ICT capital can bias the parameter estimates of other capital downward thereby exaggerating the role of ICT capital.

We can use the estimated parameters to assess the contribution of ICT capital and the other inputs to the growth in aggregate value added. Let I be the number of industries in a sector. We define aggregate growth between period 0 and period 1 as the weighted average growth across all I industries,

$$\sum_{i=1}^{I} s_{i,0}\left(\ln Y_{i,1} - \ln Y_{i,0}\right) \qquad s_{i,0} = \frac{Y_{i,0}}{\sum_{i=1}^{I} Y_{i,0}}$$

where the weights are the industry share of value added in the initial period and

$$\ln Y_{i,1} - \ln Y_{i,0} = \alpha_{IT} \Delta \ln K_{IT\,i,1} + \alpha_O \Delta \ln K_{O\,i,1} + \alpha_H \Delta \ln H_{i,1} + \lambda_1 - \lambda_0 + u_{i,1} - u_{i,0}$$

[32] When estimating the production function separately for each sector we find elasticities of 0.35, 0.32 and 0.14 as we move from the high to the low tech sector; the estimates are all significant even though the number of observations is small (40, 48 and 56, respectively).

[33] Indeed, these two conditions guarantee that the omitted interaction term in column (3) is negatively correlated with the other capital included in the regression.

with $\Delta \ln X_{i,1} = \ln X_{i,1} - \ln X_{i,0}$ for $X = K_{IT}, K_O, H$.

The contribution of ICT capital to value-added growth during the period is $\alpha_{IT} \sum_{i=1}^{I} s_{i,0} \Delta \ln K_{IT\,i,1}$ while the contribution of the residual to growth is $\sum_{i=1}^{I} s_{i,0} (\lambda_1 - \lambda_0 + u_{i,1} - u_{i,0})$.[34]

Tables 9.1-9.5 decompose growth in value added into the contributions of capital (ICT and other), hours and a residual using estimates from column 4 in Table 8. This is done for manufacturing as a whole and for groups of industries classified according to their technological sophistication.[35] During the 1995-2002 period, the manufacturing sector exhibited sharp changes in growth performance: value added grew at a moderate annual rate during 1995-1998, and accelerated considerably during the dot com "bubble" period of 1999-2000. The recession following the burst of the dot.com bubble hit the manufacturing sector hard and value added declined by almost 10 percent per year on average.

During the period 1995-2000, the main factor contributing to growth in the manufacturing sector is the accumulation of ICT capital, followed by the accumulation of other type of capital. In particular, all the growth in manufacturing value added comes from the high tech sector, in which the ICT capital was the most important

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[34] $\lambda_1 - \lambda_0 + u_{i,1} - u_{i,0}$, the residual, is often interpreted as TFP growth for industry i. This is sometimes problematic because it may also pick up demand changes, not only technical change. We do not assign any significance to the residual except for what it really is: the difference between observed and predicted growth.

[35] In each tech sector, the contributions of the different industries are weighted by the share of each industry's value added in its corresponding tech sector's value added. In the manufacturing sector as a whole, industry shares are out of total manufacturing value added. Therefore, weighting each tech sector's entries by its share of manufacturing value added and adding gives the entries in panel A. Between 1995 and 2002, the low tech sector's shares declined from 34 to 27 percent, were stable at about 24 percent in the medium tech sector and increased from 36 to 49 percent in the high tech sector.

contributor.[36] The sharp decline in growth after the dot.com bubble burst is again due mainly to the high tech sector. Note that the residual negative growth is significant especially during those years, suggesting that other external factors besides the ones used in this analysis contribute to productivity growth crisis (e.g., sharp demand fall).

Ignoring the residual, ICT capital is also the main factor driving growth in the medium tech sector, although value added declined slightly during the sample period. In the low tech sector, however, ICT is no more important than other capital accumulation.

Table 10 summarizes the contribution of ICT to valued-added growth by technological group and period. The entries are ICT capital contributions from Table 9 weighted by the share of value added in each tech sector. There was an upward trend in the contribution of ICT capital until 2000, when the dot.com bubble burst. Thereafter its contribution is zero or even negative. Moreover, we can see that all sectors suffered from the 2000 crisis, but as expected the high sector suffered most severely. Interestingly, during 1995-2000 the relative contribution of ICT capital compared to the contribution of other capital is highest in the medium tech sector, and not in the high tech sector. This finding emphasizes the importance of ICT usage in those industries.

We use the estimates in column 4 of Table 8 to derive the implied rates of return to both types of capita. Multiplying the estimated capital elasticities by the ratio of value-added to capital gives an estimated rate of return of 200% for the high tech sector, 145% for the low tech sector, and 92% for the low sector. These returns are quite large, even after accounting for user costs of ICT as high as 42%, as suggested by Jorgenson and Stiroh (1995). These large returns reflect both the low level of ICT capital in Israel and

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[36] The contributions for each period are obtained by adding up the yearly contributions and growth in value added and dividing by the number of years in the period.

the high estimated ICT capital elasticities.[37] The implied rate of return to other (non-ICT) capital is 6.5% which is within reasonable bounds.

The large magnitudes of these estimates are not unusual. Using a similar production function framework, Hempell (2002) reports even higher rates of return to ICT investments in services firms in Germany (nearly 400%), while the gross returns for the other capital were estimated to be 5.8%.[38]

7. Summary and Conclusions

This paper examines the role of ICT in fostering economic growth in Israel. The Israeli high tech sector (of which the ICT-producing sector is its main component) has a remarkable history of extremely rapid growth during the 1990s and became a hotbed of innovation and technological advance by worldwide standards. This sector, which employs only 8% of the business sectors employees, is responsible for about 30 percent of Israel's business sector GDP growth during the 1990s.

Yet, for all the staggering successes of the ICT-producing sector in Israel, the rest of the economy did not do so well. The Israeli ICT sector is overwhelmingly export-oriented (over 70% of its output is exported) so most of the local industries do not enjoy the fruits from the ICT-producing sector. Furthermore, even tough Israel is ranked number one in the world in terms of the share of R&D expenditures in GDP, the non-ICT sectors are not significantly engaged in R&D activities and lag behind comparable

[37] For example, the share of ICT capital in total GDP in 2003 was 16.7% in the US, but only 9.8% in Israel and 9.3% on average among the EU 15 original members. Notice that these are shares out of GDP and not manufacturing.

[38] But using other regression specification (specifically System-GMM) Hempell found only 96% gross returns to ICT, which is of the same order of magnitude as the results found here and in other studies (Brynjolfsson and Hitt (2000)).

sectors in the world. The result is that the non-ICT-producing sectors experienced very sluggish growth during the last decade, with the traditional sectors both in manufacturing and services seemingly unable to benefit from the success of the ICT sector. Thus, the picture that emerges in the Israeli economy is one of a *"dual economy"* in the making. Israel, therefore, provides a very good example of the potential and the limitations of relying on an ICT-producing sector as a lever for economic growth.

Despite the centrality of the ICT-producing sector in the Israeli economy, data on ICT investments by firms is not collected in any systematic way. Thus, a major goal of our analysis was to put together, for the first time, an industry-level data series on ICT investment between 1990 and 2003 in Israel. Although the quality of the assembled data can certainly be improved in the future – and we hope that data will be collected directly at the firm level -- these new data constitute a first step towards a reliable analysis of the role of ICT in Israel. The data indicate that even tough the share of ICT investment in GDP almost doubled over this period (from 1.7 percent in 1990 to 3.1 percent in 2000), Israel is still lagging behind many OECD countries. We also find that over 60 percent of the ICT capital is located in the ICT sector itself (compared to about 40 percent in the US). This implies that ICT capital per worker was 7 times larger in the ICT sector compared to other sectors and we find that this difference is part of the explanation for the overall poor productivity performance in Israel.

We estimate a large and significant value-added elasticity of ICT capital in manufacturing. This elasticity increases with the level of technological sophistication: ICT capital appears to be more productive in more high tech industries. This finding is not driven by the presence of ICT producing industries in the high tech sector. The implied rate of return of the ICT capital, based on these elasticities, is found to be very high: 200% for the medium-high tech sector, 145% for the medium-low tech sector, and 92% for the low-tech sector. Our estimates also imply that the main factor contributing to growth is the accumulation of ICT capital, followed by the accumulation of other type of capital. Because most ICT capital is concentrated in high tech industries, growth in Israel has been located in these industries only.

We believe that understanding the recent Israeli experience with ICT generates valuable insights on the different and intertwined roles of ICT-producing and ICT-using sectors in the process of economic growth. The Israeli economy offers a fascinating illustration of extraordinary successes in ICT-producing industries along with mediocre growth performance in the rest of the economy. The diffusion and adoption of ICT technologies across non-ICT producing sectors has not yet materialized and therefore the benefits from the ICT-producing sector have so far eluded the rest of the economy. As befits a GPT, it is the adoption of ICT by a widening range of additional sectors and the complementary innovations which the GPT prompts in the adopting sectors that are the main forces underlying economy-wide growth. Thus, if ICT it to act as a GPT it should induce productivity growth not only through rapid technological change in the *ICT-producing* sector but also through increased usage and investments by *ICT-using* sectors. The Israeli experience shows that the existence of a successful local ICT-producing sector by itself may not be enough to generate sustained and widespread growth (or that such growth may take too long to materialize). Facilitating the adoption of ICT in traditional industries should be a key component of a more balanced growth strategy and government intervention may be required to incentivate the adoption of ICT by non high tech users.

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Table 1: ICT Investment as Share of GDP - International Comparison

	Israel	US	EU-15	Ireland	UK	Sweden	Spain	Finland
1980		2.44	1.32	0.72	0.85	1.62	1.01	1.40
1981		2.59	1.38	0.95	0.91	1.67	1.13	1.42
1982		2.75	1.40	1.02	1.03	1.74	1.23	1.62
1983		2.97	1.52	1.43	1.25	2.04	1.42	1.72
1984		3.25	1.73	1.71	1.53	2.29	1.54	1.91
1985		3.31	1.92	1.18	1.68	2.59	1.67	1.99
1986		3.32	1.92	0.89	1.75	2.56	1.79	2.26
1987		3.20	1.97	0.66	1.84	2.72	1.97	2.38
1988		3.21	2.12	1.05	2.05	2.91	2.12	2.49
1989		3.31	2.20	0.92	2.37	2.99	2.21	2.60
1990	1.68	3.20	2.17	0.62	2.39	2.76	2.11	2.63
1991	1.62	3.18	2.10	0.72	2.20	2.52	1.93	2.65
1992	1.64	3.24	2.00	0.69	2.09	2.51	1.67	2.82
1993	1.77	3.28	1.93	0.66	2.18	3.03	1.61	2.89
1994	1.91	3.31	1.97	0.76	2.45	3.20	1.65	3.06
1995	2.01	3.53	2.06	1.17	2.89	3.40	1.69	3.38
1996	2.21	3.68	2.16	1.16	3.09	3.30	1.92	2.75
1997	2.14	3.94	2.23	1.16	2.89	3.45	1.97	3.55
1998	2.38	4.11	2.47	1.45	3.55	3.95	2.09	3.66
1999	2.89	4.44	2.57	1.77	3.39	4.39	2.21	3.78
2000	3.12	4.78	2.75	2.28	3.52	4.87	2.33	3.79
2001	2.71	4.31	2.67	1.67	3.19	4.31	2.26	4.04
2002	2.54	3.81	2.37	1.32	2.90	3.71	2.04	3.95
2003	2.27	3.85	2.23	1.03	2.74	3.61	1.89	3.55
2004		4.06	2.15	1.12	2.36	3.07	2.00	3.68

Source: Groningen Growth and Development Center, CBS and authors' calculations, using current prices. ICT definition for Israel excludes SIC 320, 340 and 342.

Table 2: The ICT Sector Relative Importance

The ICT sector as a percentage of the total business sector, 2003*

	Value added	Jobs	R&D expenditures
Israel	**16.5**	**7.6**	**88.6**
Finland	14.9	9.7	64.3
Korea	13.2	5.5	55.1
Ireland	11.8	8.1	70.2
United Kingdom	10.8	5.5	24.2
United States	10.5	5.0	35.5
Hungary	9.9	5.0	
Netherlands	9.8	7.5	36.3
OECD Average	**9.1**	**5.5**	
Sweden	9.1	9.1	32.7
Austria	8.8	6.7	
Norway	8.6	7.1	28.3
Denmark	8.5	7.2	31.5
France	8.5	7.4	30.6
Portugal	8.4	4.2	
Belgium	8.2	5.7	22.4
Australia	8.1	5.4	26.7
Japan	7.6	6.8	34.4
Canada	7.6	5.7	38.6
Italy	6.9	5.7	22.5
Germany	6.9	4.6	21.7
Spain	6.7	3.8	21.7
Czech Republic	5.7	4.3	14.5
Mexico	4.8	3.6	

Source: Israel's CBS, based on OECD data. Sorted by the ICT sector value-added share.
* For some of the countries, the data refer to other years.

Table 3: International Comparison of Labor Productivity Growth in the Manufacturing Sector (Annual Growth Rate)

Period	Israel	USA	UK	Sweden	Taiwan	France	Canada
1986-2004	3.44%	4.55%	3.48%	5.38%	5.76%	3.94%	2.69%
1986-1989	3.57%	3.36%	4.82%	2.13%	7.45%	3.19%	1.83%
1990-1994	2.26%	3.69%	4.63%	5.73%	4.54%	4.23%	4.36%
1995-1999	3.24%	5.08%	1.70%	7.02%	5.41%	4.59%	2.53%
2000-2004	2.43%	5.93%	3.81%	6.17%	5.37%	2.54%	1.81%

Source: US BLS, Bank of Israel and authors' calculations

Table 4: The Israeli Manufacturing Sector by Technological Level (US Dollars, 2000 Prices)

	Value-Added (Millions)			Value-Added per Hour		
Year	**High Tech**	**Medium Tech**	**Low Tech**	**High Tech**	**Medium Tech**	**Low-Tech**
1995	5,835	3,891	5,012	25.1	19.6	16.2
1996	6,172	3,681	4,978	25.8	18.3	16.8
1997	6,523	3,922	4,973	27.1	19.1	17.1
1998	7,121	4,001	5,031	28.6	20.2	18.0
1999	7,757	3,706	4,810	31.7	19.5	17.4
2000	9,758	3,886	4,805	38.4	21.0	17.7
2001	8,279	3,776	4,582	33.4	21.2	18.0
2002	7,596	3,787	4,169	30.7	21.1	16.8
Annual Growth Rate						
1995-2000	10.83%	-0.02%	-0.84%	8.91%	1.37%	1.82%
2000-2002	-11.77%	-1.28%	-6.86%	-10.61%	0.27%	-2.67%
1995-2002	**3.84%**	**-0.38%**	**-2.60%**	**2.93%**	**1.06%**	**0.52%**

Source: CBS and authors' calculations
The *high tech* group includes: Chemicals, Electronics, Machinery, Equipment and Transportation. The *medium tech* group includes: Metal, Metal Products, Mineral, Mining, Rubber and Plastic and Others. The *low tech* group includes: Clothing, Food, Leather, Paper, Printing, Textile and Wood.

Table 5: Definition of the ICT Sector

Industry	ISIC	SIC	Investment in ICT
Manufacturing			
Manufacture of office, accounting and computing machinery	3000	3000, 3010	√, √
Manufacture of insulated cable and wire	3130	3120, 3121	X, X
Manufacture of electronic valves and tubes and other electronic components	3210	3200, 3210	√, X
Manufacture of television and radio transmitters and apparatus for line telephony and line telegraphy	3220	3300	√
Manufacture of television and radio receivers, sound or video recording or reproducing apparatus, and associated goods	3230	3310, 3320	X, √
Manufacture of instruments and appliances for measuring, checking, testing, navigating and other purposes, except industrial process control equipment	3312	3420	√
Manufacture of industrial process control equipment	3313	3400	√
Services			
Wholesale of machinery, equipment and supplies	5150	-	X
Telecommunications	6420	66	X
Renting of office machinery and equipment (including computers)	7123	-	X
Computer and related activities	72	72	
- Hardware consultancy	721	720	X
- Software publishing, consultancy and supply	722	721, 725	√, √
- Data processing	723	722	X
- Database activities and online distribution of electronic content	724	723	X
- Maintenance and repair of office, accounting and computing machinery	725	724	X
- Other computer-related activities	729	728	X

Table 6: Non-Residential and ICT Investment in Israel (Million US Dollars, 2000 Prices)

Year	Non-Residential Investment	Total ICT Investment	ICT Share from Non-Residential Investment	Composition of ICT Investment (%) Software	Computers and Electronic Components (300,301,320)	Telecommunication and Electronic Equipment (330,332)	Control Equipment and Instruments (340, 342)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1990	7,291	1,666	22.9	39	13	19	29
1991	8,632	1,679	19.5	38	16	18	28
1992	9,814	2,013	20.5	38	13	21	28
1993	11,926	2,130	17.9	35	13	23	29
1994	14,020	2,518	18.0	34	11	25	29
1995	14,390	2,582	17.9	41	13	26	21
1996	15,898	3,000	18.9	41	15	25	19
1997	15,600	2,955	18.9	42	19	23	17
1998	15,384	3,217	20.9	45	17	23	15
1999	15,906	3,605	22.7	36	22	26	16
2000	16,929	4,168	24.6	34	25	27	13
2001	16,595	3,716	22.4	41	19	26	14
2002	15,154	3,446	22.7	44	20	24	13
2003	14,316	3,366	23.5	46	20	20	13
	Annual Rate of Growth of Investment Levels (%)						
1990-2003	5.3	5.6		7.07	8.94	5.77	-0.38
1990-1994	17.8	10.9		13.26	5.92	21.36	3.28
1995-2000	3.3	10.0		6.27	25.57	11.13	1.19
2001-2003	-7.1	-4.8		1.15	-1.94	-16.01	-7.64
1990-2000	8.8	9.6		8.29	16.83	13.25	1.65

Source: CBS and authors' calculations
Total ICT investment includes imports and domestic sales

Table 7: Distribution of ICT Investments in Israel by Sector (%)

Year	Agriculture	Manufacturing	Construction	Trade & Services	Transport, storage and communications
1990	0.5	31.2	1.1	56.2	11.0
1991	0.5	38.7	1.4	47.0	12.4
1992	0.5	31.9	1.2	50.5	15.9
1993	0.3	36.3	1.2	38.5	23.7
1994	0.2	35.6	1.0	31.9	31.3
1995	0.5	36.9	1.6	40.0	21.1
1996	0.3	37.2	1.5	34.8	26.1
1997	0.5	38.1	2.1	32.1	27.2
1998	0.6	34.5	1.7	28.5	34.7
1999	0.4	40.2	2.4	27.6	29.4
2000	0.5	39.4	2.5	23.0	34.7
2001	0.5	35.3	2.0	24.7	37.4
2002	0.6	39.4	2.7	24.3	33.1
2003	0.6	41.0	2.6	26.8	29.0
Annual Growth Rate					
1990-2003	6.8	6.7	12.0	-1.3	12.5

Source: CBS and authors' calculations
Note: Shares computed using real 2000 prices excluding software

Table 8: Production Function Regressions, Manufacturing Sector 1995-2002

	Dep. Variable: log Value Added				
	(1)	(2)	(3)	(4)	(5)
Capital	0.166	-	-	-	-
	(0.183)				
ICT Capital		0.136	0.155	0.053	0.062
		(0.060)	(0.052)	(0.058)	(0.058)
ICT CapitalxMed tech				0.131	0.140
				(0.091)	(0.091)
ICT CapitalxHigh tech				0.630	0.568
				(0.103)	(0.144)
Other Capital		0.048	0.093	0.139	0.094
		(0.081)	(0.072)	(0.072)	(0.068)
Hours	0.461	0.493	0.461	0.354	0.292
	(0.148)	(0.127)	(0.112)	(0.109)	(0.112)
Materials	-	-	-	-	
Rho	0.38	0.37	-	0.28	0.29
Observations	144	144	144	144	128

Table 9: Decomposition of Growth in Value Added

Panel A: All Manufacturing Industries

	Growth in Value Added	Contribution of ICT Capital	Contribution of Other Capital	Contribution of Hours	Residual
1995-1998	2.41	1.18	1.32	0.10	-0.19
1999-2000	5.57	3.76	1.01	-0.20	1.00
1995-2000	3.67	2.21	1.20	-0.02	0.28
2001-2002	-9.57	-0.002	0.71	-0.61	-9.66

Panel B: Low Tech

	Growth in Value Added	Contribution of ICT Capital	Contribution of Other Capital	Contribution of Hours	Residual
1995-1998	-0.29	0.45	0.77	-0.79	-0.72
1999-2000	-2.45	0.92	0.60	-0.53	-3.44
1995-2000	-1.15	0.64	0.70	-0.69	-1.81
2001-2002	-7.19	0.12	0.18	-1.36	-6.12

Panel C: Medium Tech

	Growth in Value Added	Contribution of ICT Capital	Contribution of Other Capital	Contribution of Hours	Residual
1995-1998	0.24	1.23	0.86	0.04	-1.81
1999-2000	-2.07	2.09	0.33	-1.31	-3.17
1995-2000	-0.69	1.57	0.64	-0.50	-2.40
2001-2002	-1.65	-0.36	0.45	-0.48	-1.26

Panel D: High Tech

	Growth in Value Added	Contribution of ICT Capital	Contribution of Other Capital	Contribution of Hours	Residual
1995-1998	6.02	1.79	2.05	0.87	1.32
1999-2000	14.74	6.51	1.65	0.56	6.02
1995-2000	9.51	3.67	1.89	0.74	3.20
2001-2002	-14.05	0.08	1.09	-0.29	-14.93

Table 10: Contribution of ICT capital to Growth of Value Added

	Manufacturing Sector	Low Tech	Medium Tech	High Tech
1995-1998	**1.18**	0.15	0.31	0.72
1999-2000	**3.76**	0.28	0.50	2.98
1995-2000	***2.21***	*0.20*	*0.39*	*1.62*
2001-2002	**-0.002**	0.03	-0.08	0.04

Note: entries are ICT capital contributions from Table 9 weighted by the tech sector's value added share.

Figure 1: Growth of Labor Productivity in the Business Sector (%)