Samuel Neaman Institute
FOR ADVANCED STUDIES IN SCIENCE AND TECHNOLOGY

Do High-Skill Immigrants Raise Productivity?

Evidence from Israeli Manufacturing Firms, 1990-1999

M.Daniele Paserman

36

Science, Technology and the Economy Program (STE)
Working Papers Series STE-WP-36-2007

Technion - Israel Institute of Technology

SCIENCE, TECHNOLOGY AND THE ECONOMY PROGRAM (STE)

The STE Program at Samuel Neaman Institute was established in the spring of 1999, in order to promote academic research in Science, Technology and the Economy, with emphasis on issues bearing on policy making in this area. The Israeli economy has experienced a dramatic transformation in the course of the 1990s, turning into a hotbed of innovations and an internationally recognized center of high-tech. The goal of the STE program, drawing researchers from a wide range of academic institutions in Israel, is to complement this process with supporting economic research, and in so doing to play an active role in shaping the national agenda in these areas. It does so by directly supporting original research, conducting periodical meetings and workshops where research papers are presented and discussed, having field visits and establishing a dialog with scientists engaged in R&D, bringing distinguished visitors from abroad, and publishing a working papers series. Papers can be obtained, by writing to the STE Program at the address below.

Head of the STE Program:

Prof. Manuel Trajtenberg, Eitan Berglas School of Economics, Tel Aviv University.

Academic Coordinator:

Prof. Dan Peled, Department of Economics, University of Haifa.

Address:

Samuel Neaman Institute - STE program

Technion - Israel Institute of Technology

Haifa 32000, Israel

Tel: 972-4-8237145

Fax: 972-4-8231889

E-mail: ste@techunix.technion.ac.il

Do High-Skill Immigrants Raise Productivity? Evidence from Israeli Manufacturing Firms, 1990-1999

M. Daniele Paserman
Hebrew University, CEPR and IZA

STE-WP 36-2007

March 2007

This is a report on a research project conducted as part of the activities of the Science Technology and the Economy Program, (STE), at the Samuel Neaman Institute for Advanced Studies in Science and Technology. Support for that project from the Institute is gratefully acknowledged. This paper presents the author's own view and not that of the Samuel Neaman Institute for Advanced Studies in Science and Technology or any members of its staff. I wish to thank Haim Regev, and participants in seminars at the STE program of the Neaman Institute and at the LABORatorio Riccardo Revelli in Moncalieri. Libe Crenzel and Edi Mishitz of the Israeli Central Bureau of Statistics provided helpful assistance with the data.

Do High-Skill Immigrants Raise Productivity?
Evidence from Israeli Manufacturing Firms, 1990-1999

Abstract

During the second part of the 1990s, the Israeli economy experienced a surge in labor productivity and total factor productivity, which was driven primarily by the manufacturing sector. This surge in productivity coincided with the full absorption and integration into the workforce of highly skilled immigrants from the former Soviet Union. The Soviet immigrants were disproportionately employed in manufacturing and, after an initial adjustment period, progressively moved into higher responsibility occupations where their skills could be put to use more efficiently. This raises the questions of whether the high-skilled immigration wave was one of the main determinants for the fast growth of the Israeli economy in the 1990s.

This paper uses a unique data set on Israeli manufacturing firms and investigates directly whether firms and industries with a higher concentration of immigrants experienced increases in labor productivity and total factor productivity. The analysis shows that there is no correlation between immigrant concentration and productivity at the firm level in cross-sectional and pooled OLS regressions. First-differences estimates, which control for fixed unobserved differences between firms, reveal, if anything, a *negative* correlation between the change in output per worker and the change in the immigrant share. A more in-depth analysis reveals that the immigrant share was strongly negatively correlated with output and productivity in low-tech industries. In high-technology industries, the results tend to point to a positive relationship, hinting at complementarities between technology and the skilled immigrant workforce.

Key words: Immigration, productivity, manufacturing, high-technology, growth.

JEL: D2, J24, F22, E22, E23.

M. Daniele Paserman
Department of Economics
Hebrew University
Jerusalem, 91905
Israel
dpaserma@shum.huji.ac.il

DO HIGH-SKILL IMMIGRANTS RAISE PRODUCTIVITY? EVIDENCE FROM ISRAELI MANUFACTURING FIRMS, 1990-1999

NON-TECHNICAL SUMMARY

From the last quarter of 1989 until 2001, over 1 million immigrants from the Former Soviet Union (FSU) arrived in Israel, increasing its population and labor force by extraordinary rates. At the peak of the immigration wave in 1990 and 1991, over 330 thousand FSU Jews immigrated to Israel, increasing Israel's potential labor force by 8 percent and its population by 15 percent. In addition to its size, another unique aspect of this immigration wave is that many of the immigrants were highly educated. About 60 percent of the FSU immigrants who arrived between 1989-1990 were college-educated and almost one-fourth were college graduates. In contrast, only about 30 percent of the native Israeli Jews in 1990 were college educated, and 12 percent were college graduates.

Much of the previous work on the impact of immigration on the host economy's labor market has found that wages are only mildly negatively affected by the influx of competing workers. This suggests that offsetting flows of labor or capital, or improvements in firms' productivity must occur in order for native wages to maintain their pre-immigration level. This last scenario could well be plausible in the Israeli case, because of the high skill content of the immigrant population. Indeed, the aggregate data reveals that the manufacturing sector, which employed a disproportionate share of FSU immigrants, experienced sustained growth in output per worker and total factor productivity during the 1990s.

This paper uses a unique data set on Israeli manufacturing firms and investigates directly whether firms and industries with a higher concentration of immigrants experienced increases in labor productivity and total factor productivity. The analysis reveals a number of interesting results:

a) Despite their high levels of formal education, immigrants were initially employed in low-skill occupations, and moved up the occupational ladder only a number of years after arrival.

b) In 1993, shortly after the peak of the immigration wave, the immigrant share in the firm can be predicted by a number of pre-immigration characteristics of the firm: firms that in 1990 had a high capital/labor ratio, paid low wages and were in industries with a low-educated workforce employed a relatively high share of immigrants. Immigrants were less likely to be employed in firms with a high share of output in highly concentrated industries, consistent with models of queuing in the labor market. By 1997, many of these correlations were weakened or reversed.

c) In cross-sectional and pooled OLS production function regressions, I find no evidence that the immigrant share is correlated with labor productivity or total factor productivity. First-differences estimates reveal, if anything, a *negative* correlation between the change in output per worker and the change in the immigrant share.

d) The immigrant share was strongly negatively correlated with output and productivity in low-tech industries. In high-tech industries, the results are somewhat mixed, but tend to point to a positive relationship, hinting at complementarities between technology and the skilled immigrant workforce.

1. Introduction

From the last quarter of 1989 until 2001, over 1 million immigrants from the Former Soviet Union (FSU) arrived in Israel, increasing its population and labor force by extraordinary rates. At the peak of the immigration wave in 1990 and 1991, over 330 thousand FSU Jews immigrated to Israel, increasing Israel's potential labor force by 8 percent and its population by 15 percent. In addition to its size, another unique aspect of this immigration wave is that many of the immigrants were highly educated. About 60 percent of the FSU immigrants who arrived between 1989-1990 were college-educated and almost one-fourth were college graduates. In contrast, only about 30 percent of the native Israeli Jews in 1990 were college educated, and 12 percent were college graduates.

Much of the previous work on the impact of immigration on the host economy's labor market has found that wages are only mildly negatively affected by the influx of competing workers.[1] This suggests that offsetting flows of labor or capital, or improvements in firms' productivity must occur in order for native wages to maintain their pre-immigration level. This last scenario could well be plausible in the Israeli case, because of the high skill content of the immigrant population. Indeed, the aggregate data reveals that the manufacturing sector, which employed a disproportionate share of FSU immigrants, experienced sustained growth in output per worker and total factor productivity during the 1990s.

In this paper, I use a unique data set on Israeli manufacturing firms and investigate directly whether firms and industries with a higher concentration of

[1] See Friedberg and Hunt (1995) for a survey of the early literature, or Card (2005), for a more recent appraisal. On the other hand, Borjas (2003) argues that immigration does have an adverse effect on the employment and wages of natives with the same education and experience as that of immigrants. Studies of the Israeli experience in the 1990s have also found contrasting results: Friedberg (2001) finds that the effect of immigration on native wages and employment is sensitive to the estimation procedure, while Cohen-Goldner and Paserman (2006) find some adverse effect on wages in the short run, but no effect in the long run.

immigrants experienced increases in labor productivity and total factor productivity. The analysis is carried out by running conventional production function regressions, where the share of immigrants is treated as an additional right hand side variable. This econometric specification is obtained directly from microeconomic principles if one assumes a Cobb-Douglas production function, perfect substitutability between native and immigrant labor, with possible differences in the efficiency units of labor provided by native and immigrant workers.

The analysis reveals a number of interesting results: a) Despite their high levels of formal education, immigrants were initially employed in low-skill occupations, and moved up the occupational ladder only a number of years after arrival. b) In 1993, shortly after the peak of the immigration wave, the immigrant share in the firm can be predicted by a number of pre-immigration characteristics of the firm: firms that in 1990 had a high capital/labor ratio, paid low wages and were in industries with a low-educated workforce employed a relatively high share of immigrants. Immigrants were less likely to be employed in firms with a high share of output in highly concentrated industries, consistent with models of queuing in the labor market. By 1997, many of these correlations were weakened or reversed. c) In cross-sectional and pooled OLS production function regressions, I find no evidence that the immigrant share is correlated with labor productivity or total factor productivity. First-differences estimates reveal, if anything, a *negative* correlation between the change in output per worker and the change in the immigrant share. d) The immigrant share was strongly negatively correlated with output and productivity in low-tech industries. In high-tech industries, the results are somewhat mixed, but tend to point to a positive relationship, hinting at complementarities between technology and the skilled immigrant workforce.

This paper's contribution is threefold. First, it joins the growing the literature that attempts to understand how firms and industries respond to migration waves. Lewis (2003) finds that relative labor supply shocks have little effect on the local industry mix; instead, industries respond to these shocks by changing their relative factor intensities. Lewis (2006) further corroborates these findings by showing that in markets with a higher availability of less-skilled labor manufacturing plants are less likely to introduce automated production techniques. Lewis argues that these endogenous changes in production techniques may explain why wages of unskilled workers have been found not to respond to large immigration-induced labor supply shocks. Gandal, Hanson and Slaughter (2004) obtain similar results in the Israeli context: they find that global changes in production techniques were sufficient to more than offset Israel's change in relative factor supplies induced by the Soviet immigration, while changes in output mix did not help Israel absorb changes in relative factor prices. These studies, however, did not have micro data on the distribution of immigrants across establishments, and therefore could not investigate directly the effect of immigrants on plant productivity. To my knowledge, Quispe-Agnoli and Zavodny (2002) are the only ones to estimate directly the effects of immigration on firm productivity. Using state-level data, they find that labor productivity increased more slowly in states that attracted a larger share of immigrants in the 1980s, both in low-skill and high-skill industries. The current study improves on the existing literature by exploiting information on immigrant concentration at the firm level, a unique feature of my data set.

The second strand of literature to which this paper is related is the one on the effects of a highly educated workforce on labor productivity. Moretti (2004) finds robust evidence of educational spillovers in U.S. manufacturing: the productivity of plants in cities that experience large increases in the share of college graduates rises more than the productivity of similar plants in cities that experience small increases in the share of college graduates. Exploiting the longitudinal nature of his data, Moretti can address the most relevant endogeneity and selectivity issues by including plant and city fixed effects: however, his data cannot conclusively rule out the possibility that time-varying productivity shocks are correlated with changes in the overall level of human capital in a city. One advantage of my study is that it allows to investigate the productivity effects of the large, unexpected, and arguably exogenous shock to the stock of human capital represented by the Soviet immigration to Israel.[2]

Finally, the paper helps understanding the determinants of growth in the Israeli economy in the 19990s. Hercowitz (1998), and Hercowitz, Lavi and Melnick (1999), using macroeconomic time series data up to 1995, find that immigration has a negative short-run impact on TFP growth. They interpret these results as a consequence of immigrants' slow process of adjustment to the labor market, implicitly arguing that TFP should have picked up once the adjustment process had been completed. My paper sheds light on this issue by extending the analysis to the end of the decade: this is a particularly interesting period of analysis, because by this time the most difficult part of the immigrants' adjustment process had already been completed, and because the Israeli economy experienced a surge in productivity growth in the second half of the 1990s.

The rest of the paper is structured as follows: Section 2 presents some general macroeconomic trends in the Israeli economy between 1970 and 1999, and in the manufacturing sector in particular. Section 3 describes the data. Section 4 discusses the distribution of immigrants across firms and industries in 1993 and 1997. Section 5

---

[2] Other papers that have looked at how the educational composition of the workforce affects productivity are Hellerstein, Neumark and Troske (1999) and Jones (2001).

presents the basic estimates of the production function, as well as additional robustness tests and specification tests. Section 6 concludes.

2. Israeli Productivity, 1970-1999: Macroeconomic Trends

Table 1 presents the average yearly growth rates in total output per worker and in total factor productivity, by decade, between 1970 and 1999.[3] Output per worker and total factor productivity grew at a sustained and similar rate during the 1970s, but growth slowed down considerably during the 1980s. In the 1990s, the growth rate picked up again, with the manufacturing sector leading the charge in both output per worker and TFP. Figure 1 presents the evolution of output per worker for the entire Israeli economy and for the manufacturing sector alone, between 1970 and 2000. The two series grew at fairly similar rates between 1970 and 1993, but since then manufacturing output per worker has taken off at a very fast rate, while overall output per worker has remained essentially constant. Figure 2 illustrates that much of the 1990s growth in the manufacturing sector was concentrated in high and medium-high technology industries, even though low and medium-low tech industries also experienced growth in the latter part of the decade.[4]

At the same time, many of the post-1989 immigrants found employment in the manufacturing sector, as can be seen by Table 2: throughout the decade, the share of immigrants in manufacturing was nearly double that of natives. Given the high level of educational attainment of immigrants (and in particular the high concentration of

[3] The data are from the Bank of Israel Annual Report (2003).
[4] See Appendix B for the full classification of industries by technological intensity.

engineers)[5], it is natural to think that there may be a causal link between immigrant employment and growth in the manufacturing sector.

Figure 3 presents the decomposition of manufacturing output in the 1990s into its components: value added per worker, labor, capital per worker, and total factor productivity. We see that labor input increased sharply in the first part of the decade, and then remained fairly constant in the second part. The mirror image of this trend can be seen in the evolution of capital per worker: it dropped by about 10 percent between 1990 and 1992, before rebounding to its initial level by 1995, and then growing very quickly in the second part of the decade. This matches the prediction of a simple economic model in which the capital stock is fixed in the short run, but can adjust in the long run in response to take advantage of the higher marginal productivity that arises following the influx of workers. Both value added per worker and TFP fluctuated in the first part of the decade, and then began to grow steadily since 1995.

Figure 4 also shows that the manufacturing sector experienced skill upgrading during the 1990s. The proportion of workers with high education (some college or more) rose steadily throughout the decade, from about 26 percent in 1990 to 43 percent in 1999. This may reflect the growing share of immigrants with high education in manufacturing employment, but also the increasing educational attainment of the non-immigrant workforce. When measuring skill by the proportion of workers in white-collar occupations, we see a slightly different picture: the share of white collar workers fell in the first part of the decade (from about 21 to 19 percent), but then grew very quickly in the second part of the decade. This likely reflects the occupational upgrading of the FSU immigrants, a phenomenon which has already

[5] Weiss, Sauer and Gotlibovski (2003) report that more than 70% of the immigrants worked in high-skill or medium-skill occupations in the USSR, and the supply of engineers and physicians roughly doubled between 1989 and 1993.

been studied extensively in the literature (Weiss, Sauer and Gotlibovsky, 2003; Eckstein and Weiss, 2002 and 2004).

Summing up, it appears that the manufacturing sector as a whole, and in particular high technology industries within this sector, were the main engines of growth in the Israeli economy in the latter part of the 1990s. At the same time, the manufacturing sector absorbed large numbers of highly educated immigrants, who gradually shifted from blue-collar to white-collar occupations. In the next sections we will try to analyze whether these two phenomena are linked at a more disaggregated level.

3. Data

The main source of data for my analysis is represented by the 1990-1999 Manufacturing and Crafts Surveys conducted annually by the Israeli Central Bureau of Statistics (CBS). The survey is a representative sample of manufacturing establishments employing 5 or more persons. Griliches and Regev (1995) used these same surveys to study productivity in Israeli firms during the 1980s.

The Manufacturing Surveys have been conducted regularly by the CBS since 1955. The surveys can be viewed as a succession of short panels, since every few years the sampling frame is redesigned and a new sample of establishments is drawn based on probability sampling. Large establishments (with more than 75 employed persons), and a number of smaller establishments in some economic branches are sampled with certainty, while smaller establishments are sampled with a probability determined by establishment size and economic branch. The sampled establishments are then followed for a number of years, until the next sample redesign. In the period I investigate, there were two redesigns of the sample: the 1989 redesign, which is the basis for the 1990-1994 surveys, and the 1994 redesign, which is the basis for the 1995-1999 surveys. Table 3 shows the number of establishments in each survey year, the number of establishments in each year which were surveyed in 1990, and the number of establishments in each year which were present in 1995. As can be seen, more than 800 establishments in the 1995 sample were already present in 1990, and nearly 700 establishments are sampled continuously between 1990 and 1999.[6]

The Manufacturing Surveys provide information on the usual income and expenditure variables at the firm level: local sales and exports, inventory changes, intermediate inputs, investments broken down by type (buildings, equipment, and vehicles), labor, and wages. These basic data were used to calculate gross output and value added. To calculate each establishment's fixed capital stock, I proceeded as follows: first, I linked each establishment to data on the fixed capital stock at the three-digit industry level from the CBS's 1992 Survey of the Fixed Gross Capital Stock. I then assumed that the capital-output ratio is constant within each industry to obtain an estimate of each establishment's stock of equipment, buildings, and vehicles in 1992. Then, I calculated the capital stock for every year using the perpetual inventory method (both forward and backwards, for the years 1990 and 1991), and the linear depreciation formulas used in Regev (1993).[7]

The CBS follows standard OECD definitions and classifies all industrial sectors into four different levels of technological intensity. I will also follow this standard classification throughout the paper. Table 4 presents summary statistics on the number of firms, on total employment, and on the composition of the labor force for the four levels of technological intensity. High-technology firms represented 7

[6] For more detailed descriptions of the sampling procedures, see Israel Central Bureau of Statistics (various years).
[7] Specifically, I assumed that buildings depreciate fully after 35 years, equipment after 15 years, and vehicles after 8 years.

percent of the sample in 1990, but employed about 13 percent of the total number of workers in manufacturing. By 1997, the number of high tech firms in the sample had risen to 9 percent, employing now 16 percent of the manufacturing workforce, a 41 percent increase in thelevl of employment. Note however that employment growth was not confined to the high-tech sector alone: employment grew by about 6 percent in the low-tech sector, and by about 47 percent in the medium-low tech sector. Table 4 also shows that the OECD classification reflects fairly accurately the educational composition of the workforce: workers in the high-tech sector have about two and a half more years of schooling than workers in the low tech sector. Moreover, high-tech establishments have a substantial fraction of scientists, and are substantially more likely to invest in R&D.

4. The distribution of immigrant employment

The unique feature of my analysis is the combination of the standard variables on industrial production with information on the type of workforce employed in each establishment. This information is taken from the supplemental surveys on the Structure of the Labor Force (SLF), which were administered to all firms in the Manufacturing Surveys in 1993 and 1997. These surveys collected information on the total number of scientists, white-collar workers ("academics"), technicians, and production workers employed in each establishment, *and* on the number of recently arrived immigrants in each one of the above categories. This enables me to analyze the characteristics of firms that employed immigrants, and to study whether firms who employed a large number of highly educated immigrants experienced a boost in productivity.

Table 5 presents summary statistics for the SLF data. In the top panel, I present statistics for all the firms with non-missing data in 1993 and 1997, while the bottom panel restricts attention only to those firms that appear in the sample in both 1993 and 1997 (the balanced sample). We must first note the large difference in establishment size between the full sample and the balanced sample. The average number of employees in the full sample is between 29 and 41, but it rises to 130 in the full sample. This simply reflects the sampling scheme, whereby large establishments are sampled with certainty, while small establishments only belong to the probability sample. The share of firms with at least one immigrant drops from 1993 to 1997, while the average number of immigrants per firm increases, indicating that the employment of immigrants became more concentrated in fewer firms. The average share of immigrants in the firm is fairly stable at 15 to 17 percent of the total workforce.

In contrast to the stability of immigrant employment between 1993 and 1997, there were substantial shifts in the occupational distribution of immigrants within firms, as can be seen from Table 6. The percent of scientists among immigrants more than doubled from 1993 to 1997, going from 4.3 to 9.8 percent. As a result, in 1997 the proportion of immigrants who were scientists was higher than the overall proportion of immigrants in the workforce (15.9 percent versus 15.1percent). Also, by 1997 a substantial fraction of immigrants were employed in white-collar jobs and as technicians, while the share of immigrants employed as production workers declined from nearly 94 percent to about 81.5 percent. These results further confirm that throughout the 1990s immigrants experienced substantial occupational upgrading, as they acquired local labor market skills and were able to convert part of their imported human capital into something valuable for Israeli employers.

We now move to the question of which industries and firms employed immigrants. Figures 3a and 3b show the immigrant distribution across 25 two-digit manufacturing industries. The dark bars represent high and medium-high tech industries, while the light bars represent low and medium-low tech industries. In 1993 there does not seem to be any evident correlation between the technological intensity of the industry, and immigrant concentration. In 1997, the electronic components industry stands out for its high concentration of immigrants, and overall it does seem that there has been a shift of immigrants towards more high-technology sectors.

In Table 7 I investigate directly the determinants of immigrant hiring at the firm level. Specifically, I regress the share of immigrants in the firm, for both 1993 and 1997, on a number of firm characteristics in 1990. This allows me to establish which pre-immigration characteristics of establishments were conducive to the hiring of immigrants. I include in the regressions a number of standard firm characteristics – dummies for size, the capital-labor ratio, the 1990 average wage, and value added per worker (all in logs). In addition, I include a number of variables meant to capture the concentration level of the industry, the level of competition from imports, and whether the firm enjoys a dominant position within the industry: this is meant to capture the fact that maybe workers queue for jobs in firms that enjoy monopoly rents (Katz and Summers, 1990), and outsiders such as immigrants are less likely to find jobs at these firms. Finally, I include a number of indicators for the skill of the workforce and for technological intensity at the industry level: the average years of schooling in the three-digit industry (taken from the Labor Force Survey in 1989-1990), whether the firm engages in R&D, and dummies for medium-low, medium-high and high-tech industries. I estimate two specifications, with and without two-digit industry fixed effects. The regression is estimated separately for 1993 and 1997.

The results for 1993 suggest that immigrants were more likely to be employed in medium-sized firms rather than in very small or very large firms, but the differences are small and not always statistically significant. More interesting is the coefficient on the capital-labor ratio, which is positive and significant, confirming the intuitive notion that firms that had room to grow were more likely to hire immigrants. Interestingly, there does not seem to be any correlation between a firm's productivity in 1990 and its propensity to hire immigrants in 1993. There is also some evidence that medium-low tech firms were more likely to hire immigrants, and that immigrant employment is negatively correlated with the average years of schooling in the industry in 1990, although this effect disappears when we control for two-digit industry dummies. The coefficients on the industry concentration variables reveal an interesting pattern: immigrants are more likely to be employed in highly concentrated industries, but not in those firms that enjoy a dominant position within the industry. For example, a firm with a 40 percent output share in an industry with a 0.5 three-firm concentration index employs on average 5 percent ($0.078\times0.5 - 0.122\times0.4 - 0.201\times0.5\times0.4 = -0.05$) fewer immigrants than a (hypothetical) firm in a perfectly competitive industry (i.e., infinitely small output share in an industry where the concentration index is zero). By contrast, a firm in the same industry with only 5 percent market share employs on average 2.7 percent more immigrants than its perfectly competitive counterpart. Similarly, firms that were exposed to greater competition from imports were more likely to employ immigrants. Coupled with the coefficients on the wage variable, these results suggest that there may indeed be queuing for jobs in firms that enjoy monopoly rents and immigrants are the ones least likely to be close to the front of the queue.

The results for 1997 paint a slightly different picture: Now I find a positive correlation between immigrant share and the 1990 wage, and a negative correlation between immigrant concentration and productivity in 1990. It still seems to be the case that immigrants are less likely to be employed in firms that enjoy a dominant position in their market, and they are more likely to be employed in firms that face stiff import competition, but the other variables measuring industry concentration now become insignificant.

It is difficult to tell how much of the differences between 1993 and 1997 depend on actual mobility of immigrants between firms, and how much instead depends on the fact that because of the 1995 sample redesign, I can only observe a limited number of establishments (mostly large ones) who were present in both the 1990 and 1997 sample. The last two columns of Table 7 illustrate this problem: I replicate the regressions for the 1993 sample, but now using only those firms that were present in the sample in both 1993 and 1997. Now essentially all the coefficients become insignificant, and it is difficult to draw any strong conclusions about the determinants of immigrant hiring at the firm-level.

Summing up, this section has showed that immigrants were distributed over the entire spectrum of Israeli manufacturing firms. In the early 1990s, immigrants were concentrated in firms with room to grow and with possibly low wages (possibly because their access to high paying jobs in firms that enjoy rents is obstructed), but we find little correlation between these firm characteristics and immigrant concentration later in the decade. Two additional findings deserve attention: first, immigrants were not more likely to be employed in high technology firms, which may be viewed as surprising given their high levels of human capital; second, there seems to be little or no correlation between a firm's productivity in 1990 and its propensity to employ immigrants later in the decade. In the next section, where I examine the effect of immigrants on firm productivity, one should keep in mind that there was no apparent pattern of immigrants selectively sorting themselves into firms based on their level of productivity.

5. The effect of immigrants on productivity

In this section I estimate a standard production function at the firm level, including the percentage of immigrants as a right hand-side variable. Assume that firms produce output Y using a Cobb-Douglas production function with capital (K), intermediate inputs (or materials, M), and labor (L) as its inputs. Native labor and immigrant labor (respectively, L_N and L_I) are perfectly substitutable in production, but they may have different levels of productivity.[8] Specifically, we write the firm's production function as:

$$Y = AK^{\alpha}M^{\beta}\left[L_N + (1+\mu)L_I\right]^{\gamma},$$

where the term μ denotes the difference in productivity between a unit of immigrant labor relative to a unit of native labor. This difference in productivity may be positive, if for example immigrant workers have on average higher levels of education, or negative, if immigrants face difficulties in adapting to the local work environment, (because of language barriers or other forms of low local human capital). I define s as the share of immigrants out of total employment L, so that $L_I = sL$, and $L_N = (1-s)L$. Then, we can rewrite the production function as:

$$\begin{aligned} Y &= AK^{\alpha}M^{\beta}L^{\gamma}\left[(1-s)+(1+\mu)s\right]^{\gamma} \\ &= AK^{\alpha}M^{\beta}L^{\gamma}\left[1+\mu s\right]^{\gamma}, \end{aligned}$$

[8] See Hellerstein, Neumark and Troske (1999) and Hellerstein and Neumark (2002) for a more elaborate version of this approach.

Dividing both sides of the equation by L, taking logs, and adding firm and time subscripts yields the estimating equation:

$$\log\left(\frac{Y}{L}\right)_{it} = \alpha \ln\left(\frac{K}{L}\right)_{it} + \beta \ln\left(\frac{M}{L}\right)_{it} + \left(\alpha + \beta + \gamma - 1\right)\ln L_{it} + \gamma\mu s_{it} + \delta' X_{it} + c_i + u_{it},$$

where I have used the approximation $\ln\left(1+\mu s\right) \approx \mu s$, and I have decomposed the technology shifter $\ln A_{it}$ into an observed component ($\delta' X_{it}$) and a fixed unobserved component (c_i). Following Griliches and Regev (1995), the observable technology shifters include the log of R& D expenditures, a dummy for whether the firm engages in R&D at all, region dummies, and (in some specifications) industry dummies. The c_i term is a time-invariant firm specific effect, which is potentially correlated with firm inputs, while u_{it} is an idiosyncratic error term, uncorrelated with firm inputs. Therefore, the estimating framework reduces to a standard production function, with the proportion of immigrants as an additional right hand side variable.[9]

The coefficients in the above equation can be given a causal interpretation if all the unobserved terms are indeed uncorrelated with the inputs, or if the fixed firm effects can be made to drop out of the equation by either first differencing or by subtracting firm-specific means from both sides of the equation (the within estimator). In Table 8 I report the results from cross-sectional and pooled estimation of the production function, while Table 9 presents results from the estimation in first differences. All regressions are estimated by weighted least squares, using the as weights the CBS provided sampling weights.

[9] In the current draft, I employ only linear techniques, so I will only be able to estimate $\gamma\mu$. However, one can straightforwardly estimate m directly, either by non-linear least squares, or by taking a non-linear transformation of the regression coefficients.

Basic Results

The coefficients of the production function in Table 8 are in line with much of the previous literature, and specifically with the findings of Griliches and Regev for the 1972-1988 period. The coefficient on capital in the production function ranges from 0.16 to 0.28, while the coefficient on intermediate inputs is between 0.42 and 0.52. The coefficient on employment reveals some evidence for increasing returns to scale, even though one must be cautious with this specification because of the potential endogeneity problem. What is most striking in the table, though, is the fact that the share of immigrants seems to be completely unrelated to productivity. In all specifications, the coefficient on the share of immigrants is small and insignificant, both statistically and economically. For example, the first column indicates that an increase in the share of immigrants from 0 to 0.1 lowers labor productivity by no more than 0.4 percentage points.

One should be careful in attributing to these results a causal interpretation, because the share of immigrants within a firm may be correlated with unobserved determinants of productivity. In Table 9, I address the possibility that immigrant concentration was correlated with a fixed unobservable component of firm productivity by estimating the firm's production function in first-differenced form. I estimate the relationship separately for 1990-1993 (assuming that the share of immigrants in all firms was zero in 1990) and 1993-1997, and then pooling both periods together. The first three columns of the table present the results based on the sample of all available firms, while the next three columns restrict attention only to the balanced sample of firms that were surveyed in all three years (1990, 1993 and 1997). I now find some evidence of an adverse effect of the change in immigrant share on productivity growth for the 1993-1997 period and for the pooled specification, but the effect disappears in the balanced sample. In contrast to what seemed to emerge from the time series evidence, at the microeconomic level there is clearly no evidence of a positive effect of immigrant concentration on firm productivity.

Robustness Checks

Up to now I have used labor productivity as the dependent variable, but it is possible that the immigrants' skills and know-how may affect directly total factor productivity, while having no effect on labor productivity. To test this hypothesis, I need an estimate of total factor productivity at the firm level. There are a number of different approaches that are possible. I use the simplest possible one, namely the factor share approach. For each year, I calculate the share of output accruing to labor, capital and intermediate inputs at the three-digit industry level, and I then calculate total factor productivity at the firm level as $TFP_{ijt} = \ln\left(Y_{ijt}\right) - \alpha_{jt}\ln L_{ijt} - \beta_{jt}\ln K_{ijt} - \gamma_{jt}\ln M_{ijt}$, where i denotes firms, j denotes industries, and t denotes time. I then regress these measures of total factor productivity on the share of immigrants and on the other elements of the production function. The results are presented in Table 10. The first column estimates the regression in levels, while the second and third columns use the first-difference specification for the 1993-1997 period, for the full and balanced samples, respectively. Once again, it appears that if anything the share of immigrants has a negative effect on firm productivity.

In Table 11, I perform a series of specification checks of the basic production function estimates. For all specifications, I report the results for the regression in levels, in first differences for the full sample, and in first differences for the balanced sample in 1993 and 1997.

In the top panel of the table, I assess whether the apparent lack of a correlation between the percentage immigrants and productivity is due to nonlinearities in the production function. This conjecture is soundly rejected: the quadratic term is always small and insignificant, and including it never changes the fact that the linear term is also small and insignificant.

I then explore whether the effect of immigrants varies by firm size. The different specifications do not present a consistent pattern: in the regression in levels, it appears that the effect of immigrants is most pronouncedly negative in large establishments, while the differences specification suggests that the immigrant share has a negative effect on productivity especially in small firms. Overall, it is unlikely that the explanation for the lack of an effect of immigrant concentration on productivity lies in differences between small and large firms.

The next two panels investigate whether the effect of immigrants on productivity depends on the firm's level of technological intensity, and on the pre-existing level of skills at the industry level. The third panel reveals that the share of immigrants is consistently negatively associated with productivity in low-tech industries, and the coefficient is always statistically significant at the 5 percent level. By contrast, there is some evidence for a positive effect of the immigrants share on productivity in high technology firms, especially in the first-difference specifications. However, the size and significance of the effect are sensitive to whether I use the full or the balanced sample.

The last panel in Table 11 paints a similar picture, although the results are somewhat less precise. There is some evidence that immigrant concentration is negatively correlated with productivity in industries that had a relatively low skill workforce prior to the migration wave, and is positively correlated with productivity in industries with a high skilled workforce.

One last hypothesis deserves to be investigated: maybe only immigrants that are employed in occupations where their skills can really be put to good use (i.e., scientists) have a positive effect on productivity. I explore this possibility in Table 12. For all three specifications (levels, first differences on the full sample, first differences on the balanced sample), I run two regressions, one where the key right hand side variable is the share of immigrant scientists, and one where it is the share immigrants in all other occupations. The top panel looks at the relationship in all firms. In all specification, the correlation between the share of immigrant scientists and productivity is positive but not statistically significant. On the other hand, the coefficient on the share of immigrants in other occupations reflects the results of Tables 8 and 9: small and insignificant in the levels specification, negative and significant in the first difference specification in the full sample, negative and insignificant in the first-difference specification in the balanced sample. The next panels of the table examine whether the effect of immigrant scientists differs by the type of industry. The correlation between the share of immigrants in other occupations and productivity is similar to the one found in Table 11. Interestingly, though, we also find a strong negative correlation between the share of immigrant scientists and productivity in low-tech industries, while the effect of immigrant scientists in other technology categories is never statistically significant. Finally, splitting industries based on the level of education in 1989-1990 yields mostly insignificant coefficients. Altogether, there does not seem too much evidence that immigrants employed as scientists had any positive effects on productivity, either overall or in specific industries.

6. Conclusion

This paper has studied whether the high-skilled migration wave from the former Soviet Union to Israel has had any effects on the productivity of Israeli manufacturing firms. Using a unique micro-level data set with information on standard measures of productivity and on the composition of the workforce, I found no evidence that a higher concentration of immigrants had any positive effects on firm productivity. This finding stands in contrast with the macroeconomic evidence, which revealed that the manufacturing sector employed a disproportionate share of immigrants and was the driving engine of economic growth in Israel in the 1990s. If anything, there is robust evidence that immigrant concentration was negatively related to productivity in low-technology industries. There is some evidence of a positive effect of immigrants on productivity in high technology industries, but the magnitude and significance of the results are sensitive to the econometric specification.

These results shed new light on the causes of growth in the Israeli economy in the 1990s, and casts doubt on the frequently voiced view that the high-skill immigration played a substantial role in boosting manufacturing productivity. It therefore appears that Israel did not succeed in exploiting the extraordinary windfall in human capital represented by the Russian immigration to its full extent. Besides this direct contribution to our understanding of macroeconomic trends in the Israeli economy, there may be important lessons to be learned for other countries that are moving towards a more skill-biased immigration policy.

Finally, these findings also have important implications for understanding the impact of immigration on the host country economy. I find little support for the conjecture that increases in productivity may have contributed to diffusing the adverse impact of immigration on native wages. The debate is still open and requires additional research.

References

Bank of Israel, *Annual Report*, 2003.

Borjas, George J. 2003. "The Labor Demand Curve *Is* Downward Sloping: Reexamining the Impact of Immigration on the Labor Market." *Quarterly Journal of Economics*, Vol. 118, No. 4 (November), pp.1335-1374.

Card, David. "Is the New Immigration Really So Bad?" *Economic Journal*, November 2005, 115(507), F300-323.

Cohen-Goldner, Sarit and Paserman, M. Daniele. "The Dynamic Impact of Immigration on Natives' Labor Market Outcomes: Evidence from Israel." Mimeo., Hebrew University, December 2006.

Eckstein, Zvi and Weiss, Yoram., ""The Integration of Immigrants from the Former Soviet Union in the Israeli Labor Market," in *The Israeli Economy, 1985-1998: From Government Intervention to Market Economics, Essays in Memory of Prof. Michael Bruno*, edited by Ben-Bassat, Avi. Cambridge: MIT Press, 2002.

Eckstein, Zvi and Weiss, Yoram., "On the Wage Growth of Immigrants: Israel 1990-2000," *Journal of the European Economic Association*, 2(4), June 2004, pp. 665-695.

Friedberg, Rachel M. "The Impact of Mass Migration on the Israeli Labor Market." *Quarterly Journal of Economics*, 116(4), November 2001, pp. 1373-1408.

Friedberg, Rachel M. and Hunt, Jennifer. "The Impact of Immigrants on Host Country Wages, Employment and Growth."*Journal of Economic Perspectives*, 9(2), Spring 1995, pages 23-44.

Gandal, Neil; Hanson, Gordon H. and Slaughter, Matthew J. "Technology, Trade and Adjustment to Immigration in Israel." *European Economic Review*, 48(2), April 2004, pages 403-428.

Griliches, Zvi and Regev, Haim. "Firm Productivity in Israeli Industry: 1979-1988." *Journal of Econometrics*, January 1995, 65(1), pages 175-203.

Hellerstein, Judith K and Neumark David. "Sex, Wages, and Productivity: An Empirical Analysis of Israeli Firm-Level Data." *International Economic Review*, 40(1), February 1999, pages 95-123.

Hellerstein, Judith K.; Neumark, David and Troske, Kenneth R. "Wages Productivity and Worker Characteristics: Evidence from Plant-Level Production Functions and Wage Equations." *Journal of Labor Economics*, 17(3), July 1999, pages 409-446.

Hercowitz, Zvi. "Capital Accumulation, Productivity and Growth in the Israeli Economy," in *The Israeli Economy, 1985-1998: From Government Intervention to Market Economics, Essays in Memory of Prof. Michael Bruno*, edited by Ben-Bassat, Avi. Cambridge: MIT Press, 2002.

Hercowitz, Zvi; Lavi, Yaacov and Melnick, Rafi. "The Impact of macroeconomic Factors on Productivity in Israel, 1960-1996." *Bank of Israel Economic Review*, November 1999, 0(72), pages 103-124.

Israel Central Bureau of Statistics. *Manufacturing and Crafts Surveys*, various years.

Jones, Patricia. "Are Educated Workers Really More Productive?" *Journal of Development Economics*, 64(1), February 2001, pages 57-79.

Katz, Lawrence F. and Summers, Lawrence H. "Industry Rents: Evidence and Implications." *Brookings Papers on Economic Activity*, 1989(0), Special Issue, pages 209-275.

Lewis, Ethan G. "Local Open Economies within the U.S.: How Do Industries Respond to Immigration?" Federal Reserve Bank of Philadelphia, WP 04-01, December 2003.

Lewis, Ethan G. "Immigration, Skill Mix, and the Choice of Technique." Mimeo., Dartmouth University, March 2006.

Moretti, Enrico. "Workers' Education, Spillovers and Productivity: Evidence from Plant-Level Production Functions." *American Economic Review*, 94(3), June 2004, pages 656-690.

Quispe-Agnoli, Myriam, and Zavodny, Madeline. "The Effect of immigration on Output Mix, Capital and Productivity." Federal Reserve Bank of Atlanta Economic Review, First Quarter 2002.

Weiss, Yoram; Sauer, Robert M.; and Gotlibovski, Menachem. "Immigration, Search, and Loss of Skill." *Journal of Labor Economics*, 21(3), July 2003, pp.557-591.

Figure 1: Israeli Output per Worker, 1970-2000

Figure 2: Decomposition of output growth in manufacturing, 1990-1999

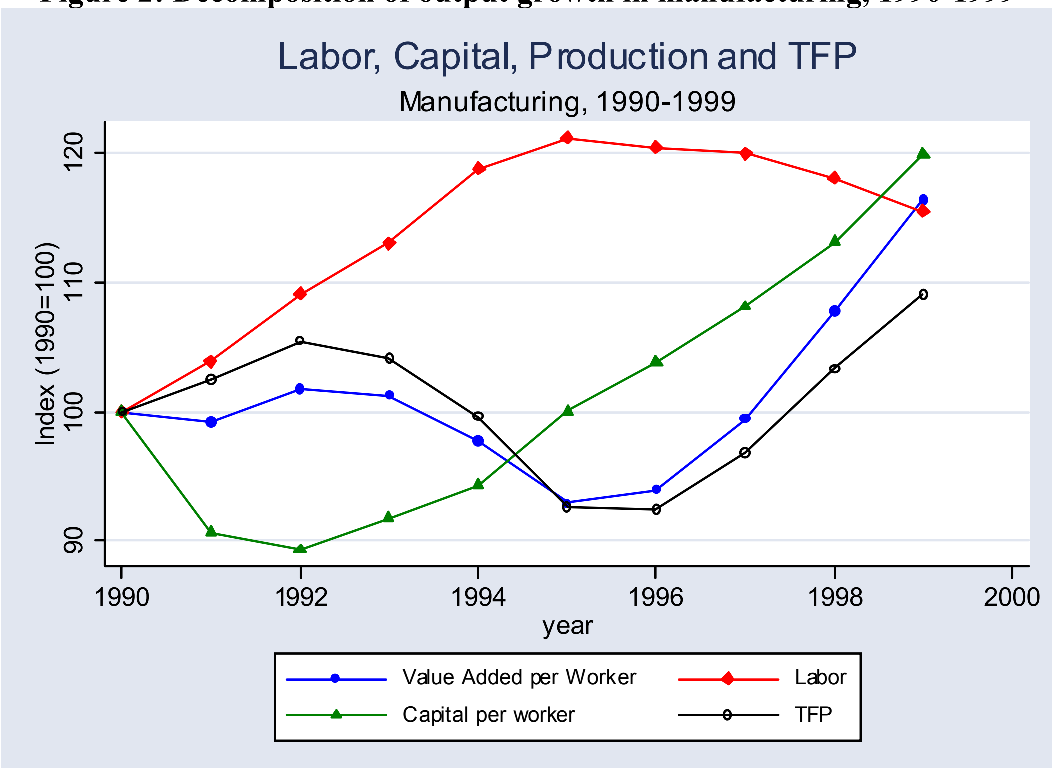


Figure 3: Manufacturing output per worker, by technological intensity

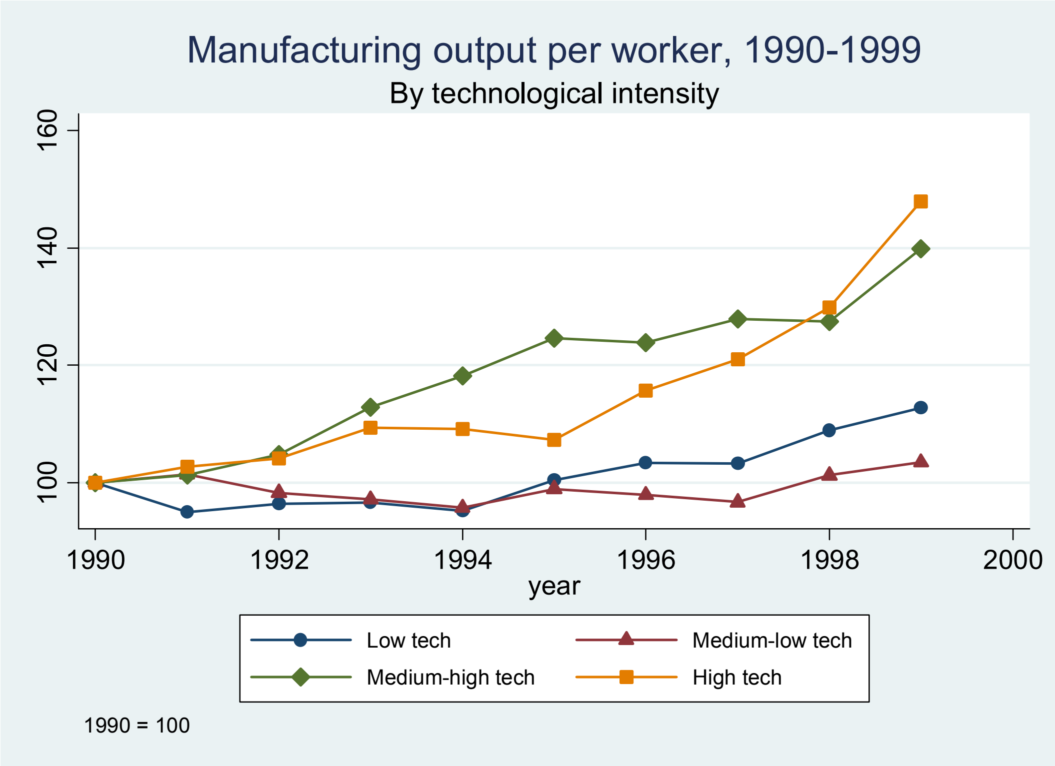


Figure 4: Skill Content in the Manufacturing Sector, 1990-1999

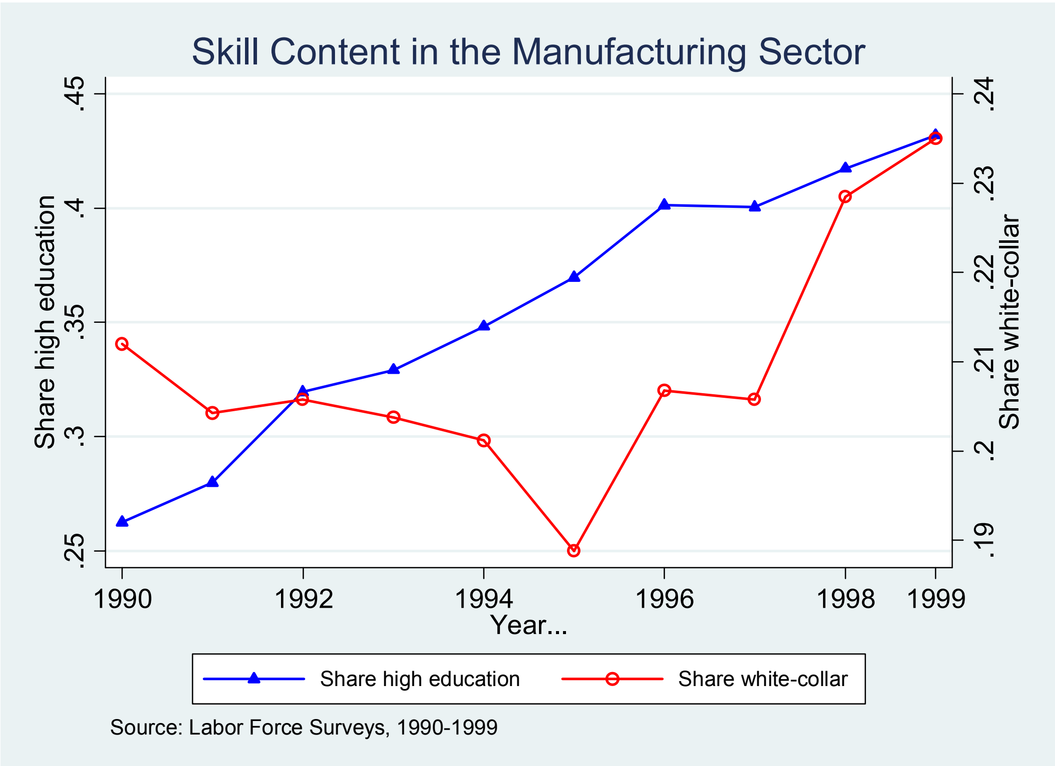


Figure 5a: Immigrant Distribution across Industries, 1993

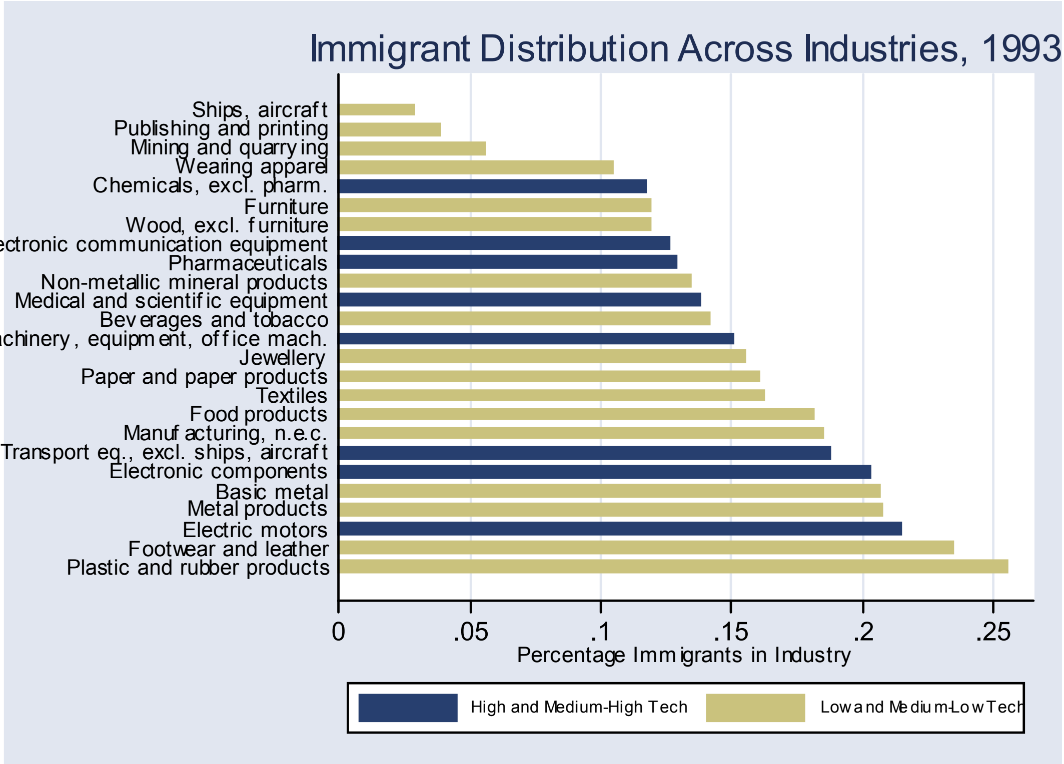
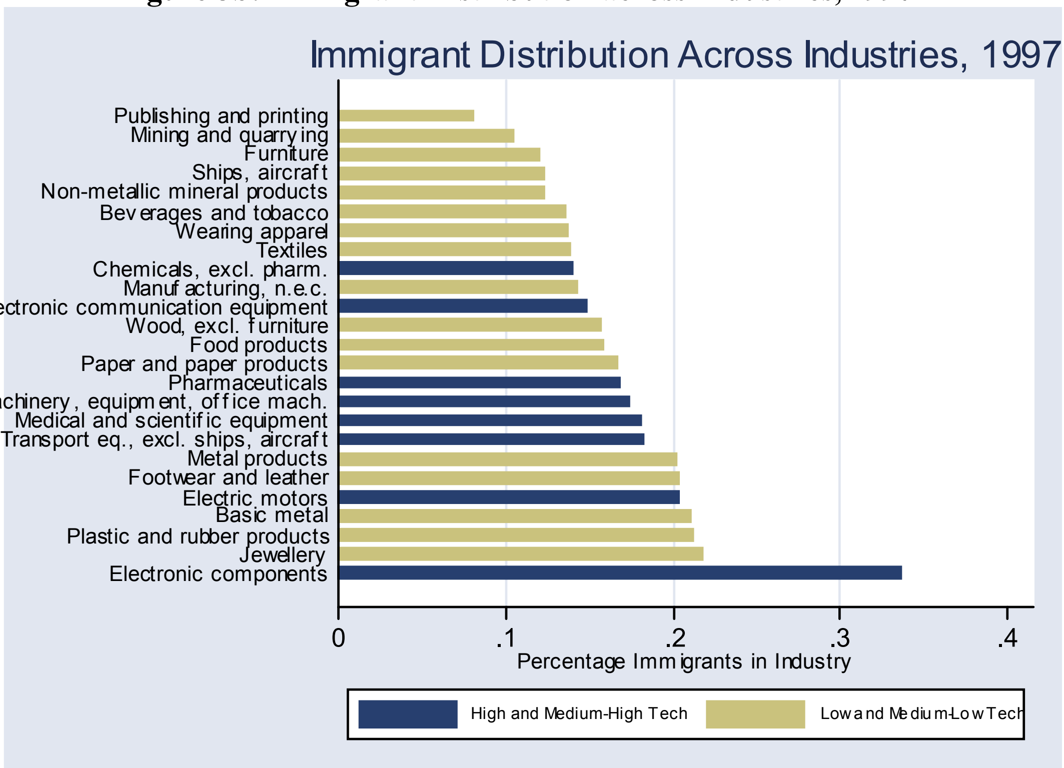


Figure 5b: Immigrant Distribution across Industries, 1997



Source: Labor Force Composition Surveys, 1993-1997.

Table 1: Output per Worker and Total Factor Productivity in Israel, 1970-1999
Average yearly change

	Output per Worker		Total Factor Productivity	
	Manufacturing	Total Private Sector	Manufacturing	Total Private Sector
1970-1979	4.42%	4.58%	2.22%	2.81%
1980-1989	1.67%	1.51%	0.15%	0.91%
1990-1999	3.14%	1.04%	1.63%	0.70%

Source: Author's calculations based on data from the *Bank of Israel Annual Report, 2003.*

Table 2: Employment Distribution of Immigrants and Natives by Industry
1991-1999

	Males		Females	
	Immigrants	**Natives**	**Immigrants**	**Natives**
Agriculture	2.14	3.88	1.83	1.42
Mining and Manufacturing	**41.68**	**25.15**	**25.53**	**11.42**
Electricity and Water	1.23	1.62	0.27	0.36
Construction	12.39	9.93	0.88	0.97
Commerce, Restaurants and Hotels	10.90	16.00	15.44	12.92
Transport, Storage and Communication	4.35	9.11	1.54	3.33
Financing and Business Services	8.98	11.59	10.79	13.87
Public and Community Services	13.12	17.84	31.41	47.33
Personal and Other Services	5.22	4.88	12.31	8.38
Total	100.00	100.00	100.00	100.0
Percentage Immigrants	9.50		11.21	

Note: Author's calculations from the 1991-1999 Labor Force Surveys

Table 3: Number of Establishments in the Manufacturing Surveys

	Total number of establishments	Number of establishments in the sample in 1990	Number of establishments in the sample in 1995
1990	2085	2085	822
1991	2151	1936	857
1992	2158	1826	878
1993	2254	1754	911
1994	2316	1666	957
1995	2041	822	2041
1996	1987	799	1879
1997	1950	768	1761
1998	1903	739	1652
1999	1865	713	1551
Total number of firms in the sample:		4378	
Firms continuously in the sample, 1990-1999		698	

Note: Author's calculations from the 1990-1999 Manufacturing Surveys

Table 4: Firm characteristics, by technological intensity

	Low-Tech			Medium-Low Tech			Medium-High Tech			High-Tech		
	1990	1993	1997	1990	1993	1997	1990	1993	1997	1990	1993	1997
Number of firms	990	1,061	832	629	703	655	305	324	284	152	166	179
Total Employment	129,215	145,976	137,841	74,353	91,446	109,470	51,030	48,904	49,768	40,018	46,916	56,555
Average years of Schooling	10.63	11.01	11.68	11.37	11.82	12.27	11.81	12.53	12.62	13.27	14.00	14.26
Percentage Scientists	-	0.53%	1.27%	-	2.43%	3.51%	-	6.45%	8.15%	-	23.43%	31.99%
Percentage of firms doing R&D	-	0.59%	0.04%	-	0.96%	0.54%	-	4.46%	4.26%	-	16.05%	21.03%

Note: Author's calculations from the 1990-1999 Manufacturing Surveys, Labor Force Composition Surveys, and Labor Force Surveys. For the classification of industries by technological intensity, see Appendix Table A1.

Table 5: Percentage Immigrants in Manufacturing:
Labor Force Composition Surveys, 1993 and 1997

	1993	**1997**
	All Firms	
Number of firms with non-missing LFC data	2,254	1,437
Average number of employees	28.53	40.97
Share of firms hiring immigrants	0.692	0.514
Average number of immigrants in firm	4.21	6.20
Median number of immigrants in firm	1	1
Average share of immigrants in firm	0.152	0.155
Average share of immigrants in firms with at least one immigrants	0.218	0.301
	Balanced Sample	
Number of firms with non-missing LFC data	762	617
Average number of employees	128.11	134.11
Share of firms hiring immigrants	0.933	0.697
Average number of immigrants in firm	26.82	34.04
Median number of immigrants in firm	18	13
Average share of immigrants in firm	0.174	0.170
Average share of immigrants in firms with at least one immigrants	0.186	0.244

Note: Firms in the balanced sample are firms that were present in the sample in 1990, 1993, and 1997.

Table 6: Occupational Distribution of Immigrants in Manufacturing

	1993			1997		
		Occupational Distribution			Occupational Distribution	
	Share of occupation who are immigrants	Immigrants	Total	Share of occupation who are immigrants	Immigrants	Total
Scientists	0.074	0.043	0.075	0.159	0.098	0.093
Academics	0.021	0.004	0.026	0.081	0.022	0.042
Technicians	0.028	0.016	0.072	0.111	0.064	0.088
Other Production	0.148	0.937	0.827	0.159	0.815	0.777
Total	0.130	1.000	1.000	0.151	1.000	1.000

Source: Author's calculations from the LFCS.

Table 7: 1990 Firm Determinants of Immigrant Concentration, 1993-1997

	Share immigrants in 1993		Share immigrants in 1997		Share immigrants in 1993	
	All available firms		All available firms		All firms in 1997 sample	
Number employed: 10-24	0.009 (0.014)	0.001 (0.013)	0.014 (0.052)	0.001 (0.056)	0.051 (.044)	0.025 (0.043)
Number employed: 25-49	0.039** (0.152)	0.028* (0.015)	-0.005 (0.041)	-0.015 (0.054)	0.127** (0.043)	0.090** (0.041)
Number employed: 50-99	0.035** (0.015)	0.022 (0.015)	-0.045 (0.044)	-0.048 (0.050)	0.062 (0.042)	0.040 (0.040)
Number employed: 100+	0.014 (0.016)	0.000 (0.016)	-0.029 (0.047)	-0.058 (0.049)	0.025 (0.041)	-0.007 (0.039)
Log (K/L)	0.032** (0.009)	0.022** (0.008)	0.044 (0.027)	0.051* (0.029)	0.015 (0.013)	0.014 (0.013)
Log Wage	-0.051** (0.018)	-0.044** (0.016)	0.116** (0.053)	0.074* (0.038)	-0.053* (0.030)	-0.039 (0.030)
Log value added per worker	0.014 (0.015)	0.019 (0.013)	-0.142** (0.059)	-0.126** (0.051)	0.019 (0.021)	0.015 (0.021)
Output share in 3-digit industry	-0.122* (0.065)	-0.126* (0.067)	-0.347** (0.154)	-0.264* (0.142)	-0.056 (0.065)	-0.086 (0.067)
Three-firm concentration index (3-digit industry)	0.078** (0.037)	0.081** (0.039)	-0.053 (0.111)	0.010 (0.111)	-0.034 (0.050)	0.071 (0.055)
Output share × Concentration index	-0.201** (0.096)	-0.203** (0.101)	0.065 (0.211)	0.125 (0.217)	-0.088 (0.088)	-0.119 (0.086)
Import penetration index (3-digit industry)	0.099** (0.038)	0.119** (0.045)	0.287** (0.127)	0.374** (0.128)	0.015 (0.057)	0.021 (0.059)
Avg. years of schooling in 3-digit industry	-0.021** (0.008)	-0.017 (0.011)	0.022 (0.020)	0.059** (0.026)	-0.014 (0.011)	0.001 (0.016)
High tech	0.047 (0.029)	-	-0.009 (0.083)	-	0.009 (0.043)	-
Medium-high tech	0.042 (0.022)	-	0.010 (0.062)	-	0.020 (0.032)	-
Medium-low tech	0.061** (0.014)	-	0.139** (0.047)	-	0.020 (0.027)	-
Any R&D	0.000 (0.014)	0.004 (0.014)	-0.037 (0.030)	-0.034 (0.032)	0.004 (0.021)	-0.008 (0.021)
Traded on stock market	-0.016 (0.022)	-0.006 (0.021)	0.137** (0.068)	0.150** (0.062)	-0.001 (0.030)	0.008 (0.030)
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
2- digit industry dummies	No	Yes	No	Yes	No	Yes
N	1704	1704	616	616	609	609
R^2	0.107	0.198	0.358	0.475	0.140	0.234

*: Statistically different from 0 at the 10% level.
**: Statistically different from 0 at the 5% level.

Table 8: Production Functions, Cross-sectional and Pooled Estimates

Full sample

Dependent variable: log output per worker

	1993	1993	1997	1997	Pooled, 1993-1997	Pooled, 1993-1997
Share Immigrants	-0.039 (0.054)	0.024 (0.055)	-0.040 (0.038)	0.008 (0.033)	-0.034 (0.032)	0.022 (0.029)
Log capital per Worker	0.163** (0.012)	0.243** (0.018)	0.194** (0.017)	0.276** (0.024)	0.177** (0.012)	0.244** (0.015)
Log materials per worker	0.516** (0.016)	0.465** (0.018)	0.472** (0.019)	0.422** (0.020)	0.497** (0.013)	0.453** (0.014)
Log employment	0.037** (0.008)	0.042** (0.007)	0.043** (0.009)	0.042** (0.008)	0.038** (0.006)	0.039** (0.006)
Log R&D expenditures	0.037** (0.010)	0.019** (0.009)	0.010 (0.019)	0.014 (0.023)	0.022** (0.009)	0.009 (0.010)
1 if no R&D	-0.123** (0.032)	-0.105** (0.029)	-0.026 (0.049)	-0.027 (0.058)	-0.077** (0.030)	-0.055* (0.032)
Region Dummies	Yes	Yes	Yes	Yes	Yes	Yes
3-digit industry dummies	No	Yes	No	Yes	No	Yes
N	2087	2087	1421	1421	3508	3508
R^2	0.865	0.895	0.860	0.892	0.861	0.887

Note: Entries in the table represent weighted least squares coefficients. Robust standard errors in parentheses

*: Statistically different from 0 at the 10% level.

**: Statistically different from 0 at the 5% level.

Table 9: Production Functions – First Differences Estimates
Dependent variable: Change in log output per worker

	Sample: All available firms			Sample: Balanced Sample		
	1990-1993	1993-1997	Pooled	1990-1993	1993-1997	Pooled
Share Immigrants	-0.048 (0.059)	-0.094** (0.042)	-0.073** (0.030)	0.065 (0.067)	-0.056 (0.042)	-0.029 (0.036)
Log capital per worker	0.188** (0.044)	0.068 (0.044)	0.121** (0.028)	0.168** (0.048)	0.049 (0.041)	0.071** (0.034)
Log materials per worker	0.584** (0.031)	0.490** (0.056)	0.567** (0.030)	0.651** (0.044)	0.449** (0.055)	0.493** (0.050)
Log employment	0.085* (0.044)	-0.029 (0.045)	0.032 (0.028)	0.029 (0.039)	-0.089** (0.038)	-0.052 (0.035)
Log R&D expenditures	0.006 (0.013)	0.001 (0.023)	-0.009 (0.011)	0.007 (0.015)	0.006 (0.022)	-0.009 (0.012)
1 if no R&D expenditures	-0.028 (0.059)	-0.030 (0.152)	-0.088 (0.060)	0.012 (0.079)	-0.005 (0.153)	-0.063 (0.073)
Region dummies	Yes	Yes	Yes	Yes	Yes	Yes
3-digit industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
N	1700	661	2361	611	611	1222
R^2	0.766	0.864	0.780	0.812	0.832	0.773

Note: All the explanatory variables are expressed in first differences.
**: Statistically significant at the 5% level

Table 10: Immigrants and Total Factor Productivity

Dependent variable: total factor productivity

	Levels, all available firms, 1993-1997	First Differences, all available firms, 1993-1997	First Differences, balanced sample, 1993-1997
Share Immigrants	-0.032 (0.036)	-0.093** (0.043)	-0.060 (0.064)
Log capital per worker	0.140** (0.015)	0.0249 (0.041)	-0.028 (0.047)
Log materials per worker	-0.099** (0.014)	0.014 (0.030)	-0.051 (0.045)
Log employment	0.162** (0.006)	0.152** (0.041)	0.345 (0.043)
Log R&D expenditures	0.062** (0.019)	-0.018 (0.021)	-0.023 (0.025)
1 if no R&D expenditures	0.279** (0.124)	-0.124 (0.113)	0.118 (0.146)
Region dummies	Yes	Yes	Yes
3-digit industry dummies	Yes	Yes	Yes
N	3508	2361	1222
R^2	0.742	0.532	0.631

Table 11: Production Functions – Nonlinearities and Interactions

	Levels, all available firms, 1993-1997	First Differences, all available firms, 1993-1997	First Differences, balanced sample, 1993-1997
Nonlinearities in immigrant share			
Share immigrants	0.045	0.022	-0.013
	(0.080)	(0.086)	(0.121)
Share immigrants square	-0.033	-0.123	-0.027
	(0.098)	(0.105)	(0.177)
Industry dummies	3 digit	3 digit	3 digit
Immigrant share and firm size			
Share immigrants × number employed 0-9	0.083	-0.110***	-0.156
	(0.067)	(0.042)	(0.120)
Share immigrants × number employed 10-49	0.017	-0.035	0.005
	(0.038)	(0.042)	(0.055)
Share immigrants × number employed 50-99	0.005	-0.052	-0.048
	(0.049)	(0.042)	(0.046)
Share immigrants × number employed 100 +	-0.233***	-0.050	-0.039
	(0.064)	(0.047)	(0.059)
Industry dummies	3 digit	3 digit	3 digit
Immigrant share and technological intensity			
Share immigrants × low tech industry	-0.102**	-0.123***	-0.165***
	(0.049)	(0.032)	(0.047)
Share immigrants × medium-low tech industry	-0.015	0.063	0.026
	(0.048)	(0.059)	(0.066)
Share immigrants × medium-high tech industry	-0.036	0.152**	0.060
	(0.058)	(0.060)	(0.091)
Share immigrants × high tech industry	-0.040	-0.015	0.301**
	(0.220)	(0.117)	(0.143)
Industry dummies	None	None	None
Immigrant share and 1989-1990 average years of schooling in industry			
Share immigrants × (average years of schooling ≤ 10.5)	0.009	-0.121***	-0.105
	(0.059)	(0.034)	(0.075)
Share immigrants × (average years of schooling $\in [10.5, 11.5)$	-0.014	0.043	-0.015
	(0.042)	(0.054)	(0.061)
Share immigrants × (average years of schooling > 11.5	-0.021	0.066	0.047
	(0.068)	(0.069)	(0.085)
Industry dummies	2 digits	2 digits	2 digits
Number of observations	3,508	2,361	1,222

Table 12: Production Functions – Immigrant Scientists versus Others

	Levels, all available firms, 1993-1997		First differences, all available firms, 1993-1997		First differences, balanced sample, 1993-1997	
	Share immigrant scientists	Share immigrants other occ.	Share immigrant scientists	Share immigrants other occ.	Share immigrant scientists	Share immigrants other occ.
All firms	0.386 (0.438)	0.013 (0.030)	0.014 (0.198)	-0.073** (0.028)	0.221 (0.229)	-0.034 (0.040)
Industry dummies	3 digit		3 digit		3 digit	
Low tech industries	1.005 (0.664)	-0.108 (0.049)	-0.977*** (0.225)	-0.119*** (0.032)	-0.734*** (0.258)	-0.154*** (0.050)
Medium-low tech industries	-0.290 (0.279)	-0.009 (0.050)	0.185 (0.131)	0.058 (0.063)	0.254 (0.294)	0.019 (0.069)
Medium-high tech industries	0.092 (0.212)	-0.046 (0.059)	0.677 (0.467)	0.131** (0.057)	0.220 (0.628)	0.056 (0.094)
High tech industries	1.250 (0.882)	-0.267 (0.174)	-0.219 (0.460)	0.045 (0.118)	0.541 (0.402)	0.271* (0.148)
Industry dummies	None		None		None	
Average years of schooling ≤ 10.5	-0.352 (0.512)	0.014 (0.059)	0.241 (0.181)	-0.125*** (0.034)	0.707 (0.819)	-0.124 (0.077)
Average years of schooling $\in [10.5, 11.5)$	-0.046 (0.386)	-0.014 (0.044)	0.137 (0.263)	0.043 (0.057)	0.241 (0.364)	-0.013 (0.066)
Average years of schooling > 11.5	0.708 (0.600)	-0.079 (0.074)	-0.215 (0.390)	0.086 (0.065)	-0.150 (0.332)	0.056 (0.087)
Industry dummies	2 digits		2 digits		2 digits	

Appendix Table A1: Manufacturing Industries, by Technological Intensity

Low-Tech	Medium-Low Tech	Medium-High Tech	High-Tech
140 Processing of meat and poultry	130 Quarrying of stone and sand	230 Manufacture of refined petroleum and its products	245 Manufacture of pharmaceutical products for human veterinary use
141 Processing of fruit and vegetables	131 Mining of minerals and extraction of salts	231 Processing of nuclear fuel	300 Manufacture of office machinery
142 Processing of fish	138 Mining and quarrying of non-metallic minerals n.e.c.	240 Manufacture of basic industrial chemicals	301 Manufacture of automatic data processing machinery
143 Manufacture of edible oils, margarine and oil products	250 Manufacture of plastic boards and pipes	241 Manufacture of fertilizers	320 Manufacture of electronic components
144 Manufacture of dairy products and ice cream	251 Manufacture of plastic sleeves and sheets	242 Manufacture of petrochemicals and plastics in primary forms	321 Manufacture of semi-conductors
145 Manufacture of grain mill products	252 Manufacture of plastic containers and bottles	243 Manufacture of pesticides and disinfectants	330 Manufacture of telecommunication equipment
146 Bakeries	253 Manufacture of products from armored plastic	244 Manufacture of paints and varnishes	331 Manufacture of data-communication equipment
147 Manufacture of cakes, cookies and biscuits	254 Manufacture of plastic products for kitchen, table and domestic uses	246 Manufacture of soap, detergents and cosmetics	332 Manufacture of domestic electronic equipment
148 Manufacture of unleavened bread	255 Manufacture of plastic products for technical, agricultural and industrial uses	247 Manufacture of man-made fibers	340 Manufacture of industrial equipment for control and supervision
149 Manufacture of noodles and pastry products	256 Manufacture of plastic products n.e.c.	248 Manufacture of chemical products n.e.c.	341 Manufacture of medical and surgical equipment
150 Manufacture of sugar	257 Manufacture of rubber products	290 Manufacture of general purpose machinery and equipment, parts and maintenance thereof	342 Manufacture of instruments for measuring, testing, and navigating
151 Manufacture of chocolate, cocoa, and sugar confectionery	258 Manufacture of tyres and tubes	291 Manufacture of agricultural and forestry machinery parts and maintenance thereof	343 Manufacture of optical instruments and photographic equipment
152 Manufacture of prepared food	260 Manufacture of glass and glass products	292 Manufacture of industrial machinery, parts and maintenance thereof	355 Manufacture of aircraft
158 Manufacture of food products n.e.c	261 Manufacture of ceramic tiles	293 Manufacture of machinery for construction and road works, parts and maintenance thereof	
160 Manufacture of wine and other alcoholic beverages	262 Manufacture of other ceramic products	294 Manufacture of domestic appliances	
161 Manufacture of beer and malt	263 Manufacture of cement and plaster		
162 Manufacture of soft drinks	264 Manufacture of articles of cement, concrete,plaster and clay		
163 Manufacture of tobacco products	265 Cutting, shaping and finishing of stone		
170 Spinning, winding and interweaving of yarns	268 Manufacture of non-metallic mineral products n.e.c.		
171 Weaving of fabrics			
172 Weaving of terry towels			
173 Finishing of textiles			
174 Manufacture of bedclothes and bedspreads			

Appendix Table A1: Manufacturing Industries, by Technological Intensity, continued

Low-Tech	Medium-Low Tech	Medium-High Tech	High-Tech
175 Manufacturing of other textile products 176 Manufacture of carpets and rugs 177 Manufacture of knitted fabrics 178 Manufacture of knitted wearing apparel 180 Manufacture of outwear (except knitted) and tailors dressmakers 181 Manufacture of swim suits 182 Manufacture of underwear (excl. knitted) 188 Manufacture of wearing apparel n.e.c. 190 Tanneries 191 Manufacture of footwear and footwear articles of leather and its substitutes 192 Manufacture of products of leather and leather substitutes n.e.c. 200 Sawmills 201 Manufacture of plywood and by-products 202 Manufacture of builders' carpentry and joinery and of wood products n.e.c. 210 Basic manufacture of paper and cardboard 211 Manufacture of paper and cardboard products 220 Publishing of books, pamphlets and other publications 222 Printing and service activities related to printing 223 Publishing and reproduction of recorded media 360 Manufacture of furniture (excl. metal and plastic one) 361 Manufacture of metal furniture 362 Manufacture of plastic furniture	270 Manufacture of basic iron and steel 271 Manufacture of non-ferrous and precious metals 272 Iron and steel founders 273 Founders of non-ferrous metals 274 Manufacture of metal pipes 280 Manufacture of structural metal products, tanks and steam boilers 281 Metal processing (metal workshops) 282 Metal coating 283 Manufacture of cutlery 284 Manufacture of cutting and hand tools 285 Manufacture of plumbing fixtures 286 Manufacture of tinware products 287 Manufacture of wire and wire products 288 Manufacture of metal products n.e.c. and n.s. 353 Building of ships and boats 380 Manufacture of goldsmiths' articles 381 Manufacture of silversmiths' articles 382 Manufacture of gift items 390 Manufacture of musical instruments 391 Manufacture of sports goods 392 Manufacture of toys and games 393 Manufacture of medical equipment and orthopedic articles 394 Manufacture of disposable medical equipment 395 Manufacture of school and office supplies 398 Manufacture of products n.e.c.	310 Manufacture of electric motors, generators and transformers 311 Manufacture of electricity distribution and control apparatus 312 Manufacture of insulated wire and cables 313 Manufacture of cells and batteries 350 Manufacture of motor vehicles 351 Manufacture of bodies for motor vehicles, trailers and semi-trailers 352 Manufacture of parts for motor vehicles 354 Manufacture of railway equipment 358 Manufacture of transport equipment n.e.c.	

Working and Position Papers

1) Lach, S., “Do R&D Subsidies Stimulate or Displace Private R&D? Evidence from Israel”, Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

2) Trajtenberg, M., “R&D Policy in Israel: An Overview and Reassessment”, Science, Technology and the Economy Program (STE) – Working Papers Series, March 2001.

3) Lichtenberg, F. R., “Sources of U.S. Longevity Increase, 1960-1997”, Science, Technology and the Economy Program (STE) - Working Papers Series, November 2000.

4) Peled, D., “Defense R&D and Economic Growth in Israel: A Research Agenda”, Science, Technology and the Economy Program (STE) - Working Papers Series, March 2001.

5) Trajtenberg, M., “Innovation in Israel 1968-1997: A Comparative Analysis using Patent Data”, Science, Technology and the Economy Program (STE) - Working Papers Series, 2001.

6) Silipo, D.B. and Weiss, A., “Cooperation and Competition in R&D with Uncertainty & Spillovers”, Science, Technology and the Economy Program (STE) - Working Papers Series, August 2001.

7) Lach, S. and Sauer, R.M., “R&D, Subsidies and Productivity”, Science, Technology and the Economy Program (STE) - Working Papers Series, September 2001.

8) Bizan, O., “The Determinants of Success of R&D Projects: Evidence from American-Israeli Research Alliances”, Science, Technology and the Economy Program (STE) - Working Papers Series, September 2001.

9) Ber, H., “Is Venture Capital Special? Empirical Evidence from a Government Initiated Venture Capital Market”, Science, Technology and the Economy Program (STE) - Working Papers Series, February 2002.

10) Blass, A. and Yosha, O.,”Financing R&D in Mature Companies: An Empirical Analysis”, Science, Technology and the Economy Program (STE) - Working Papers Series, April 2002.

11) Breznitz, D., "Conceiving New Industrial Systems: The Different Emergence Paths of the High-Technology Industry in Israel and Ireland", Science, Technology and the Economy Program (STE) - Working Papers Series, May 2002.

12) Gandal, N. "A First Look at Internet Business Methods Patents", Science, Technology and the Economy Program (STE) - Working Papers Series, May 2002.

13) Breznitz, D., "The Military as a Public Space—The Role of the IDF in the Israeli Software Innovation System", Science, Technology and the Economy Program (STE) - Working Papers Series, May 2002.

14) Bar-Eliezer, S. and A. Bregman, "The Impact of Research and Development Spillover on Growth and Productivity in Israeli Manufacturing Industries 1990–1994", Science, Technology and the Economy Program (STE) - Working Papers Series, September 2002.

15) Shaked, A.,"Universal Banking and Investment in R&D Intensive Firms-An Empirical Investigation", Science, Technology and the Economy Program (STE) - Working Papers Series, September 2002.

16) Bental, B. and D. Peled, "Quantitative Growth Effects of Subsidies in a Search Theoretic R&D Model", Science, Technology and the Economy Program (STE) - Working Papers Series, October 2002.

17) Dan Galai and Zvi Wiener, "A Micro-Economic Approach to Government Support of R&D Investments in the Private Sector", Science, Technology and the Economy Program (STE) - Working Papers Series, November 2002.

18) Lach S., Schankerman M., "Incentives and Invention in Universities", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-18-2003, May 2003.

19) Miron E., Erez M., Naveh E., "Do Personal Characteristics and Cultural Values that Promote Innovation, Quality, and Efficiency Compete or Complement Each Other?", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-19-2003, June 2003.

20) Avnimelech, Gil and Morris Teubal, "Evolutionary Venture Capital Policies: Insights from a Product Life Cycle Analysis of Israel's Venture Capital Industry", Science,

Technology and The Economy Program (STE) Working Papers Series STE-WP-20-2003, November 2003.

21) Breznitz, Dan, "Innovation and the Limits of State's Power: R&D and Industrial Policy in Taiwan in IC Design and Software", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-21-2004, April 2004.

22) Cohen-Goldner, Sarit and Zvi Eckstein, "Immigrants in the Hi-Tech Sector: Comparison to Natives and the Effect of Training", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-22-2004, October 2004.

23) Ber, Hedva and Yishay Yafeh, "Can Venture Capital Funds Pick Winners? Evidence from Pre-IPO Survival Rates and Post-IPO Performance", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-23-2004, October 2004.

24) Jonathan Menuhin and Niron Hashai, "Firm Growth Profiles (FGPs): Towards an Action-Based View of Firm Development", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-24-2005, January 2005.

25) Avnimelech, Gil and Morris Teubal, " Evolutionary Innovation and High Tech Policy: What can we learn from Israel's Targeting of Venture Capital?", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-25-2005, March 2005.

26) Frenkel, Amnon , Daniel Shefer, Michal Miller , "Public vs. Private Technological Incubator Programs: Privatizing the Technological Incubators in Israel", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-26-2005, March 2005.

27) Gal, Michal, "Monopolies in Competition: The Balance between Innovativeness and Competition in the Israeli Competition Law", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-27-2005, March 2005. In Hebrew.

28) Breznitz, Shiri, "From Ivory Tower to Industrial Promotion: The Case of Yale University and the Biotechnology Cluster in New Haven, Connecticut", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-28-2005, May 2005.

29) Kandel, Eugene, Dima Leshchinskii and Harry Yuklea, "Start-up funding inefficiencies due to VC's Limited horizon", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-29-2005, May 2005.

30) Feigenbaum, Avi, Scott Shane, Miriam Erez, Oshrat Kremer Srabstein and Moshe Givon, " What Affects Technion Faculty Members' Decision to Found a Start-Up Firm? Effects of the Business Opportunity and the Entrepreneur's (faculty) Personal Characteristics", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-30-2005, November 2005.

31) Niron Hashai and Jonathan Menuhim, "Venture Capitalists, Public Offerings or Strategic Investors? Financial Liquidation Profiles of Israeli Hi-Tech Firms" Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-31-2006, January 2006.

32) David Genesove, "The Dye Famine and its Aftermath: Knowledge Diffusion and Entry, Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-32-2006, February, 2006.

33) Avnimelech, Gil and Morris Teubal, " Microeconomic Insights from Israel's Venture Capital Emergence: Towards a Theory of Evolutionary Targeting of Infant Industries", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-33-2006, May 2006.

34) Trajtenberg, Manuel, "Innovation Policy for Development: An Overview", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-34-2006, July 2006.

35) Belenzon, Sharon and Mark Schankerman, " Harnessing Success: Determinants of University Technology Licensing Performance",", Science, Technology and The Economy Program (STE) Working Papers Series STE-WP-35-2007, March 2007.

36) Paserman, M. Daniele, "Do High-Skill Immigrants Raise Productivity? Evidence from Israeli Manufacturing Firms, 1990-1999", Science, Technology and The Economy Program (STE) Working Paper Series STE-WP-36-2007, April 2007.

ABOUT THE INSTITUTE

The Samuel Neaman Institute for Advanced Studies in Science and Technology is an independent public-policy research institute, established in 1978 to assist in the search for solutions to national problems in science and technology, education, economy and industry, and social development. As an interdisciplinary think-tank, the Institute draws on the faculty and staff of the Technion, on scientists from other institutions in Israel, and on specialists abroad. The Institute serves as a bridge between academia and decision makers in government, public institutions and industry, through research, workshops and publications.

The main emphasis in the professional activity of the Samuel Neaman Institute is in the interface between science, technology, economy and society. Therefore the natural location for the Institute is at the Technion, which is the leading technological university in Israel, covering all the areas of science and engineering. This multi-disciplinary research activity is more important today than ever before, since science and technology are the driving forces for growth and economic prosperity, and they have a significant influence on the quality of life and a variety of social aspects.

The Institute pursues a policy of inquiry and analysis designed to identify significant public policy problems, to determine possible courses of action to deal with the problems, and to evaluate the consequences of the identified courses of action.

As an independent not-for-profit research organization, the Institute does not advocate any specific policy or embrace any particular social philosophy. As befits a democratic society, the choices among policy alternatives are the prerogative and responsibility of the elected representatives of the citizenry. The Samuel Neaman Institute endeavors to contribute to a climate of informed choice.

The Institute undertakes sponsored research, organizes workshops and implements continuing education activities on topics of significance for the development of the State of Israel, and maintains a publications program for the dissemination of research and workshop findings. Specific topics for research may be initiated by the Institute, researchers, government agencies, foundations, industry or other concerned institutions. Each research program undertaken by the Institute is designed to be a significant scholarly study worthy of publication and public attention.

Origins

The initiative for establishing this Institute in Israel was undertaken by Mr. Samuel Neaman. He nurtured the concept to fruition with an agreement signed in 1975 between himself, the Noon Foundation, the American Society for Technion, and Technion. It was ratified in 1978 by the Senate of the Technion. Mr. Neaman, a prominent U.S. businessman noted for his insightful managerial concepts and innovative thinking, as well as for his success in bringing struggling enterprises to positions of fiscal and marketing strength, devoted his time to the activities of the Institute, until he passed away in 2002.

Organization

The Director of the Samuel Neaman Institute, appointed jointly by the President of the Technion and by the Chairman of the Institute Board, is responsible for formulating and coordinating policies, recommending projects and appointing staff. The current Director is Professor Nadav Liron. The Institute Board of directors is chaired by Prof. Zehev Tadmor. The Board is responsible for general supervision of the Institute, including overall policy, approval of research programs and overseeing financial affairs. An Advisory Council made up of members of the Technion Senate and distinguished public representatives, reviews research proposals and consults on program development.

Daniele Paserman received his B.A. in economics and statistics from the Hebrew University in 1993, and his Ph.D. in economics from Harvard University in 2000. He is currently a Lecturer in Economics at Hebrew University, a Research Affiliate of CEPR, and a Research Fellow at IZA.

His research on immigration looks at how the initial environment affects the educational and labor market outcomes of immigrants, both in the short and in the long run; how immigrants affect the human capital accumulation of native workers; how immigration affects the labor market outcomes of native workers, recognizing that the effect need not be uniform over time; and how highly skilled immigrants affect the productivity and investment behavior of firms. Most of this research draws inspiration from the large migration wave experienced by Israel since the fall of the Berlin Wall from the Soviet Union and other Eastern bloc countries. From this episode it is possible to draw important insights on the assimilation of migrants, on their impact on the host economy, and on other issues that are of central importance in economics and the social sciences, even outside of the Israeli context.

Other lines of research include behavioral models of search in the labor and marriage markets, and a project on the dynamics of violence in the Palestinian-Israeli conflict, which attempts to use these dynamics to understand the strategies of militant groups and of the central government that is fighting against them.

Technion - Israel Institute of Technology
Technion City, Haifa 32000, Israel
www.neaman.org.il