11 *Why Is Labor Productivity in Israel So Low?*[*]

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11.1 Introduction

This chapter reviews the development of output in Israel between 1995 and 2014. Its main goal is to understand why gaps in output per capita and output per worker, "labor productivity," have not narrowed over the past twenty years and have remained substantial, relative to developed economies. The empirical approach is to compare Israel to a set of countries that Israel could resemble, namely small, open, developed economies. Based on this criterion and data availability, we chose Austria, Denmark, the Netherlands, Finland, and Sweden. Henceforth we refer to these countries as the "comparison group."

Below we begin with the main developments over the relevant period. In section 11.2 we review the data. We begin with the development of output per capita and output per worker in Israel relative to the United States and the comparison group. We then look at the inputs, namely, the labor force, years of schooling of the adult population, and investment in physical capital. Finally we review the development of total factor productivity. Section 11.3 presents the development accounting exercise. The main innovation is the use of the Survey of Adult Skills, "PIAAC," to measure human capital, in addition to years of schooling. Our findings show that while Israel is perceived as a high human-capital country, even relative to other developed economies, it has large disadvantages in terms of literacy and numeracy skills. This implies that when we estimate human capital including these skills, gaps in accumulated factors explain 76 percent of the gap in output per worker, while total factor productivity (henceforth: TFP) explains the

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remaining 24 percent.[1] This is against a split of 60–40, when only years of schooling are used as input into the human capital production function. In section 11.4 we estimate physical capital per worker at the industry level for both Israel and the comparison group. We show that industrial composition cannot explain any of the large gap in physical capital per worker. When we distinguish between equipment and machinery and nonresidential buildings, we find that the stock of equipment in Israel is about 50 percent of that of the comparison group, while the stock of nonresidential buildings is about 60 percent of that of the comparison group. In section 11.5 we estimate human capital per worker at the industry level for both Israel and the comparison group. The main finding in the section is that the industrial composition contributes 4 percent to the stock of human capital. That is, had the industrial composition of Israel been the same as in the comparison group, the stock of human capital in Israel would have been 4 percent lower. In section 11.6 we extend our sample to include all OECD countries for which we can estimate physical capital and human capital per worker at the industry level. We end up with thirteen countries. We show that there is a strong positive correlation between physical capital and human capital per worker. Our estimates suggest that if Israel closes its gap in numeracy skills, it will lead to an increase of its physical capital per worker by nearly 9 percent and will close about one-fifth of the gap in output per worker, relative to the comparison group.

11.1.1 Main Events During the Reviewed Period

Several events that took place either just before 1995 or during the period 1995–2014 have had profound effects on the development of output per worker. These include (i) the mass migration from the former Soviet Union (henceforth: FSU) to Israel, (ii) the unilateral reduction in trade barriers vis-à-vis developing countries, (iii) the large expansion of higher education in the form of public colleges, and (iv) the process of reducing the size of the public sector.

[1] These results are obtained when we use only numeracy, rather than numeracy and literacy skills. Since Israel's achievements in literacy and numeracy, relative to to the comparison group are remarkably similar, the results are very almost identical when using both skills. For brevity we do not present them in the paper.

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During the 1990s, about 1 million immigrants arrived in Israel from the FSU. On the eve of this large migration inflow, the Israeli population was about 4.8 million. The absorption of this flow of migrants required large investments in infrastructure, in housing, and in the stock of productive capital that substantially contributed to the growth process in the 1990s. Additionally, the migrants came with high human capital. About 60 percent of the adult migrants had an academic education, and a quarter of them had advanced degrees. Nevertheless, some of this education was useless in Israel. Paserman (2013) found that initially the immigrants were employed in unskilled jobs and occupations, and only after a few years did some of them settle into technological occupations and begin to contribute to labor productivity. Overall, however, Paserman concluded that immigration from the FSU had little effect on labor productivity in Israel.

Another important development that took place during the 1990s was the unilateral reduction in trade barriers vis-à-vis developing countries. As Gabai and Rob (2002) wrote, only during these years did free trade policy gain the support of the political leadership in Israel. This process dramatically increased the exposure of Israel to international trade and contributed to large increases in imports that competed with local traditional, low-productivity industries. This led to a decline in employment in traditional industries, and many of the workers in these industries found themselves in low-paid jobs in trade and services. Brand and Regev (2015b) found that this process contributed to the polarization in output per worker between trade and services industries with low labor productivity and tradeable sectors with high productivity. Nevertheless, Brand and Regev (2015a) showed that the process also led to an increase in labor productivity in traditional sectors that had to cope with international competition and focus in more intensive human capital products for which they had comparative advantage.

The 1990s saw a large expansion of public colleges which were established in response to the growing size of the population and governmental effort to increase the supply of higher education, on the one hand, and keep the quality of the universities, especially of the elite ones, on the other hand (Volansky, 2005). The fraction of students enrolled in these colleges as a share of total students in the higher education system grew from 12 percent in 1995 to 50 percent by 2014. At the late stages of this process, the fraction of individuals who receive at least a bachelor's degree out of the population aged

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25–34 was close to 50 percent, similar to the fraction of those obtaining matriculation certificate ("Bagrut"). The large expansion of colleges triggered research on whether the returns to a college degree is similar to that of a university degree. Achdut et al. (2018) showed that the annual wage of graduates of universities was 10 to 20 percent higher than the wage of public college graduates. Consistent with that, Lipiner et al. (2019) showed that among people with a bachelor's degree, those who are most likely to be employed in jobs but are educated beyond what is necessary for their job are graduates of public colleges. In summary, while the expansion of colleges contributed to the increase in the proportion of the population with an academic degree, the rate at which the quality of human capital increased is not entirely clear These question marks highlight the importance of measuring human capital not only by average years of schooling but also by measures of the quality of education. We elaborate on that in section 11.3.

Starting in 2002, the government began a process of reducing the size of the public sector. This policy renewed the passage of the process that had started in the 1980s as part of the Stabilization Program (Strawczynski and Zeira, 2002). This policy included a drastic reduction in direct taxes, on the one hand, and a reduction in defense expenditure, interest rate payments, and in government transfers on the other hand (Dahan and Hazan, 2014). In addition to the immediate need to reduce the governmental deficit, the declared objective of the policy was to foster the private sector of the economy and increase the participation rates among segments of the population that rely on transfers. Flug and Strawczynski (2007) found that about one-third of the transition to growth in 2004 can be attributed to changes in economic policy, such as the tax cuts. Using a calibrated representative model, Hercowitz and Lifschitz (2015) found that the tax cuts contributed significantly to the increase in labor force participation and output growth. However, using administrative data, Igdalov et al. (2017) found that tax cuts had little effect on labor force participation. An alternative explanation is that labor supply has been increasing in the intensive, rather than the extensive margin, though this hypothesis has not received serious attention. In section 11.2 we elaborate on the growth in labor force participation rates (henceforth: LFPR).

11.2 Overview of the Data

11.2.1 Output per Worker and Output per Capita

Israel's GDP per capita in 2014 was $31,250 (in 2011 Dollars). This is compared to $51,600 in the United States and $44,900 in the comparison group. On relative terms, Israel's GDP per capita was 60 percent that of the United States and 70 percent that of the comparison group. The gap in GDP per capita reflects the gap in GDP per worker, given the similarity in employment rates in 2014 among Israel, the United States, and the comparison group. Figure 11.1 displays the dynamics of output per capita and output per worker in Israel, relative to the United States and to the comparison group over the period 1995–2014. The figure shows that Israel has not closed any of the gaps over these two decades, though the dynamics have not been monotone. The decline in the early period is mainly due to the decline in GDP per worker, relative to the comparison group and the United States, while the later increase is due to an increase in employment rates. Our main conclusion is that over

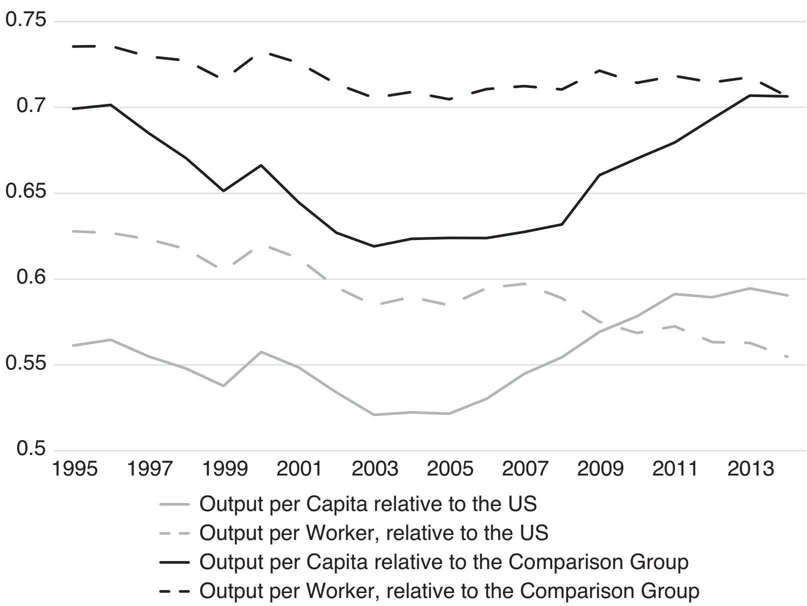

Figure 11.1 Israel's output per capita and output per worker relative to the United States and to the comparison group

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these two decades, Israel has not been able to close the gap in terms of income per capita and that gaps in output per worker have mildly increased.

11.2.2 The Labor Force

The labor force has increased at an annual rate of 2.5 percent, faster than the growth of the population aged 15 and above or of prime working age, 25–64, which were 2.1 percent and 2.2 percent, respectively. With the end of the large inflow of immigrants from the FSU in the early 2000s, the growth rate of the working age population subsided, but the growth rate of the labor force declined only slightly due to an acceleration in labor force participation rates (Figure 11.2). Between 1995 and 2003, participation rates increased by 1.8 percentage points, whereas during the period 2003–2011, it increased by 2.9 percentage points.[2] The increase in LFPR is not unique to these two decades and reflects a long process of increasing female LFPR, similar to a worldwide trend, whereby women's participation rates became similar to men's (Goldin, 2006; Blau and Kahn, 2013). The acceleration during the 2000s reflects the cessation of the decline of men's participation rates accompanied with a secular acceleration in women's LFPR. This is not trivial, since the typical dynamics of female LFPR is an S-shape: When LFPR are low, they increase very slowly but at an accelerating rate. However, at a relatively high rate, the growth rate of LFPR decelerates till it stays relatively constant (Hazan and Maoz, 2002; Fernandez, 2013). There are, potentially, three factors that can account for this: the rise in the level of education, the cut in welfare payments, and the rise in the mandatory age of retirement for both men and women.[3]

[2] In 2012, the Central Bureau of Statistics changed its Labor Survey and increased its frequency from quarterly to monthly. Additionally, the definition of participation in the labor force has changed, with the main change being a switch from "civilian workforce" to "workforce," which includes military service. Therefore, one should be very cautious about interpreting changes in labor force participation for the periods up to 2011 and from 2012. For more information, seewww.cbs.gov.il/he/publications/doclib/2019/lfs17_1746/intro4a_e.pdf.

[3] Hercowitz and Lifschitz (2015) suggest an alternative view, arguing that the increase in LFPR is the outcome of a process of cuts to the marginal tax on labor, which occurred between 2003 and 2012.

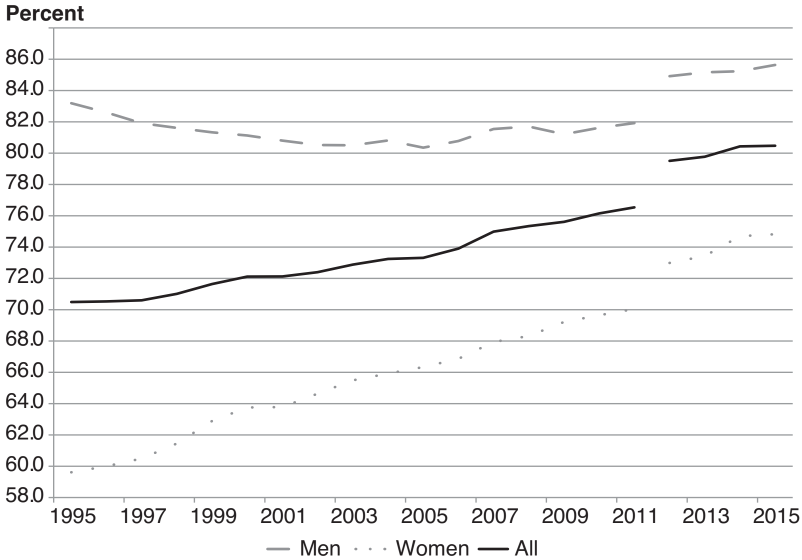

Figure 11.2 Israel's labor force participation, ages 25–64

The rise in the level of education is a secular phenomenon Argov (2016) that was temporarily intensified during the 1990s, perhaps as a result of the expansion of public colleges and the absorption of the inflow of immigrants from the FSU. Since LFPR increase with the level of education, one can attribute at least part of the rise in LFPR, especially that of women, to the rise in average years of schooling. However, there is no evidence that the rise in the level of education caused a rise in LFPR during the 2000s (Bank of Israel Report, 2017).

As part of the government policy to cut welfare payments since 2003, the cut in child allowances was very pronounced. Theoretically, such cuts to government transfers can have large effects on the LFPR of both men and women during the child-bearing years. Mazar and Reingewertz (2018) found that this cut has contributed 4.3 percentage points and 2.8 percentage points to the LFPR of women and men with four or five children, respectively, compared to women and men with two or three children.

Finally, in 2004, the mandatory retirement rate increased by two years for both men and women. This should have had a positive effect on the LFPR of the older population. Indeed, the *Bank of Israel Annual*

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Report (2017) found that men aged 60–64 contributed 0.9 percentage points (out of a total increase of 1 percentage point for men aged 25–64) to male LFPR between 2003 and 2011, whereas LFPR among this age group dropped in the earlier period, 1995–2003. For women, the rise in LFPR among the age group 60–64 contributed 1.2 percentage points out of a total of 3.8 percentage points for women aged 25–64. In the earlier period, 1995–2003, the age group 60–64 contributed only 0.5 percentage points to the rise of women's LFPR.

Although some of these are only descriptive statistics, as a whole they suggest that government policy in the form of welfare payment cuts, and especially in raising the mandatory retirement age positively contributed to the increase in LFPR. Either way, the rise in LFPR closed the gap in LFPR between Israel, on the one hand, and the United States and the comparison group on the other hand. This happened, despite the very low LFPR among two subgroups that are not very small – ultra-Orthodox men and Arab women. Thus, the rise in LFPR allowed Israel to increase its relative income per capita to its 1995 level, while at the same time output per worker fell. These are likely to be interdependent, as the marginal workers presumably have low market skills, thus contributing less than the average worker. The next two subsections discuss the dynamics of education and investment in fixed assets that are of great importance to the determination of output per worker.

11.2.3 The Evolution of Average Years of Schooling

The long-run secular rise in the average years of schooling of the adult population (ages 25–64) has continued during the period 1995 and 2014 (see Figure 11.3).[4] Over this time period, however, the rate of growth in years of schooling has been decelerating. In the early 1990s, the growth rate of the average years of schooling had been affected in part by the inflow of immigration from the FSU, who were more educated than the native population in Israel (Cohen-Goldner et al., 2015), and in part by the expansion of the public colleges in Israel, which allowed more high-school graduates access to higher education (Volansky, 2005). As the expansion of public

[4] We use average years of schooling from Argov (2016). He adjusts the estimates on various dimensions, among them a downward correction to the average years of schooling of ultra-Orthodox yeshiva students.

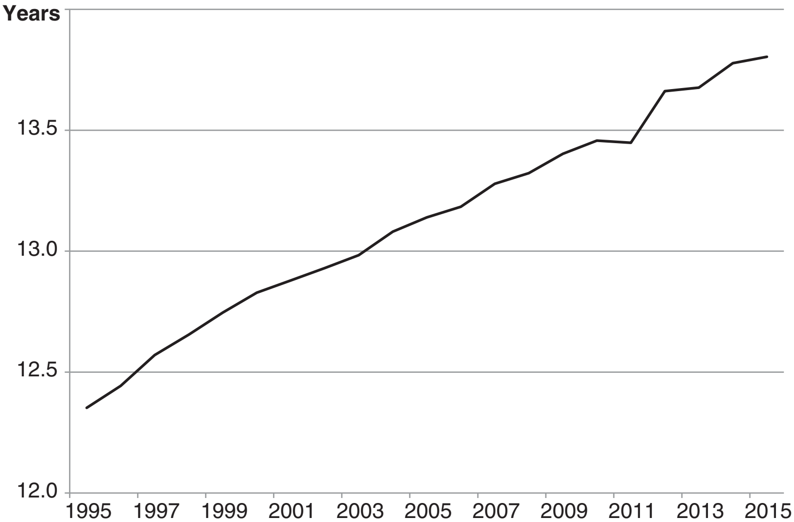

Figure 11.3 Israel's average years of schooling, ages 25–64

colleges subsided over time, it stopped contributing to the growth of education. Finally, throughout this time period the exit of older cohorts, who are characterized by low levels of education, and the entrance of younger cohorts have been an additional force behind the increase in average years of schooling among the population aged 25–64.

11.2.4 Investment in Fixed Assets

Investment in fixed assets as a share of total gross domestic product (henceforth: GDP) was especially high in the mid-1990s as part of an adjustment process of the stock of physical capital to the inflow of immigrants from the FSU (see Figure 11.4). Investment then declined until the mid-2000s. The mild rise in recent years reflects "one-time" investments which are related to the discovery of natural gas in the Mediterranean. In the mid-2000s, the investment rate stabilized at about 18 percent, about 2 percentage points below the comparison group. This gap has remained intact in recent years, despite the increased rate in Israel and the economic crisis in the European Union.

The relatively low investment rate is due to the low investment rates of the private sector as well as the public sector. As we elaborate in

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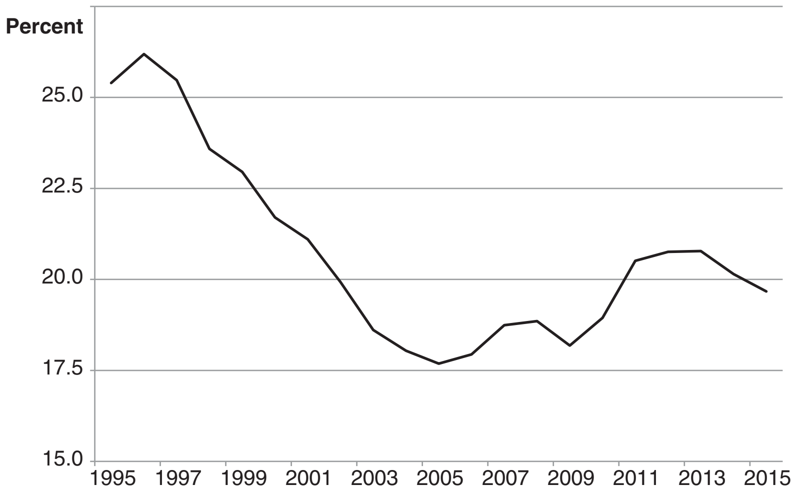

Figure 11.4 Israel's investment in fixed assets, relative to GDP

section 11.4, the accumulation of physical capital per worker is much lower than in the comparison group in almost all industries. In addition, public investment conducted by the government is lower than in the past and in international perspectives. Indeed, the level of net public capital per capita in Israel is much lower compared to the comparison group (Eckstein and Lifschitz, 2017).

11.2.5 Total Factor Productivity

The tradition in the field of economic growth is to decompose growth into the growth arising from the accumulation of factors of production and an unexplained growth that is attributed to total factor productivity (Solow, 1957; Kendrick, 1961). Gaaton was the pioneer in this field in Israel with the publication of his book *Economic Productivity in Israel* in 1971 (Gaaton, 1971). Hercowitz (2002) examined the evolution of TFP in Israel and concluded that between 1975 and 1989, GDP increased by 60 percent, the stock of physical capital and labor increased by 30 percent, and TFP increased by 23 percent. In contrast, between 1989 and 1997, TFP was constant as both GDP and physical capital and labor increased by 60 percent. Hercowitz attributed the stagnation in TFP to the absorption of immigrants from the FSU. Whereas during the period explored by Hercowitz, Israel was mostly

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affected by local developments, such as the historical peace agreement with Egypt, the hyperinflation followed by the stabilization, and the large inflow of migrants from the FSU, between 1995 and 2014, the developments in Israel were mostly related to development in the global economy (with the exception, perhaps, of the temporary effect of the Second Intifada). Indeed, during the period 1995 and 2014, average annual growth of GDP per capita was 1.6 percent, similar to the average among the comparison group.[5]

A decomposition of the growth in Israel between 1995 and 2014 is consistent with the statement that developments in Israel go hand in hand with development in the global economy. During this period, factors of production per worker have increased by about 15 percent, while TFP has increased by 8 percent. In the comparison group the equivalent numbers are 16 percent and 11 percent, respectively.[6] Since the evolution of both factors of production and TFP has been very similar over this period, our analysis below focuses on the gap in output per worker as of 2014. Such an analysis enables us to use the PIAAC, which encompasses both Israel and the comparison group. As we show below, this survey sheds new light on the sources of the gap between Israel and the comparison group.

11.3 Development Accounting

11.3.1 Theoretical Framework

Development accounting is a useful tool to understand differences in output per worker in a given point in time. It assumes a production function, calibrates its parameters, and uses measures of its inputs and output to decompose observed differences in output into differences in measured factors of production and unobserved differences in total factor productivity.[7]

[5] The increasing importance of exports to growth in Israel during the 1995–2014 period is consistent with the increased correlation between the growth in Israel and worldwide economic developments. Leiderman and Bahar (Chapter 5, this volume) show that the elasticity of exports with respect to world trade is close to unity.

[6] Author's calculation using data from the Penn World Tables (Feenstra et al., 2015).

[7] See Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) for early applications of this methodology, and Caselli (2005) for a survey of this literature.

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Let the aggregate production function be:

$$Y_i = A_i K_i^{\alpha} (L_i h_i)^{1-\alpha}, \tag{11.1}$$

where Y_i is total output, K_i is the aggregate stock of physical capital, L_i is total number of workers, h_i is the average human capital per worker, and A_i is TFP). i is an index for countries and $\alpha \in (0, 1)$ is the elasticity of output with respect to physical capital. Divide equation (11.1) by L_i to get:

$$y_i = A_i k_i^{\alpha} h_i^{1-\alpha} \equiv A_i X_i, \tag{11.2}$$

where y_i and k_i are output and physical capital per worker, respectively, and $X_i \equiv k_i^{\alpha} h_i^{1-\alpha}$ is the composite inputs per worker. Let us now assume only two countries, Israel, denoted by IL and the comparison group denoted by C. Using equation (11.2) we can write:

$$\frac{y_{IL}}{y_C} = \frac{A_{IL} k_{IL}^{\alpha} h_{IL}^{1-\alpha}}{A_C k_C^{\alpha} h_C^{1-\alpha}} = \frac{A_{IL} X_{IL}}{A_C X_C} \tag{11.3}$$

Equation (11.3) decomposes the ratio of output per worker to differences in TFP and differences in accumulated factors of production. In our empirical implementation we use equation (11.3) to calculate the contribution of the relative TFP, $\frac{A_{IL}}{A_C}$, and the contribution of the relative factors of production, $\frac{X_{IL}}{X_C}$, to the relative output per worker.

11.3.2 Empirical Implementation

11.3.2.1 The Elasticity of Capital with respect to Output, Output per Worker, and the Stock of Physical Capital per Worker

To apply equation (11.3) to the data, we need information on output per worker, human capital per worker, and physical capital per worker and an estimate on the elasticity of physical capital with respect to output. For the latter, we assume $\alpha = 0.42$.[8,9] Data on output and

[8] Under the assumption of perfect competition, $1 - \alpha$ is also the share of labor in national income. Over the period 1990–2014, the share of labor in national income has declined in most countries (Karabarbounis and Neiman, 2014). The value of 0.42 is based on the average labor share in the OECD in 2016.

[9] Caselli and Feyrer (2007) showed that the share of national income that is accrued to reproducible capital varies greatly across countries, mostly due to agricultural land and urban land. Nevertheless, reproducible capital share across Israel and the comparison countries are very similar.

Table 11.1 ***Data for development accounting: Israel and the comparison country***

	Output per worker (1)	Physical capital per worker (2)	Human capital per worker 1 (3)	Human capital per worker 2 (4)	Human capital per worker 3 (5)
Israel	63,162	196,844	3.582	3.314	0.925
Comp. group	90,550	398,559	3.139	3.207	1.022
Ratio	0.698	0.494	1.141	1.027	0.905

Notes: Data on output per worker and physical capital per worker are in 2011 US dollars. "Human capital per worker 1" uses only years of schooling, "Human capital per worker 2" uses years of schooling, and numeracy skills, and "Human capital per worker 3" uses numeracy skills.

physical capital per worker, adjusted for purchasing power parity (henceforth: PPP), and number of workers are taken from the Penn World Table (henceforth: PWT) (Feenstra et al., 2015).[10]

Table 11.1 shows the data for Israel and the comparison group. The comparison group is measured as a weighted average of the six countries, where the weight is the relative employment of each country. As can be seen from the table, output per capita in Israel is 69.8 percent of the output per capita in the comparison group. Israel's physical capital per worker is only about one-half that of the comparison group.

11.3.2.2 Human Capital per Worker Based on Schooling

Since Hall and Jones (1999), it is standard to measure human capital per worker by:

$$h_i = e^{rs_i} \tag{11.4}$$

where s_i is average years of schooling and r is the returns to schooling. In contrast to its inferiority in physical capital, the average number of years of schooling in Israel exceeds the average numbers years of

[10] We use Penn World Table V9.0. We use the variables "cgdpo" for total output, "rkna" for aggregate physical capital, and "emp" for the number of workers.

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schooling in the comparison group by about a year and a half.[11] Moreover, average years of schooling in Israel is higher than in any of the countries underlying the comparison country. The smallest gap is between Israel and Ireland – about one-half a year – and the largest gap is between Israel and Austria – nearly three years of schooling. The accepted estimates for the returns to schooling, r, is in the range of 7–13 percent (Hall and Jones, 1999). Hanushek et al. (2015a) conducted a development accounting exercise across states in the United States. They assume that $r = 0.1$. We follow them and assume that the return to a year of schooling is 10 percent.[12] Column (1) in Table 11.1 shows that under this assumption, the human capital per worker in Israel is larger by 14.1 percent compared to the comparison group.

11.3.2.3 Human Capital per Worker Based on Schooling and Skills

The literature that followed Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) has tried to improve the measurement of human capital in an attempt to increase the variance in output per worker that is accounted for by accumulated factor of production. Caselli (2005) summarizes this literature. The motivation for these attempts comes from the presumption that the quality of schooling varies across countries and therefore taking into account only differences in the quantity of schooling is not accounting for other dimensions, such as quality.

Starting in 2011–2012, the OECD has conducted a survey of adult skills, called the Programme for the International Assessment of Adult Competencies, or "PIAAC," with the goal of measuring the key cognitive and workplace skills needed for adult individuals to participate in society and in the workforce. The survey measures three main skills: literacy, numeracy, and problem solving in technology-rich environments. The main advantage of this survey is that it provides comparable data across OECD countries regarding the skills of adult individuals. Round 1 of the first cycle of PIAAC was conducted in 2011–2012 and included all the countries in our comparison group. Israel participated in Round 2 of the first cycle, in the years 2014–2015. In Israel about 9,000 individuals were assigned to the survey and about 6,000 were tested. The test was conducted in Hebrew, Arabic, and Russian.

11 Years of schooling for all countries have been calculated based on PIAAC variable "Education – Highest qualification – Level" (B_Q01a).

12 Frish (2007) estimated the casual effect of schooling on wages and found that the returns to schooling in Israel are about 9 percent.

Hanushek et al. (2015a) conducted a development accounting exercise across states in the United States. They proposed an extended form of (11.4) to estimate human capital and used micro data on skills in the USA to calibrate it. Specifically, they assumed that:

$$h_i = e^{rs_i + wT_i}, \tag{11.5}$$

where T_i is a measure of skills and w is the returns to skills. Notice that T could be a vector containing all three skills measured in PIAAC. To calibrate (11.5), we need estimates for the vector w. Hanushek et al. (2015b) used micro data from PIAAC for twenty-three countries to estimate the returns to skills. For each country, Hanushek et al. (2015b) standardize each skill to have mean zero and standard deviation of one and regressed log wages on this Z-score in a similar fashion to Mincerian wage regression. We follow Hanushek et al. (2015a) and use years of schooling and numeracy skills. We parameterize this specification by assuming that the return to a year of schooling is 10 percent and the return for each standard deviation in numeracy is 17.8 percent.[13] We also considered an alternative specification where we use both numeracy and literacy in addition to schooling. Quantitatively, this specification yields very similar results because the gap in the numeracy and literacy tests between Israel and the comparison country is very similar. We therefore do not report based on this specification for brevity. Finally, there are good reasons to believe that estimates of human capital based on measured skills (quality) are more desirable than those based on years of schooling (quantity). Hanushek and Kimko (2000) conducted a "horse race" between years of schooling and test scores in affected growth rates. They found that the former declines sharply and loses its statistical significance when the latter is added to the regressions. Hence, we also calibrate a version of (11.5) where we assume that only numeracy skills affect human capital. We use the same return to a standard deviation, namely that $w = 0.178$.

The achievement of the Israeli population in PIAAC is substantially lower than what the average years of schooling in Israel would predict. In numeracy and literacy the average score was 251 and 255, respectively. The average across all OECD countries is 266 and 269,

13 Setting the return to each standard deviation in numeracy to 0.178 is based on table 2 of Hanushek et al. (2015b).

respectively, with a standard deviation of 12.3 and 10.3, respectively.[14] Note, however, that the returns estimated in Hanushek et al. (2015b) is per standard deviation in the micro data for each country. The latter is much higher than the standard deviation across countries. Averaging the standard deviation in the micro data across all OECD countries, we find that the standard deviation in numeracy is 47 (and 47 in literacy as well). This implies that the Z-score for Israel is –0.44 and –0.39 standard deviations in numeracy and in literacy, respectively. The countries underlying the comparison group, in contrast, are all above the OECD average, with the exception of Ireland.[15] In numeracy the smallest gap is between Israel and Ireland and is equal to 0.1 standard deviation and the largest gap is between Israel and Finland and is equal to 0.66 standard deviation. In literacy the smallest gap is 0.26 (vis-à-vis Ireland) and the largest is equal to 0.70 (vis-à-vis Finland). Hanushek et al. (2015a) report similar gaps across US states.[16]

The large disadvantages that the adult population in Israel has in terms of skills offset the advantage Israel has in years of schooling, such that human capital is fairly similar between Israel and the comparison group. Column (4) in Table 11.1 shows the estimates of human capital per worker when schooling and numeracy skills are used to calibrate equation (11.5). Under this specification, the human capital in Israel is larger by only 2.7 percent of the comparison group. Finally, when the specification of equation (11.5) includes only numeracy skills the human capital in Israel is equal to 90.5 percent of the comparison group.

11.3.3 Results

11.3.3.1 Human Capital per Worker Based Only on Schooling

Assuming that human capital is solely determined by schooling (column 3 in Table 11.1), we calculate the ratio between the contribution of accumulated factors of production in Israel and the comparison

[14] We omitted Turkey and Chile because although these countries are in the OECD, they are much less developed than other member countries.

[15] The average score in numeracy and literacy are 275 and 269 in Austria, 280 and 275 in Belgium, 285 and 271 in Denmark, 282 and 288 in Finland, 256 and 267 in Ireland, 280 and 284 in the Netherlands, and 279 and 279 in Sweden.

[16] The gap between the state with the highest skills, Minnesota, and the state with the lowest skills, Mississippi is 0.87 standard deviations.

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group and find that it is equal to 0.8. Using this ratio and equation (11.3), we find that TFP in Israel, relative to that in the comparison group, is equal to 0.87. This implies that accumulated factors of production contribute 60 percent to the gap in output per worker, while the gap in TFP contributes the remaining 40 percent.[17]

11.3.3.2 Human Capital per Worker Based on Schooling and Skills

An alternative to the case where only schooling determines human capital is to assume that human capital is determined by both schooling and numeracy skills (column 4 in Table 11.1). Under this calibration of the human capital production function, we recalculate the ratio between the contribution of accumulated factors of production in Israel and the comparison group. We find that it equals 0.76. This is smaller by 4 percentage points, relative to the case where human capital is determined solely by years of schooling. Again, using and equation (11.3) we find that TFP in Israel, relative to that in the comparison group, is now equal to 0.92. In terms of the contribution of accumulated factor of production contribute to the gap in output per worker vs the contribution of TFP, we now find that accumulated factors of production contribute 76 percent while TFP contributes the remaining 24 percent.

11.3.3.3 Human Capital per Worker Based only on Skills

Finally, we assume that human capital is solely determined by numeracy skills (column 5 in Table 11.1). We recalculate the ratio between the contribution of accumulated factors of production in Israel and the comparison group. We find that it is equal to 0.70. This is smaller by an additional 6 percentage points, relative to the case where human capital is determined by both years of schooling and numeracy skills. Once again, using equation (11.3), we find that TFP in Israel, relative to that in the comparison group, is now equal to 0.92. This implies that accumulated factors of production contribute 76 percent to the gap in output per worker, while TFP contributes the remaining 24 percent.[18]

[17] The contribution of accumulated factor is given by $\frac{1-0.8}{(1-0.8)+(1-0.87)} \approx 0.6$.

[18] More precisely, accumulated factors of production contribute 97 percent while TFP contributes the remaining 3 percent.

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11.4 Physical Capital per Worker at the Industry Level

In the previous section, where we conducted a development accounting exercise, we saw that the physical capital per worker in Israel is substantially lower than that of the comparison group. Specifically, according to the PWT, the physical capital per worker in Israel, adjusted for PPP, is slightly below 50 percent that of the comparison group.

In this section we address two hypotheses as to why this ratio is so low. First, we examine the industrial composition of the Israeli economy. If Israel specializes in industries that have low capital intensity, then the main question to be asked is why Israel chose to specialize in these sectors: is it because of Israel's lack of physical capital, or is it due to other factors. One reason for that could be related to Israel's chronic balance of payments deficits, which lasted for decades until the early 2000s (see Leiderman and Bahar, Chapter 7, this volume). In that case, history dependency can explain such specialization. Second, the low level of physical capital per worker could be driven by differences between structures and equipment. For example, if Israel is more densely populated, it could be the case that Israel is lagging behind in physical capital per worker mostly or entirely because of structural disadvantage. To address these questions, we estimate physical capital per worker by industry for both Israel and the comparison group.

11.4.1 Methodology

The estimation of physical capital per worker uses the perpetual inventory method. According to this method, the stock of physical capital in industry j, in country c, in period t +1, $K_{jc,t+1}$, depends on the stock of physical capital in period t in that industry country, $K_{jc,t}$, and on investment in period t, $I_{jc,t}$:

$$K_{jc,t+1} = (1 - \delta_j)K_{jc,t} + I_{jc,t}. \tag{11.6}$$

Here δ_j is the depreciation rate in industry j. Using equation (11.6) recursively we can write:

$$K_{jc,t+1} = (1 - \delta_j)^{t+1}K_{jc,0} + \sum_{i=0}^{t}(1 - \delta_j)^{t-i}I_{jc,i}. \tag{11.7}$$

To estimate physical capital using (11.7), one needs data on investment at the industry level, as well as data on depreciation rates by industry. In addition, one needs data on $K_{jc,0}$.[19]

Inklaar and Timmer (2013) offer a method for estimating $K_{jc,0}$. The idea is to assume that in $t = 0$, each or industry is in steady-state of the neoclassical growth model. Thus:

$$K_{jc,0} = \frac{I_{jc,0}}{g + \delta} \tag{11.8}$$

where g is the growth rate of investment. Thus, using equations (11.7) and (11.8) we can estimate physical capital at the industry level in each country in each year. As in Inklaar and Timmer (2013), we assume that $g = 0.02$, consistent with output growth of 2 percent and the assumption that, in the steady-state, investment grows at the same rate as output. Finally, we need to parameterize δ_j. Again, following Inklaar and Timmer (2013) we assume that depreciation on structures is 2 percent. Inklaar and Timmer (2013) divided equipment into five categories, with annual depreciation rates that are in the range of 12.6–31.5 percent. We choose an annual depreciation rate of 15 percent for equipment. Under these two values, we estimate that 77 percent of the capital stock is structure and the remaining 23 percent is equipment. In turn, this implies that the average depreciation rate is 5 percent, similar to Inklaar and Timmer (2013).

11.4.2 Data

Data on investment and employment at the industry level for the countries underlying the comparison group are available from Eurostat for the years 1995–2014. The investment data are in 2010 Euros. Similar data for Israel were obtain from the Israeli Central Bureau of Statistics and the Bank of Israel.[20]

19 Notice that the importance of $K_{jc,0}$ diminishes as one uses data further back in time. Nevertheless, since depreciation on structures is fairly low, even if we had data on investment going back to 1950, still 28 percent of structure capital would be in use in 2014 with an annual depreciation rate of 2 percent. Moreover, our data only begins in 1995, thus $K_{jc,0}$ plays an important role.

20 Data on investment in Israel are in 2010 constant NIS. We converted them to Euro prices using the average exchange rate between the NIS and the Euro in 2010.

11.4.3 Results

Figure 11.5 shows physical capital per worker by industry in Israel relative to the comparison group. As can be vividly seen from the figure, it varies greatly across industries, ranging from 0.105 in public services to 2 in textiles, apparel, and leather. While some of these estimates are very small, perhaps unrealistically, the average across all industries is 52.4 percent. Interestingly, the gap between our (aggregate) estimate and that of the PWT is fairly close, standing at 3 percentage points.[21]

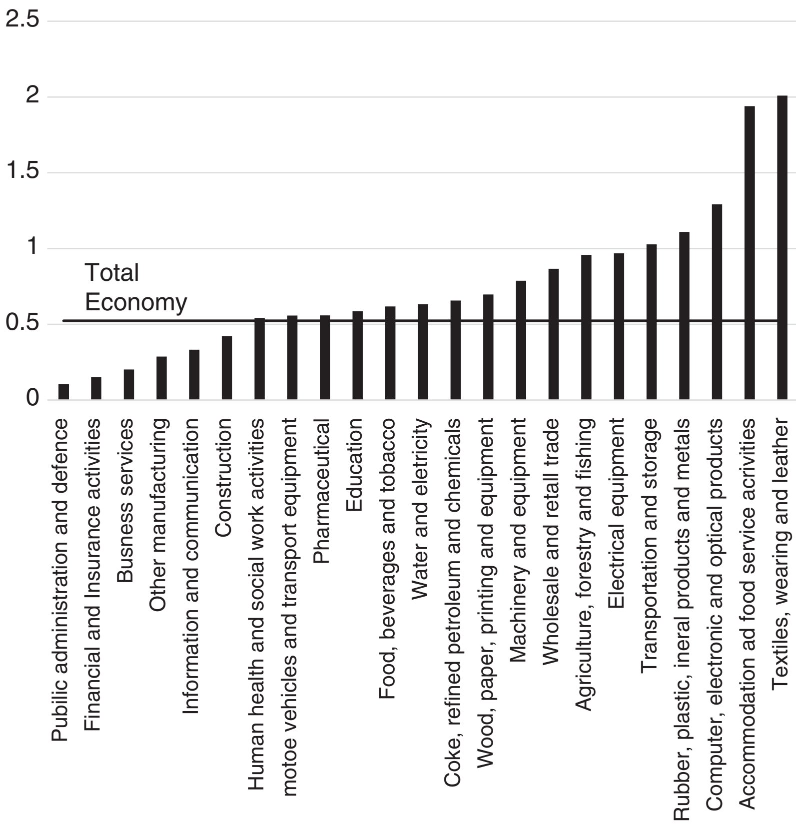

Figure 11.5 Israel's physical capital per worker at the industry level relative to the comparison group

[21] we used investment in constant NIS and converted them to Euro using the average exchange rate in 2010, so that our estimates are unadjusted to PPP.

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The Contribution of Industrial Composition to Gaps in Physical Capital per Worker. To evaluate the contribution of industrial composition to gaps in physical capital per worker, we compute the hypothetical physical capital per worker that Israel would have had if its industrial composition had been as in the comparison group. This is measured in terms of relative employment. Formally, the hypothetical capital per worker is computed as:

$$k_{IL}^{h} = \sum_{j} \omega_{jC} k_{j,IL} \tag{11.9}$$

where ω_{jC} is the fraction of workers employed in industry j in the comparison group and $\sum_j \omega_{jC} = 1$. If Israel's industrial composition explained the whole gap between Israel and the comparison country, we would expect no gap between Israel and the comparison group in each industry. Figure 11.6 shows the fraction of workers employed in industry j in Israel and the comparison group. As the figure makes clear, there are relatively small differences in the industrial composition

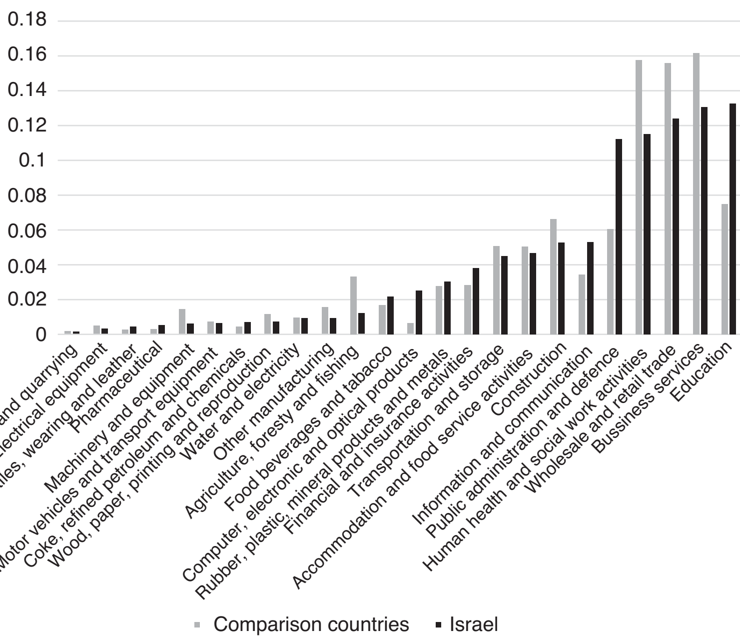

Figure 11.6 The distribution of employment by industries: Israel and the comparison group

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between Israel and the comparison country. Consistent with that, computing the hypothetical capital per worker using (11.9) yields capital per worker that is larger than the actual capital per worker in Israel by less than 2 percent.

Structure versus Equipment and Machinery. Our second hypothesis is that Israel's disadvantage is mainly in structures. As we noted above, structures constitute about 77 percent of the physical capital stock and equipment constitutes the remaining 23 percent. In the comparison group, the division is 80 percent structures and 20 percent equipment. We find that the stock of structures in Israel is only 50.8 percent relative to the comparison group, while the stock of equipment is about 60.8 percent, relative to the comparison group. This finding in consistent with the hypothesis that the cost of building in Israel is higher than in the comparison group. While we do not investigate this issue in more depth, we think this deserves further research in the future.

Our overall assessment is that the composition of the industrial composition in Israel is relatively unimportant to understand why Israel's capital per worker is only about one-half that of the comparison group.

11.5 Human Capital per Worker at the Industry Level

As discussed in Section 11.3 Israel leads the comparison group in terms of formal schooling while lagging behind in terms of cognitive skills. Figure 11.7 shows human capital per worker at the industry level, relative to the comparison group. It varies from about 0.8 in construction to more than 1.2 in textile, wearing, and leather. Below we answer the question what is the contribution of the industrial composition of Israel to its human capital. We evaluate this question the same way we did when asking the hypothetical question what would have been Israel's physical capital per worker, had the industrial composition of Israel been that of the comparison country. Formally, the hypothetical capital per worker is computed as:

$$h_{IL}^{h} = \sum_{j} \omega_{jC} h_{j,IL} \tag{11.10}$$

where ω_{jC} is as defined above in section 11.4. If Israel's industrial composition explained the whole gap between Israel and the

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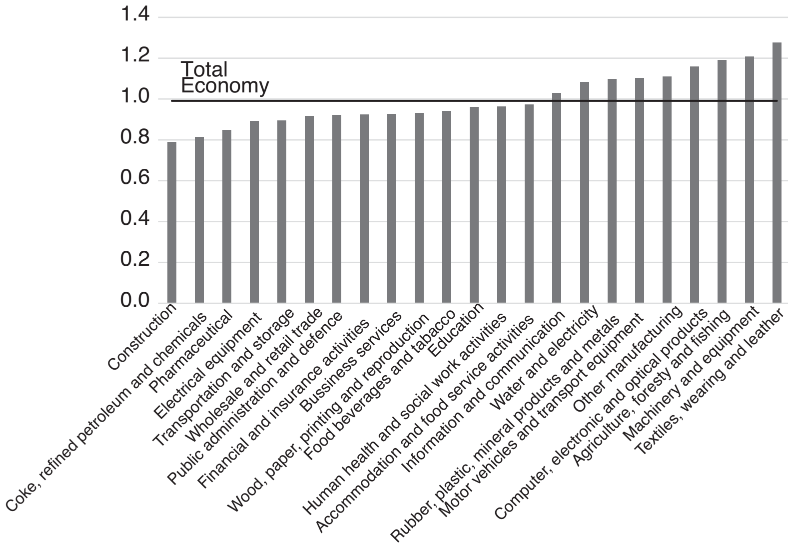

Figure 11.7 Israel's human capital per worker at the industry level relative to the comparison group.
Human capital is based on (11.5)withr = 0.1 for each year of schooling and w = 0.178 per one standard deviation in numeracy skill.

comparison country, we would expect no gap between Israel and the comparison country in each industry. We find that the industrial composition contributes 4 percent to the stock of human capital. That is, had the industrial composition of Israel been the same as in the comparison group, the stock of human capital in Israel would have been 4 percent lower. Again we conclude that the industrial composition of Israel is relatively unimportant in explaining difference in average human capital, relative to the comparison group.

11.6 Physical and Human Capital per Worker at the Industry Level

There is a theoretical justification to assume that there is a positive relationship between the stock of physical capital per worker and the average human capital per worker. Acemoglu (2003) argues that the development of new technologies responds to the quality of the workforce. Thus, when the stock of human capital increases, new technologies are developed. Krusell et al. (2000) estimated the elasticity of substitution between physical capital and unskilled workers and between physical capital and skilled workers. They found that while the former is 1.67, the latter is 0.67.[22] Zeira (1998) shows that adoption of technologies depends on the price of labor relative to capital. The higher the price of labor, the larger the incentive for firms to invest in capital that embodied labor-saving technology.

In our development accounting exercise, we assume that the aggregate production function is Cobb–Douglas. If we assume that this holds true also at the industry level, we get:

$$\frac{\partial y}{\partial k} = \alpha A \left(\frac{h}{k}\right)^{i-\alpha} \tag{11.11}$$

The left-hand side (henceforth: LHS) of equation (11.11) is the marginal product of physical capital per worker. Under the assumption that it is determined by the real interest rate, and that the real interest rate is exogenously given to a small open economy, the LHS is constant. Taking logs of (11.11) and manipulating, we obtain a linear relationship between the log of physical capital per worker and the log of human capital per worker, with a coefficient of one on the log of human capital per worker.

Below we examine this hypothesis. Specifically, we estimate the relationship between the log of physical capital per worker and the log of human capital per worker at the industry level across countries. To this end, we estimated physical capital and human capital per worker at the industry level for all countries for which we have investment level at the industry level in Eurostat and data on numeracy skills at the industry level in PIAAC. In total, we have data for thirteen countries.[23] The goal of this analysis is to examine if Israel's disadvantage in the skills of the adult population, also negatively affect the accumulation of physical capital.

Table 11.2 shows summary statistics of the data. There are two salient features in the data. First, there is large variation in physical capital per worker across industries. Second, structures represent the lion share of capital.

[22] There is a large literature on the elasticity of substitution between capital and labor. Even though this literature has not reached a consensus, most research finds an elasticity smaller than 1. For a review of this literature, see Chirinko (2008).

[23] These are Austria, Cyprus, the Czech Republic, Denmark, Finland, France, Greece, Ireland, Israel, Italy, the Netherlands, Slovakia, and Sweden.

Table 11.2 ***Summary statistics***

Variable	Observations	Mean	Standard deviation	Minimum	Maximum
Physical capital per worker	260	198.72	319.02	8.43	3,255.55
Structures per worker	260	153.91	282.32	1.61	2,996.09
Machinery per worker	260	44.81	63.08	1.22	555.57
Log physical capital per worker	260	4.72	1.00	2.13	8.09
Log structures per worker	260	4.34	1.11	0.48	8.02
Log machinery per worker	260	3.22	1.09	0.20	6.32
Human capital per worker	260	3.66	0.68	1.74	5.82
Log human capital per worker	260	1.28	0.19	0.55	1.76

Notes: Physical capital, structures, and equipment per worker are measured in thousands of 2010 Euros. Human capital per worker is parameterized under the assumption that both schooling and numeracy skills contribute to human capital.

Figure 11.8 shows a scatter plot of the log of physical capital per worker and human capital per worker across thirteen countries and twenty-three industries.[24] The figure shows that there is a positive relationship between the log of physical and the log of human capital per worker. Additionally, we see that the dispersion of observations for Israel is not different from the dispersion for the other countries in the data.

[24] Human capital per worker is based on (11.5) with $r = 0.1$ for each to year of schooling and $w = 0.178$ per one standard deviation in numeracy skill.

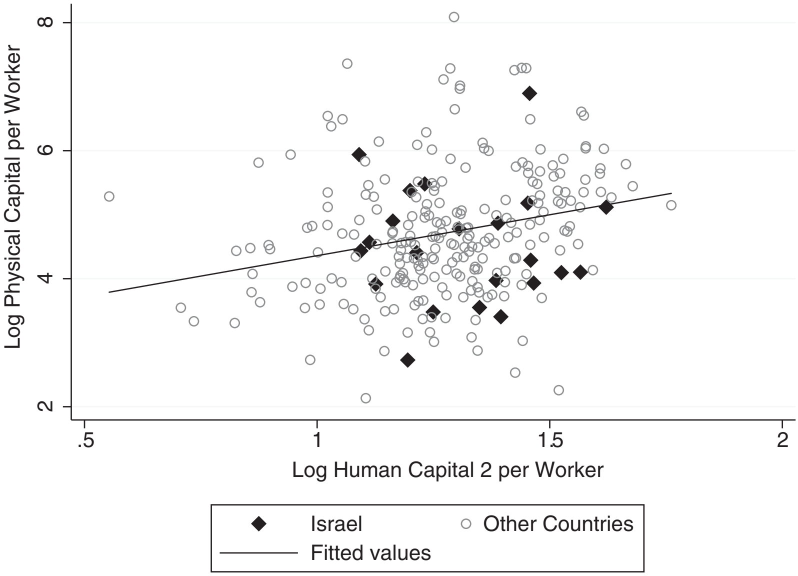

Figure 11.8 The stock of physical capital and human capital per worker: Israel and 12 OECD countries

Despite this clear relationship, it is better to examine the relationship using regressions to account for country and industry characteristics. For example, it could be the case that industries with more physical capital per worker employ workers with lower human capital per worker, but that more productive countries have higher physical and human capital. If this is the case, then country fixed effects would weaken, or even eliminate the relationship shown in the figure. Likewise, it could be the case that within industries there is small variation in physical capital because they use similar technologies. Again, if this is the case, then industry fixed effects would weaken or eliminate the relationship altogether.

Hence we estimate regression of the form:

$$\log k_{ic} = \alpha + \beta \log h_{ic} + \delta_c + \delta_i + \in_{ic}, \tag{11.12}$$

where k_{ic} and h_{ic} are physical and human capital per worker in country c in industry i, δ_c and δ_i are country and industry fixed effects, and $\in_{ic}$ is a random error. As we described above, given our Cobb–Douglas production function specification, we expect to find $\beta = 1$. We note that although our purpose is to document a relationship between

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physical and human capital per worker and not a casual relationship between the two, there are at least two reasons why we choose to put physical capital as the dependent variable in (11.12). First, human capital is determined in a process that usually takes longer than physical capital. It is the result of formal schooling, starting at a young age, going through high school, and sometimes college, and continues with on the job training, and so on. We measure human capital as a weighted average over workers at different ages, and so this average changes relatively slowly. In contrast, physical capital can be adjusted at a faster pace, especially in industries where technological progress is important. A second reason for our choice is that for the most part, human capital is determined by the public education system, whereas most of the physical capital is determined by the private sector. Thus, if one wants to take a causal interpretation of (11.12), then the government should improve the average human capital through its public education system, if it wants to contribute to fostering investment in physical capital by the private sector.

Table 11.3 presents the results of estimating (11.12). The table has three panels, where each corresponds to a different specification of the human capital production function. In Panel A, human capital is based on (11.12) with $r = 0.1$ for each to year of schooling. In Panel B, human capital is based on (11.5) with $r = 0.1$ for each to year of schooling, and $w = 0.178$ per one standard deviation in numeracy skill. Finally, in Panel C, human capital is based on (11.5), but only numeracy skills are rewarded: $r = 0$ and $w = 0.178$ per one standard deviation in numeracy skill.

In each panel there are three "blocks" of regressions: in columns (1)–(3) the dependent variable is the total physical capital per worker, whereas in columns (4)–(9) we breakdown the total physical capital per worker into two components: physical capital per worker in the form of structures (columns 4–6) and physical capital per worker in the form of equipment and machinery per worker (columns 7–9).

In column (1) we present estimates of β without controlling for fixed effects. The estimates range between 1.278 and 2.659, and are all statistically significant. When we add both country and industry fixed effects, the estimates are very close to 1 and are highly statistically significant in Panels A and B. In column (2) we add country fixed effects. The point estimates in Panels A and B increase due to this inclusion but remain statistically significant, while the one in Panel

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Table 11.3 *The relationship between physical capital and human capital per worker*

	Log capital per worker			Log structures per worker			Log machinery per worker		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
				Panel A: Human capital based solely on years of schooling					
Log HC1	1.**	2.019**	1.081***	1.943***	2.512***	1.635***	0.254	0.385	0.844
	(0.583)	(0.757)	(0.379)	(0.684)	(0.847)	(0.538)	(0.682)	(0.849)	(0.633)
R2	0.048	0.175	0.772	0.059	0.165	0.680	0.001	0.186	0.775
				Panel B: Human capital based on years of schooling & numeracy skills					
Log HC2	1.278**	1.424**	0.836***	1.460**	1.670**	1.225***	0.631	0.548	0.782
	(0.453)	(0.616)	(0.264)	(0.525)	(0.695)	(0.373)	(0.500)	(0.652)	(0.477)
R2	0.061	0.172	0.772	0.065	0.153	0.680	0.012	0.192	0.777
				Panel C: Human capital based solely on numeracy skills					
Log HC3	2.659**	2.384	1.017	2.640**	2.314	1.337	2.851**	2.232	1.450*
	(1.121)	(1.657)	(0.713)	(1.238)	(1.766)	(0.931)	(1.170)	(1.711)	(0.840)
R2	0.046	0.140	0.768	0.037	0.108	0.671	0.045	0.203	0.775
					Common to all panels				
Country FE	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Industry FE	No	No	Yes	No	Yes	Yes	No	Yes	Yes
Obs.	260	260	260	260	260	260	260	260	260

Notes: The dependent variable in columns (1)–(3) is the log of physical capital per worker, the dependent variable in columns (4)–(6) is the log of structures per worker, and the dependent variable in columns (7)–(9) is the log of equipment and machinery per worker. The main regressor in Panel A, Log HC1, is the log of human capital per worker, where human capital is based on (11.4) with $r = 0.1$ for each year of schooling. The main regressor in Panel B, Log HC2, is the log of human capital per worker, where human capital is based on (11.5) with $r = 0.1$ for each to year of schooling and $w = 0.178$ per one standard deviation in numeracy skill. The main regressor in Panel C, Log HC3, is the log of human capital per worker, where human capital is based on (11.5) but only numeracy skills are rewarded: $r = 0$ and $w = 0.178$ per one standard deviation in numeracy skill. Observations are at the country–industry level. Standard errors, clustered at the industry level are in parentheses. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

C remains relatively stable but loses its statistical significance. Finally, in column (3), we add industry fixed effects. The estimates in all panels decrease, getting fairly close to 1, and are statistically significant in Panels A and B. Looking at the goodness of fit, the R^2, across columns (1)–(3), we see that it increases substantially between columns (2) and (3), suggesting that much of the variation in the data is due to variation across industries rather than across countries.

The breakdown of physical capital to its two components in columns (4)–(9) reveal an interesting pattern. While in Panels A and B the positive correlation between physical capital and human capital is due to a positive correlation between structures and human capital, in Panel C the positive correlation is mostly due to a positive correlation between equipment and machinery and human capital per worker. Our prior was that human capital would be more correlated with this type of physical capital than with structures. We interpret this result as consistent with the literature that emphasizes the superiority of quality of schooling over the quantity of schooling in relation to output growth (see Hanushek and Kimko, 2000).

We can use the estimates presented in Table 11.3 to examine by how much output per worker would have increased had the gap in numeracy skills between Israel and the comparison group been closed. The gap in numeracy skills equals 0.56 standard deviations. With a return of 17.8 percent to one standard deviation, the direct effect on Israel's human capital is an increase of 10.4 percent. Such an increase, in turn, would increase the stock of physical capital per worker. Taking the estimate of 0.836 (column 3 in Panel B), this implies that the stock of physical capital would increase by 8.7 percent. Together, these direct and indirect effects would increase output per capita by 9.7 percent, or 6.75 percentage points. Given that the gap in output per capita is 30.5 percentage points, closing the gap in numeracy skills can account for about 22 percent of the gap in output per worker.

11.7 Concluding Remarks

We analyzed differences in labor productivity between Israel and a group of small OECD countries. We assumed a more general human capital production function and calibrated it using PIAAC surveys, which examine the literacy and numeracy skills of the adult population in OECD countries. Whereas Israel has more years of schooling, its population has lower measured skills. Using a development accounting exercise, we show that once literacy and numeracy skills are taken into account, differences in accumulated factors explain more than three-quarters of the gap. This is against a split of 60–40 between accumulated factors and total factor productivity, when these skills are ignored. We also estimated physical capital per worker and human capital per worker at the industry level. We show that differences in the industrial composition between Israel and the comparison group can explain very little of the gap in physical capital per worker or in human capital per worker. When we distinguish between structures and equipment and machinery in physical capital per worker, we do see that Israel's disadvantage is larger in structures, although this finding cannot explain why physical capital is generally so low in Israel. Finally, using panel data on thirteen OECD countries, we estimate the relationship between physical and human capital. A causal interpretation of our estimates implies that closing the gap in skills – an increase in human capital per worker of 10.4 percent – will indirectly close 18 percent of the gap in physical capital and 22 percent of the gap in output per worker

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