



The Real Exchange Rate and the Balassa-Samuelson Hypothesis: An Appraisal of Israel's Case Since 1986¹

by

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Abstract

The Balassa-Samuelson hypothesis, explaining real exchange rate volatility by the differential productivity of the tradable and nontradable sectors, was found to generally fit macro-economic developments since 1986. It turns out that the traditional measures of real exchange rate – the ratio of export/import prices to business-sector product prices – overstated the extent of real appreciation in 1993, 1997-1998, and 2001, being influenced by declining world trade prices, in comparison to the exchange rate of shekel to the US dollar adjusted by GDP deflators. The latter measure has a U-form with a turning point in 1997, suggesting robust real depreciation since then. The elasticity of this real exchange rate with regard to the appreciation of nontradable goods is estimated at 0.7-0.85, while the elasticity with regard to the terms of trade is unitary.

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“When it comes to the real exchange rate, we are enriched by the apparent insights from these models, but impoverished by their lack of empirical confirmation” (Froot and Rogoff, 1991)

1. Introduction

Israel once seemed to be a showcase for the well-known Balassa-Samuelson Hypothesis (BSH), associating real exchange rate (RER) developments with productivity differentials between tradable and nontradable sectors. Provided the prices of tradable goods tend to equalize across countries, a higher increase in the productivity of tradables will cause an increase in the relative price of nontradables, leading to real appreciation in a fast-growing economy. In the Bank of Israel 1997 Annual Report, BSH was presented as *the* mechanism behind the decade-long RER trend: “In recent years economic growth, which was led by a rise in productivity in the traded sector and increased demand for nontradable goods, has caused real appreciation” (p. 36).

Then came the puzzle of 2000 and 2001: given almost the same rate of real appreciation, in these two years per capita growth was 3.6 and –2.8 percent, respectively, clearly contradicting the predictions of the Balassa-Samuelson Hypothesis. With the economy suddenly tumbling into recession in the second half of 2001 as a result of plummeting high-tech exports, the world-wide slowdown and the beginning of the *intifada*, it was hoped that real depreciation would contain further economic deterioration while improving the balance of payments. “An analysis of the current economic situation in Israel and elsewhere shows that real depreciation is one of the most significant endogenous mechanisms for contending with a recession...” (Bank of Israel, Annual Report 2001, p. 20).

Another reason why BSH has been considered outdated during the recent economic turbulence is the belief that the global events pushing Israel into the current ongoing recession are demand-side shocks. As such, they are hardly compatible with the Balassa-Samuelson Hypothesis representing a pure supply-side mechanism. One way or

another, the confidence in the BSH explanation of the relationship between growth, relative sectoral productivity, and the real exchange rate in Israel was shattered.

This paper aims to re-examine the applicability of BSH to Israel's economic development since 1986.¹ The main conclusion is that the Balassa-Samuelson mechanism did indeed "work" throughout the studied period, including the slowdown after 1996 and the growth roller-coaster of 2000-2001. It turns out that confusion regarding the appropriateness of BSH since 1997 is due to the way Israel measures RER – the ratio of exports or imports prices to GDP, or the business-sector deflator. Being depressed because of the decline in world trade prices in 1997-1998 and 2001, these measures showed excessive appreciation. By contrast, the exchange rate of the dollar, adjusted by the ratio of US and Israel GDP deflators, is robust to fluctuations in world trade prices, showing that the picture is consistent with the BSH mechanism. Empirical analysis of this RER examines the impact of the relative productivity of the tradable sector, the relative price of the nontradable sector, and the terms of trade. Analytical decomposition of RER leads to another specification of the RER model, separating the “Balassa-Samuelson effect” – productivity-induced appreciation of nontradables – from other – nominal – factors. In these two models the elasticity of RER with regard to the "Balassa-Samuelson effect" is estimated at 0.7 to 0.85. Empirical analysis indicates that while the contribution of supply-side factors to explaining RER variation was dominant in 1998-2000, for instance, the real depreciation of 2001-2002 was produced mainly by demand-side and nominal factors.

The rest of the paper is organized as follows. Section 2 presents the Balassa-Samuelson Hypothesis, its assumptions and predictions. Section 3 studies various factors associated with the hypothesis and the development of RER, reviewing previous empirical findings in Israel and abroad. Section 4 contains an analytical decomposition and empirical analysis of RER variance.

¹ Meridor and Pesach (1994) analyzed the long- and short-run behavior of RER from 1964 to 1990, using the standard cointegration/error-correction model, with real factors (terms of trade, government expenditure, tax rate, capital stock) determining the long-run and nominal factors (money supply and rate of currency devaluation) dominant in the short run. Zussman (1988) reached qualitatively similar conclusions when using the same econometric framework in a study of RER in 1980-1997.

2. The Balassa-Samuelson hypothesis

To begin with, consider the conjecture of Balassa (1964) and Samuelson (1964) in a model of a small open economy (Froot and Rogoff, 1995). The economy produces tradable and nontradable goods with a Cobb-Douglas production function in two sectors denoted by superscripts T and N respectively:

$$Y^T = A^T (L^T)^{\theta^T} (K^T)^{1-\theta^T} \quad (1)$$

$$Y^N = A^N (L^N)^{\theta^N} (K^N)^{1-\theta^N} \quad (2)$$

where Y is sectoral output; and L, K and A are labor, capital and productivity, respectively. Assuming perfect competition in both sectors, perfect capital mobility across the sectors and internationally, and perfect labor mobility between the sectors, profit maximization implies:

$$R = (1 - \theta^T) A^T (K^T / L^T)^{-\theta^T} = P(1 - \theta^N) A^N (K^N / L^N)^{-\theta^N} \quad (3.1)$$

$$W = \theta^T A^T (K^T / L^T)^{1-\theta^T} = P\theta^N A^N (K^N / L^N)^{1-\theta^N} \quad (3.2)$$

where R is the rental rate of capital determined in world markets; W is the wage rate (in terms of tradables); and P is the relative price of nontradables. Log-differentiating of (3.1)-(3.2) gives:

$$\dot{p} = (\theta^N / \theta^T) \dot{a}^T - \dot{a}^N \quad (4)$$

where small dot letters denote the percentage change of the respective variables denoted by capital letters.

The key result of BSH is that relative price changes are driven entirely by the production side of the economy. Intuitively, because the rate of return on capital in a small open economy is tied by international capital mobility, productivity growth raises the wage/rental ratio, causing an increase in the relative price of the labor-intensive nontradable good. If both sectors have the same degree of capital intensity ($\theta^N = \theta^T$) then the relative price of nontradables appreciates at the same pace as sectoral productivity differentials. But if $\theta^N > \theta^T$ (because the nontradable sector is generally more labor intensive), then even balanced productivity growth will be accompanied by the appreciation of the relative price of the nontradable sector. Note that with

$\theta^N / \theta^T > 1$, productivity growth in the tradable sector has a higher marginal effect on the real appreciation than of nontradables.²

Demand factors may influence RER in the short run if either labor or capital mobility is limited. Froot and Rogoff (1991) show, in the framework of the Ricardian neo-classical model, that an unanticipated increase in government spending affects nontradables disproportionately (relative to private spending) and causes real appreciation.³

The same model is used in Rogoff (1992) to examine how capital market liberalization affects the volatility of RER. This question is clearly relevant for Israel since 1986 because these were years of massive capital market deregulation, opening the economy for foreign investment, and dismantling the barriers for investment abroad by Israelis. It turns out that the effect of capital market liberalization on RER behavior depends on the extent to which the productivity of traded goods is stationary. For Israel, where the productivity of tradables is stationary in growth rates, the model predicts more volatility in the real exchange rate with greater openness of the capital markets.

As an alternative to BSH in explaining RER movements, another strand of literature links them to terms of trade – the relative price of exports to imports.⁴ De Gregorio and Wolf (1994) combine the two approaches in a model of a small open economy with two tradable goods (imports and exports) and one nontradable good, allowing both productivity and the terms of trade to determine the real exchange rate.

Now it is time to examine the facts and their connection to this theory.

3. The theory and the facts

This section opens with a detailed consideration of three connections underlying the Balassa-Samuelson thesis. These are the relationships between: a) the real exchange rate and growth; b) growth and productivity differentials; c) differential productivity and

² This invalidates the claim by Alquist and Chinn (2002) that, when regressing RER on inter-country productivity differentials, the slope is bounded by absolute value between zero and one. On the other hand, it does not necessarily endorse the elasticity of 4.4 or 5.3, as estimated by them.

³ Appreciation is permanent and does not change the current account position when the shock is permanent. A transitory shock produces temporary appreciation, while the effect on the current account is ambiguous. The increase in Israel's defense spending during the *intifada* provides an opportunity to check this prediction.

⁴ See Obstfeld and Rogoff (1996) for review and discussion.

relative prices of tradable and nontradable goods. I then examine ‘off-the-record’ factors such as government spending, capital mobility, and the terms of trade.

The real exchange rate and growth

BSH unequivocally relates RER behavior to growth.⁵ In fact, this was the picture observed in Israel in 1989-1996: the real exchange rate (e.g., as measured by the export price index) appreciated when the growth rate was above 4% and depreciated when the economy slipped below this level in 1989 and 1993 (Figure 1). Since 1997 this relationship has apparently broken down: in the years of slowdown – 1997, 1998, and 2001 – there was no real depreciation. The first question is, therefore, whether this change indicates a structural break in the relationship between RER and growth.

Traditionally, the real exchange rate in Israel is measured as the ratio of derived export/ import prices (both excluding diamonds) to the business-sector deflator. Implicitly weighted by the quantity of Israel’s foreign trade, these ratios indicate the profitability of exports and the competitiveness of domestic production vis-à-vis imports. The Balassa-Samuelson hypothesis, however, rests on a different definition of the real exchange rate – one used in bilateral international comparisons – the exchange rate of two currencies adjusted by the ratio of general price indices (the CPI or the GDP deflator) in two countries. It turns out that this measurement of RER settles all the confusion regarding the abnormal volatility of the real exchange rate since 1997.

I examine six alternative indices of RER: export/import prices relative to the business-sector deflator, export/import prices relative to the GDP deflator, and the exchange rate (NIS per US dollar) adjusted by the ratio of Israel and US CPI or GDP deflator.

Figure 2 shows that using the GDP deflator instead of the business-sector deflator in export/import price-based indices (P_m/P_{gdp} vs. P_m/P_b and P_x/P_{gdp} vs. P_x/P_b) makes no

⁵ Razin and Collins (1999) claim that RER misalignments (above or under some “equilibrium” level) influence growth – not vice versa (however, the RER “equilibrium” level in their model is determined by the economy’s growth rate, among other factors). They cite two channels of this influence: a) by affecting the capital accumulation process via RER’s impact on domestic and foreign investment; b) by changing the competitiveness of the tradable sector vis-à-vis the rest of the world. Besides, the volatility of RER misalignment per se is said to hinder economic growth. Their estimates from a panel of 93 countries during 16- to 18-year periods since 1975 imply that 10% overvaluation of RER is associated with a 0.6% decline in per capita GDP, whereas RER undervaluation was not found to significantly affect growth.

difference other than shifting the RER downward, due to the greater share of nontradables (public services, nonprofit organizations and housing services) covered by the GDP deflator than by the business-sector deflator. The prices of these nontradables tend to rise faster than the aggregate price of business-sector product.

The indices of the exchange rate adjusted by the ratio of CPI or GDP deflators (SP^*/P and SP^*_{gdp}/P_{gdp}) exhibit essentially the same picture. To enable comparison with other measures of RER, only the latter is used.

Figure 2 compares of export/import price-based RER (P_m/P_{gdp} and P_x/P_{gdp}) with the exchange rate adjusted by the GDP deflator (SP^*_{gdp}/P_{gdp}). In 1986-1992 they behave alike, with a real depreciation in 1989 and appreciation around 1989. In 1993, exchange rate-based RER bounces by 5.8% while the export/import price-based indices indicate continuing real appreciation till 2001 (with an upward swing of P_x/P_{gdp} in 1999). Unlike export/import price-based indices, exchange rate-based RER has a U-form, showing a robust trend of real depreciation since 1997 with an episode of real appreciation in 2000. Not surprisingly, in 1986-2002 the correlation coefficient between per capita growth in Israel (net of US per capita growth) and changes in the exchange rate adjusted by the GDP deflator is -0.69, as compared to -0.50 with the export-based measure and -0.23 with the import-based measure of RER.

This is good news for those confused by the inexplicable swings of export/import price-based RER since 1997, because the exchange rate adjusted by the GDP deflator exactly fits the path of Israel's growth in the 1990s. This RER denotes all years with growth below 4% (1989, 1993, 1997-99 and 2001-2002) by real depreciation, and all high-growth years by real appreciation!

To understand what led export/import price-based RER measures astray, compare them⁶ (P_x/P_{gdp} or P_m/P_{gdp}) to the exchange rate adjusted by the GDP deflator (SP^*_{gdp}/P_{gdp}). With the same denominator, the divergence is due to different numerators. But as P^*_{gdp} (the US GDP deflator) is pretty stable relative to the exchange rate,⁷ it is all about the difference between export/import prices and the exchange rate. The

⁶ In sake of simplicity, the GDP deflator is taken as the denominator instead of the business-sector deflator. This substitution has no impact on the RER trend (see Figure 2).

⁷ In 1986-2001, the average annual change of the implicit US GDP deflator was 2.5% with a standard deviation of 0.8%. The average annual change of the exchange rate (NIS/USD) was 9.2% with a standard deviation of 9.5%.

depreciation of the shekel in 1997-1998 outpaced the rise in foreign trade prices. Furthermore, in 2001 the shekel depreciated when export/import prices dived. Though showing a great deal of stickiness with respect to exchange-rate volatility, export/import prices are nevertheless strongly influenced by world market prices. In 1997-1998, world unit export (import) prices dipped 11.9 (11.8) percent, while in 2001 the decrease was 3.4 (3.3) percent.⁸ It is clear, therefore, that export/import price-based RER measures are sensitive to world trade shocks. As long as prices in the global marketplace are depressed, Israel's traditional measures of the real exchange rate will be biased downward, confusing economists by “inexplicable” real appreciation.

Now, with a robust measure of RER in hand, we turn to the second part of the Balassa-Samuelson thesis, namely, that high growth reflects inter-sectoral productivity differentials.

Growth and productivity differentials

The productivity of labor-intensive service industries tends to grow at a slower pace than that of capital-intensive manufacturing.⁹ Because the lion's share of services are nontradable while most of manufacturing production belongs to tradables, productivity differentials between the two sectors are linked in this way to the production function structure and technology. BSH takes this argument one step further by positing that productivity differentials are wider in rapidly growing economies. In other words, growth and productivity differentials between tradables and nontradables in two countries should be positively correlated.

A question arises regarding an appropriate measure of productivity differentials. A standard approach makes use of total factor productivity (TFP) – computed from the Cobb-Douglas production function – representing in fact Solow residuals (Froot and Rogoff, 1991 and 1995, De Gregorio et al., 1993, De Gregorio and Wolf, 1994, among others). However, Canzoneri et al. (1996) proved that when using average labor

⁸ In 1993 export/import based RER indicated slight appreciation, as a result of a sharp decline in world trade prices (9.6% in exports, 10.8% in imports). In contrast, the exchange rate adjusted by GDP deflators shows 7.6% depreciation.

⁹ This statement is known as Baumol-Bowen hypothesis [Baumol W., and Bowen, W., (1966) *Performing arts: the economic dilemma*. The Twentieth Century Fund, New York]. Labor-intensive agriculture is a counterexample because it experienced a tremendous rise in productivity (at least in the 20th century), probably surpassing that in manufacturing.

productivity (ALP) one implicitly accounts for both supply and demand shocks affecting RER. Besides, ALP-based measurement of productivity holds for a broader class of technologies than the Cobb-Douglas production function which is the cornerstone of TFP calculation. Since for Israel both TFP and ALP data are available, both are used to make sure that inter-countries differentials are invariant to the choice of productivity measure.

Figure 3 depicts Israel's growth rates against the difference between the total factor productivity of tradable business-sector industries (agriculture and manufacturing) and that of nontradable industries (construction, electricity and water, transport and communications, commerce and business services).¹⁰ Years of slowdown (notably in 1989, 1993, 1998, 2001) are associated with the contraction of productivity differentials, while a surge in economic activity (1987, 1990, 1994-1995, 2000) coincides with widening productivity differentials. Average labor productivity exhibits a similar development. It follows that a positive correlation (for 1986-2001, correlation coefficient between the GDP and TFP differentials is 0.29, and 0.37 between GDP and ALP differentials) between the pace of growth and the relative productivity of the tradable sector is robust to alternative ways of measuring productivity.

In analyzing the relationship between *relative* growth and sectoral productivity, ALP is defined as the ratio of labor productivity (output per hour) in manufacturing to that in the non-farm business sector (in Israel it is business-sector product excluding agriculture). Figure 4 indicates that the relative productivity differentials and per capita growth (Israel relative to the US) are positively correlated, but there are notable departures in 1988-1990, 1997, and 2002.

Differential productivity and relative prices

The key proposition of the Balassa-Samuelson hypothesis (Equation 4) is that differential productivity in the tradable and nontradable sectors ought to cause the appreciation of nontradables (in terms of tradables). Because the prices of tradable goods across countries tend to equalize (absolute PPP), or at least to grow at the same pace (relative PPP), aggregate price indices such as the CPI, WPI or the GDP deflator – being

¹⁰ Tourism, sea and air travel should be included in the tradable sector, but data limitations preclude this disaggregation. TFP is calculated as a weighted average of labor input and capital stock productivity with the weights 0.68 and 0.32 respectively.

weighted averages of prices of tradable and nontradable goods – would indicate higher inflation in rapidly growing economies. Hence, BSH predicts real appreciation during periods of accelerated growth.

Figures 5 and 6 present compelling evidence of a negative relationship between sectoral productivity and prices in the US and Israel throughout the examined period.¹¹ Manufacturing and agriculture – two tradable industries – experience a substantial productivity rise and mild price rise, whereas major nontradable industries – construction, personal and business services, financial services and trade – are characterized by a very low productivity increase and flourishing prices.¹²

However, establishing a connection between productivity differentials and the relative price of nontradables in each country does not prove the case for BSH, because it stipulates a link between RER fluctuations and the excessive rise in the price of nontradables in a faster growing economy. The relative price of nontradables is measured by the ratio of the business-sector deflator to the average weighted deflator of agriculture, mining, and manufacturing (weighted by industry output). This ratio, differenced between Israel and the US, is plotted against ALP differentials in Figure 7. Remarkably, in the first half of the 1990s the correlation between the two variables was weak and negative. The surge in the relative price of nontradables in 1990-1991 is explained by the demand shock in Israel in the years of the absorption of the mass immigration from the former USSR, whose aggregate demand was biased toward nontradables. Thus, an increase in the relative price of the nontradable sector was not determined by supply-side productivity differentials, but was demand-driven. In the second half of the 1990s, when the immediate impact of the immigrants on aggregate demand weakened, the positive correlation between the relative price of nontradables and productivity differentials was restored. This connection is the third – and last – link closing the chain of empirical evidence proving that the behavior of Israel's real exchange rate in 1986-2002 *is consistent* with the Balassa-Samuelson hypothesis.

¹¹ Canzoneri et al. (1996) find in a panel of 13 OECD countries in 1985-2001 that the relative price of nontradables and the relative productivity in the tradable and nontradable sectors are generally cointegrated with the unitary slope.

¹² The prices of communications plummeted in 2000-2001 because of the bursting of the internet and telecom bubble; transportation prices were hit by the contraction in world trade and tourism after September 11, 2001. In 1986-1999 the average price increase in the transportation and communications industry was similar to that of commerce.

An issue which is closely related to relative price dynamics is the well-known "law of one price" in tradable goods.

The law of one price, which is based on the commodity arbitrage argument, says that – in the absence of trade barriers and transportation costs – trade should ensure the identical price of a traded good across countries. Primary commodities and standardized basic materials (e.g., steel items) in dollar values do indeed hold to the law of one price. As to other manufacturing products, Isard (1977) reports that the prices of matching goods in different countries (US, Canada, Germany and Japan) do not substantiate the law of one price and concludes that “products of different countries exhibit relative price behavior which marks them as differentiated products, rather than near-perfect substitutes” (p. 942). In a study of intra-US commodity trade that naturally bypasses two potential hindrances to the law of one price – trade barriers and exchange-rate volatility – Parsley and Wei (1996) find that the gap between prices in different cities tends to close, with a half-life of four to five quarters for goods and fifteen quarters for services. Convergence rates for tradable goods are much faster than those found in cross-country trade. The convergence rate is found to be a non-linear positive function of initial price differences, and a negative function of the distance between trading cities.

Trade barriers and transportation costs evidently impede the law of one price, as does exchange-rate volatility. Comparing the prices of 27 goods traded between the US and Japan over 22 years, Parsley and Wei (2001) find strong evidence of stickiness of prices to the nominal exchange rate. Distance, unit-shipping costs, and exchange-rate variability jointly explain a substantial portion of the observed international market segmentation.

If the law of one price holds for any tradable good, it must hold for any identical basket of tradable goods in two countries. But initial composition and changes in foreign trade baskets differ from country to country, depending on resources and needs, specialization in the international division of labor, and historic trade patterns. Thus, even if the law of one price holds regarding any tradable good, aggregate indices of export/import prices are not expected to obey absolute or relative purchasing power parity. Kravis and Lipsey (1988) find in a cross-sectional study of 60 countries for twenty

five years beginning in 1960 that the aggregate price level of tradable goods rises with income (per capita GDP), which clearly violates the law of one price. On the other hand, global economic integration, which accelerated notably in the 1980s and 1990s, a greater openness to trade,¹³ and reduction of trade barriers are among the factors tending to equalize the prices of tradables across countries. “The degree of openness to trade pulls a country’s prices towards the world average – upwards for poor countries and downwards for rich countries” (Kravis and Lipsey, 1988).

The real exchange rate and government spending

As Froot and Rogoff (1991) concede when summarizing empirical research on RER in the OECD countries since 1973, “there is very little empirical evidence that any known fundamentals – let alone government consumption in particular – have reliable effects on the real exchange rate” (p. 10). Their own examination of RER in eight EMS countries indicates a positive correlation between government spending and real appreciation in some countries, but the estimation omits productivity as the explanatory variable and is plagued by serial correlation. De Gregorio et al. (1993) conclude that government expenditure was not among the factors determining real appreciation in European countries. De Gregorio and Wolf (1994) report quite contrasting results for fourteen OECD countries in 1970-1985: both government spending and TFP have a significant positive impact on RER appreciation, with respective elasticities of 3-4 and 0.1-0.2, depending on the regression specification.

The use of different co-integration techniques and tests produced controversial results as well. Alquist and Chinn (2002) do not find any significant effect of government spending on dollar/euro RER during 1985-2001. Chinn (1999) discovers a short-run contemporaneous effect of government spending in a twenty year-long panel of OECD countries. Razin and Collins (1999) fail to prove any significant impact of government spending in a panel of 60 countries in the 1970s and 1980s.

Turning to the relationship between fiscal position and RER in Israel, one might speculate that if both the Israeli and US economies are correlated via the global business

¹³ For a discussion of trade and economic interdependence see “World Economic Outlook”, October 2001, International Monetary Fund, chapter 2; regarding trade and financial integration see “World Economic Outlook”, September 2002, International Monetary Fund, chapter 3.

cycle, and government spending is counter-cyclical with a higher volatility in Israel, then the relative budget deficit should be negatively correlated with growth and positively correlated with RER. However, the facts do not support this speculation. Throughout the 1990s, business cycles in Israel and the US were not synchronized at all, and budget discipline in the two countries had nothing in common either. Mass immigration was a key factor behind Israel's growth in 1992-1996 and slowdown in 1997-1999, when the contraction of investment in residential construction was accompanied by tight fiscal and monetary policies and geo-political instability (Flug and Strawczynski, 2002). In the US, the 1990s were a decade of persistent improvement in budget deficits that eventually became surplus in 1998. In Israel, the years of irresponsible government spending (public-sector wage increases in 1995-1996) was first changed by greater fiscal consciousness (1997-2000), but a sizeable expansion of defense expenses in 2001-2002, due to the outbreak of the *intifada*, deferred budget tightening again. In light of these facts, it is not surprising that the relative budget deficit and real exchange-rate movements are generally uncorrelated, as shown in Figure 8.

The real exchange rate and capital market liberalization

According to the neo-classical model of RER (Froot and Rogoff, 1991, Rogoff, 1992), capital market liberalization will lead to greater real exchange-rate volatility if the productivity of the traded sector is stationary in growth rates (as it is in Israel in the reviewed period). Supporting evidence was found in increased real yen/dollar volatility in the 1980s as compared to the 1970s (Rogoff, 1992).

The real exchange rate in Israel appears to show the opposite to the model's prediction. Dividing the period of 1986-2000 into three five-year periods and computing the standard deviations of the real exchange rate's annual change (6.1, 4.7 and 2.9), indicates that greater openness of the capital market in the second half of 1990s is accompanied by lower RER volatility. It may be claimed, however, that the actual source of the higher volatility in the 1980s and early 1990s is greater variance in nominal exchange rates and sectoral inflation; in Israel's case this induces a spurious negative correlation between RER volatility and capital market openness. After controlling for this

factor,¹⁴ it turns out that the volatility of (residual) RER is constant throughout the period (five-year period standard deviations are 3.0, 2.8, 2.9), still contradicting Rogoff's thesis.

The real exchange rate and the terms of trade

De Gregorio and Wolf (1994) empirically examine the impact of the terms of trade on RER *jointly* with the effect of productivity differentials in 14 OECD countries in 1970-1985 and find that both factors are highly significant determinants of both the relative price of nontradables and real exchange rate behavior. In theory, changes in export and import prices may cause substitution and income effects, but the empirical results suggest that the terms of trade affect the RER mainly through the income effect. Export prices exert a stronger (in absolute value) influence on the RER and the relative price of nontradables than import prices. Alexius and Nilsson (2000) explore the same set of countries in 1960-1996; they prove that high relative productivity is associated with RER appreciation in most cases, but do not find solid support for the hypothesis that the terms of trade affect the equilibrium RER.

Figure 9 shows that the relationship between the terms of trade and RER in Israel was not uniform throughout the considered period. The two factors were weakly negatively correlated before 1993, but since 1993 there is robust positive correlation. The question whether this relation contains additional information explaining RER movements controlled for the effect of productivity differentials can be answered only by the econometric analysis that follows.

¹⁴ By deducting the deviations from PPP (see Model 2, Table 3) from RER.

Empirical analysis of the real exchange rate

Table 1 presents a number of regressions that quantitatively explore the relationship between RER and the various factors discussed above. This analysis is necessarily cursory, because short series do not allow any richer specification of the model. Nevertheless, the high values of the goodness-of-fit measure indicate that the variables included play a pivotal role in explaining the RER variation. Marginal contributions of three significant explanatory variables are depicted in Figure 10.

The estimation results lead to the following conclusions. Both productivity and price differentials are significant determinants of RER fluctuations. On average, the elasticity of RER with regard to both factors is the same (0.85). Surprisingly, the relative price of nontradables remains significant even in the presence of a relative productivity factor, indicating that this variable contains some additional information, probably associated with demand shocks or nominal factors. The elasticity of RER with regard to the terms of trade is unitary – twice the value found by De Gregorio and Wolf (1994) in a panel of 14 OECD countries in 1970-1985. As Figure 10 indicates, throughout the period, except 2002, favorable terms of trade exerted pressure for real appreciation, while in 2002 worsening export prices contributed greatly to sharp real depreciation. Both the civilian public expenditure (as the annual rate of change or as the share of GDP) and general government deficit (in terms of GDP) have found exerting no significant impact on the RER in the presence of other explanatory variables.¹⁵

4. Decomposition of real exchange rate changes

To assess the relative importance of nominal and real factors which influence real exchange-rate variability, it is useful to decompose its changes in the following manner:¹⁶

The real exchange rate in year t is:

$$q_t \equiv s_t + p_t^* - p_t \quad (5)$$

¹⁵ These results are qualitatively similar to Zussman's (1998) estimates, obtained for 1980-1997 in the cointegration/error-correction model. The long-run elasticity of (export-price based) RER with respect to the productivity differentials was -0.46 (compared to -0.77); the elasticity with respect to the terms of trade was -1.65 (compared to -1.15); the impact of government consumption (as a share of GDP) was statistically insignificant.

¹⁶ This decomposition, following MacDonald (1997), encompasses the specification of econometric analysis (see Hsieh, 1982 for an alternative specification of the regression).

where S is the nominal exchange rate in terms of local currency per US dollar (say, NIS per USD), and P^* and P are the aggregate price indices in foreign and domestic economies, respectively. Small letters denote natural logarithms. In this definition, real appreciation (depreciation) is denoted by a negative (positive) change in q .

Aggregate price indices can be represented as a weighted geometric average of the price indices for tradable and nontradable goods included in the index basket:

$$p_t = (1 - a_t)p_t^T + a_t p_t^{NT} \quad (6.1)$$

$$p_t^* = (1 - a_t^*)p_t^{T*} + a_t^* p_t^{NT*} \quad (6.2)$$

where $a_t = (p_t - p_t^T)/(p_t^{NT} - p_t^T)$ and analogically for a_t^* . Substituting (6.1)-(6.2) into (5) gives:

$$q_t = s_t + p_t^{T*} - p_t^T + a_t^*(p_t^{NT*} - p_t^{T*}) - a_t(p_t^{NT} - p_t^T) \quad (7)$$

Assume that the composition of the price indices in both countries does not change drastically from year to year, i.e., a and a^* are constant in adjacent years. Then, differencing expression (7) gives the decomposition of the RER's annual percent change:

$$\dot{q} = \dot{s} + \dot{p}^{T*} - \dot{p}^T + a^* \dot{p}^{NT-T*} - a \dot{p}^{NT-T} \quad (8)$$

where \dot{p}^{NT-T} is the change in the relative price of nontradables.

Expression (8) identifies four sources of RER movements:

- Changes in the nominal exchange rate (\dot{s});
- Inter-country differences in tradable sector inflation ($\dot{p}^{T*} - \dot{p}^T$);
- Inter-country differences in the relative increase in the price of nontradables ($\dot{p}^{NT-T*} - \dot{p}^{NT-T}$);
- Differences in the composition of aggregate price indices (a and a^*).

Note that the law of one price for tradable goods implies $\dot{s} + \dot{p}^{T*} - \dot{p}^T = 0$, then

$$\dot{q} = a^* \dot{p}^{NT-T*} - a \dot{p}^{NT-T} \quad (9)$$

but this decomposition seems to be too restrictive, given little empirical evidence supporting the law of one price in internationally traded goods (see discussion in Section 3 and sizeable deviations from PPP in Table 2).

In the case of balanced growth ($\dot{p}^{T*} = \dot{p}^T$ and $\dot{p}^{NT-T*} = \dot{p}^{NT-T}$), RER appreciation will be caused solely by the appreciation of the nominal exchange rate because the share of nontradable goods in aggregate price indices is a positive function of the economy's income level; in the comparison of Israel to the US this implies $a^* > a$.

Table 2 presents the decomposition of changes in the real exchange rate into four factors according to Equation (8): nominal exchange-rate volatility (column 4), inter-country differences in the prices of tradable goods (column 5), the increase in the price of nontradable goods relative to tradables¹⁷ in the US (column 6) and in Israel (column 7). The two last columns of Table 3 are statistical discrepancies of the decomposition¹⁸ that sum up the joint impact of the four factors on the total change in RER [(8)=(3)-(4)-(5)-(6)+(7)], and deviations from relative PPP in tradable goods [(9)=(4)+(5)]. RER is defined in terms of implicit GDP deflators. The tradable sector includes agriculture, mining and manufacturing; the remaining business sector industries belong to the nontradable sector.

A number of conclusions emerge from Table 2. First, the deviations from relative PPP in tradable goods may be quite large (relative to the magnitude of RER changes) and persistent, with an autocorrelation of 0.4. Consensus estimates put the half-life of deviations from PPP for exchange rates among industrialized countries at about 4 years (Froot and Rogoff, 1995). Second, decomposition discrepancies seem to be white noise,¹⁹ suggesting that the regression may be used for the analysis of variance and estimation of the marginal impact of factors, with reservations regarding the estimates' significance.

The regression of (stationary) RER changes on the decomposition factors listed in Table 3 allows us to quantify the relative importance of aggregated nominal factors (the nominal exchange rate and the price of tradables) and the “Balassa-Samuelson effect”

¹⁷ The values in the table are the difference between the percentage change in the prices of nontradables and tradables, multiplied by the value of a^* or a (derived geometric weight of nontradable sector in implicit GDP deflator).

¹⁸ There are two technical sources of the discrepancies: first, representing aggregate price indices as a geometric mean when they are actually computed as a weighted arithmetic mean; second, assuming a smooth change in the structure of the indices. Then there is a meaningful source: tradable and nontradable goods are identified on the level of the primary industries. In fact, not all agricultural and manufacturing production is traded, and there are numerous services that are not nontradable (e. g., communications, transportation, business and financial services, etc.).

¹⁹ Autocorrelation is 0.08. Because discrepancies are not zero-mean, a constant is required in the regression.

induced by productivity differentials, measured as the difference between the relative price of nontradables in the US and Israel.

Since the restriction of equality between the slopes of the nominal factors (in Model 1) cannot be rejected, Model 2 (specified under this restriction) indicates that the elasticity of the real exchange rate with respect to the Balassa-Samuelson effect is close to 0.7 – slightly lower than in a multiple regression controlling for the impact of terms of trade (Table 1). Figure 11 illustrates the partial contributions of both effects to the RER change. It is evident that, for example, the "Balassa-Samuelson effect" was dominant in 1988-2000. In 2001, it contributed only one third to the joint impact of two explanatory variables. In 2002, its impact was negligible, as might be expected given the wide disparity between relative productivity and growth (see Figure 3).

To summarize, the Balassa-Samuelson hypothesis, explaining real exchange rate volatility by supply-side factors reflected by the differential productivity of the tradable and nontradable sectors, was found to generally fit macro-economic developments since 1986. The importance of this finding is underscored by the major demand shocks experienced by the Israeli economy in the period considered and the autonomous influx of capital, especially in the second half of the 1990s, which apparently was among the factors supporting the decade-long trend of real appreciation. The traditional measures of RER based on export/import prices relative to implicit GDP or business-sector product prices are vulnerable to the fluctuations of world trade prices. This factor is responsible for the "inexplicable" real appreciation in 1993, 1997-1998, and 2001. An alternative measure of RER – the exchange rate adjusted by GDP deflators – has a U-form with a turning point in 1997, suggesting robust real depreciation since then. The elasticity of this RER with regard to the appreciation of nontradable goods is estimated at 0.7-0.85, depending on the specification of the model, while the elasticity with regard to the terms of trade is unitary.

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Table 1: Empirical analysis of RER, 1986-2002 (t-values in parentheses)

Explanatory variables	Dependable variable: RER, annual percent change				
	Model A	Model B	Model C	Model D	Model E
dALP	-0.766 (3.1)				
d ² ALP		1.023 (2.8)			0.841 (2.4)
dP			-1.073 (2.2)		
d ² P				1.153 (2.3)	0.847 (3.5)
T-O-T	-1.150 (3.7)	-0.997 (3.0)	-0.981 (2.9)	-0.924 (2.6)	-1.064 (1.5)
Constant	2.938 (1.2)	1.648 (1.1)	0.329 (0.1)	0.432 (0.3)	1.144 (1.371)
R ² adjusted	0.544	0.506	0.411	0.433	0.585
dw statistics	1.40	1.79	1.57	1.58	1.56

Definitions of explanatory variables:

- dALP – the difference in average labor productivity between tradable and nontradable sectors, annual percent change;
- d²ALP – dALP differenced between US and Israel;
- dP – the difference in increase of prices between nontradable and tradable sectors, annual percent change;
- d²P – dP differenced between US and Israel;
- T-O-T – terms of trade (Px/Pm), annual percent change;

Table 2: Decomposition of real exchange rate, 1986-2002, annual percent change

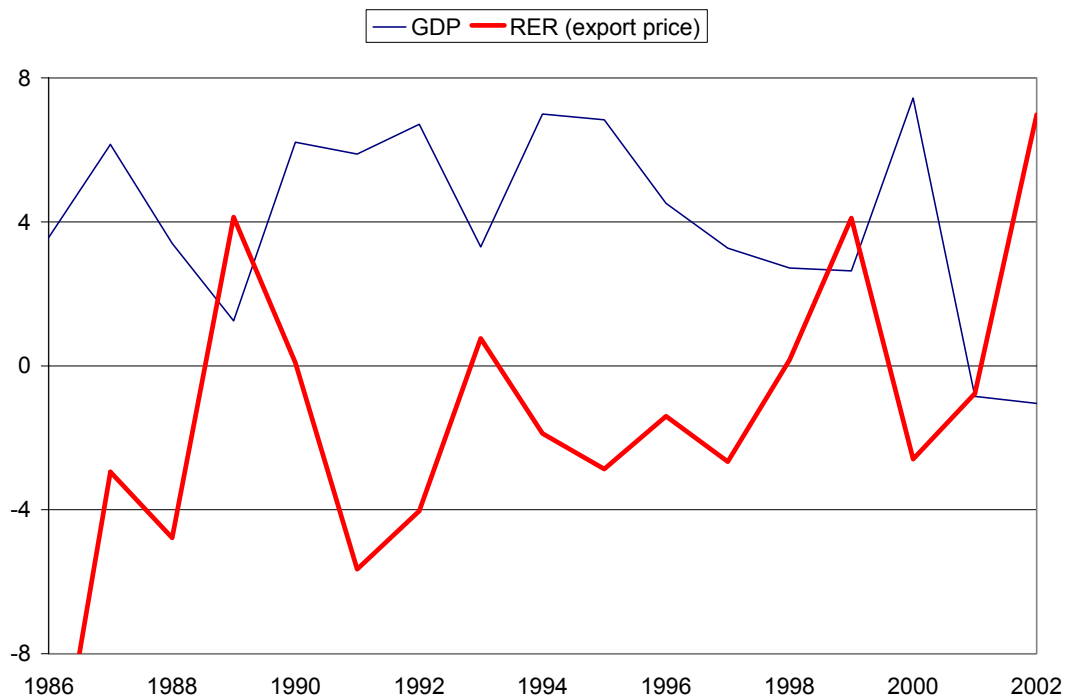
Year	Real exchange rate	Nominal exchange rate	Price of tradable goods	Relative price of nontradable goods		Discre- pancies	Deviations from PPP
				US	Israel		
				(6)	(7)		
(1)	(2)	(4)	(5)	(6)	(7)	(8)	(9)
1986	-5.9	38.2	-47.4	0.9	-6.4	-4.1	-9.2
1987	-8.5	7.2	-23.7	1.5	3.0	9.5	-16.6
1988	-13.6	0.3	-17.2	0.3	0.7	3.8	-16.9
1989	3.3	19.7	-19.2	-0.4	-4.6	-1.3	0.5
1990	-6.0	5.4	-8.8	0.1	0.7	-2.0	-3.4
1991	-3.3	12.8	-10.7	0.7	3.0	-3.1	2.0
1992	-2.3	7.3	-12.2	0.6	-0.1	2.0	-4.9
1993	7.6	17.1	-6.7	0.7	0.3	-3.2	10.4
1994	-4.6	6.1	-10.4	0.8	0.1	-0.9	-4.4
1995	-7.2	0.0	-2.5	1.1	0.9	-4.9	-2.5
1996	-2.2	6.5	-6.7	-0.1	-0.8	-2.7	-0.2
1997	0.0	6.9	-4.7	1.1	1.9	-1.3	2.2
1998	5.6	11.5	-12.4	1.1	-2.8	2.6	-0.9
1999	3.2	8.3	-8.0	0.9	-0.1	1.9	0.4
2000	-3.2	-4.0	3.7	0.4	2.7	-0.6	-0.3
2001	4.4	4.2	-0.4	0.8	-1.0	-1.1	3.8
2002	10.5	14.3	0.2	0.8	0.2	-4.6	14.5

Source: Israel's Central Bureau of Statistics; US Department of Commerce Bureau of Economic Analysis.

Table 3: Decomposition of RER changes as a regression, 1986-2002 (t-values in parentheses)

	Model 1	Model 2
Nominal exchange rate	0.657 (4.8)	
Difference in price of tradable goods	0.707 (7.5)	
“Balassa-Samuelson effect”	0.830 (1.8)	0.680 (2.3)
Deviations from PPP		0.700 (7.9)
Constant	-0.418 (-0.4)	-0.788 (-1.1)
R ² adjusted	0.79	0.80
dw statistics	1.83	1.80

Figure 1. Growth and real exchange rate, 1986-2002, percent change



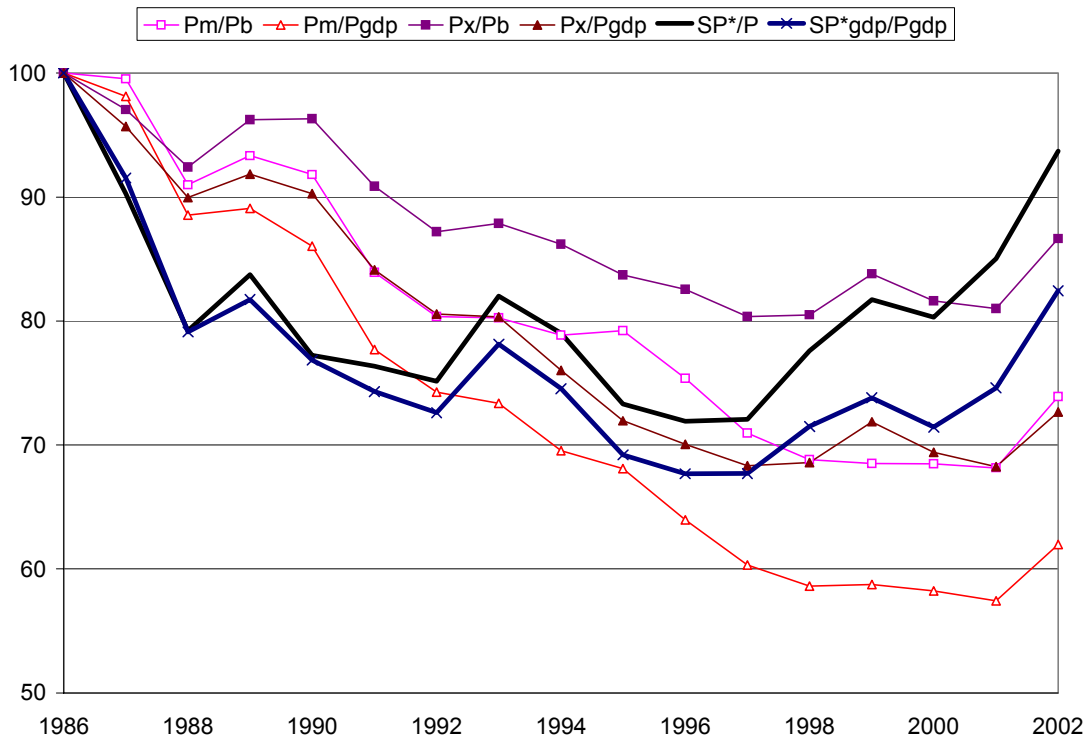
Source: CBS and Bank of Israel, author's calculations; Federal Reserve Economic Database.

Legend:

GDP – year-on-year volume change of GDP.

RER (export price) – ratio of prices of exports of goods and services to implicit deflator of business sector product (excluding public services, NPO and housing services).

Figure 2. Different indices of real exchange rate, 1986-2002 (1986=100)



Source: CBS and Bank of Israel, US BEA, author's calculations.

Legend:

Pm/Pb – ratio of prices of civilian imports of goods and services to implicit deflator of business sector product (excluding public services, NPO and housing services).

Px/Pb – ratio of prices of exports of goods and services to implicit deflator of business sector product (excluding public services, NPO and housing services).

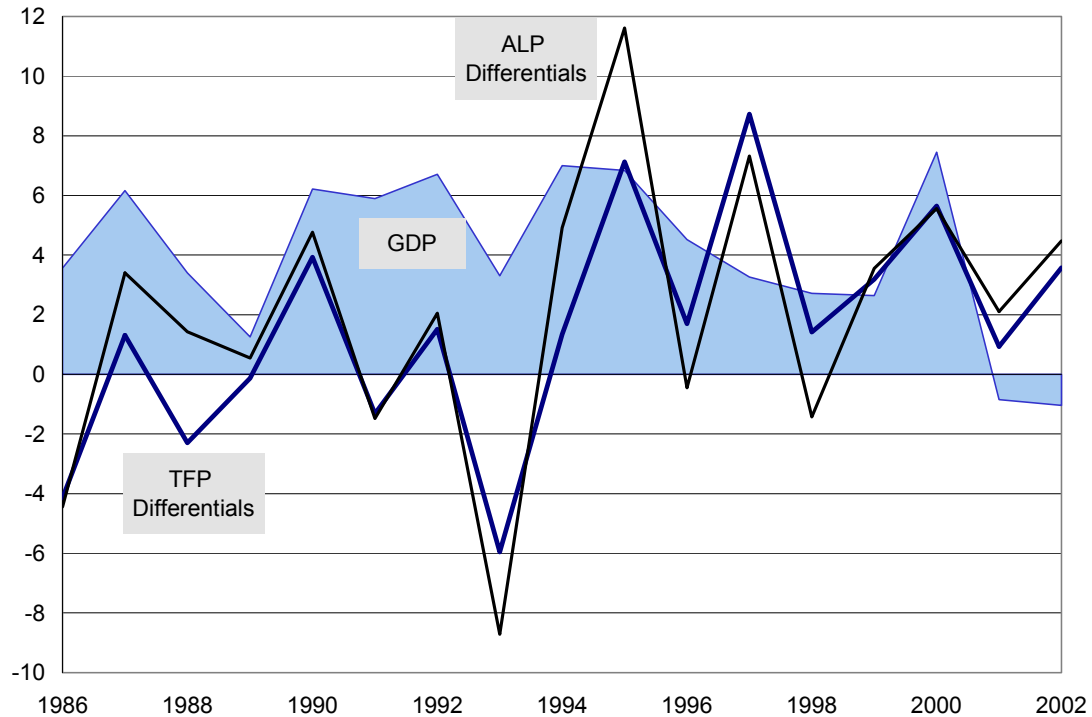
Pm/Pgdp – ratio of prices of civilian imports of goods and services to implicit GDP deflator.

Px/Pgdp – ratio of prices of exports of goods and services to implicit GDP deflator.

SP*/P – exchange rate (NIS for USD) deflated by the ratio of U.S. and Israel's CPI.

SP*gdp/Pgdp – exchange rate (NIS per USD) deflated by the ratio of U.S. to Israel's implicit GDP deflators.

Figure 3. Growth, total factor productivity and average labor productivity differentials between tradable and nontradable sectors, 1986-2002, percent change



Source: CBS and Bank of Israel, author's calculations.

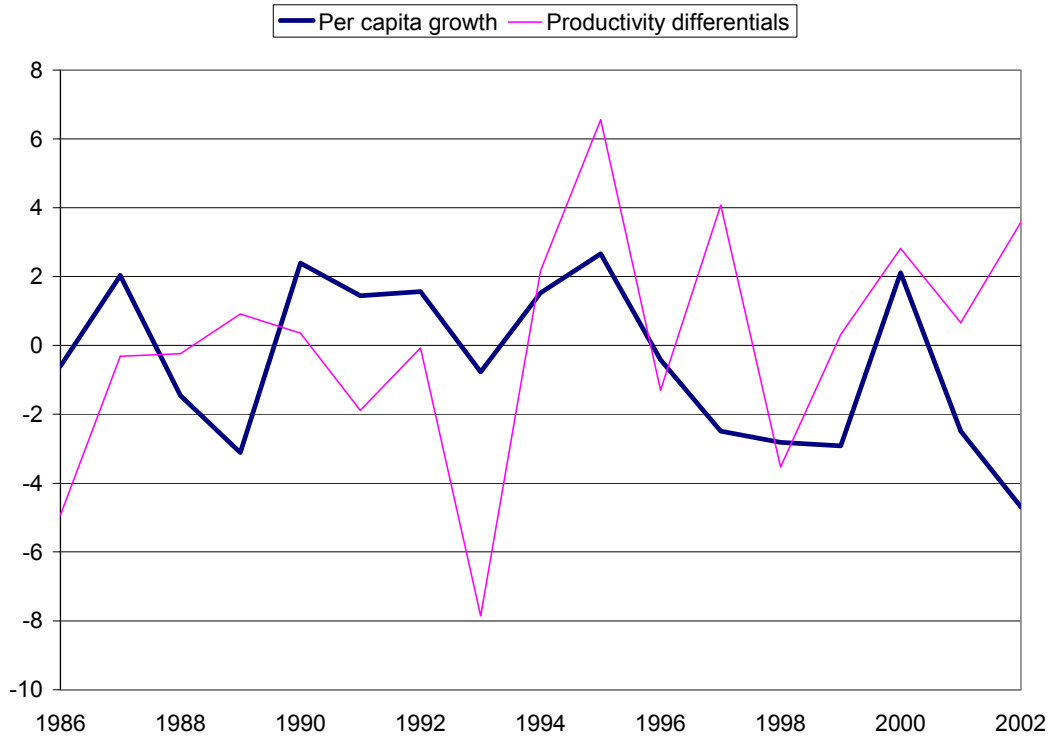
Legend:

GDP – year-on-year volume change.

TFP Differentials – average weighted change in total factor productivity (TFP) of tradable industries (manufacturing and agriculture) less average weighted change in TFP of nontradable industries (transport and communication, construction, electricity and water, commerce and business services).

ALP Differentials – average weighted change in labor productivity (LP) of tradable industries (manufacturing and agriculture) less average weighted change in LP of nontradable industries (transport and communication, construction, electricity and water, commerce and business services).

Figure 4. Growth and sectoral productivity differentials, Israel relative to US, 1986-2002, percent change



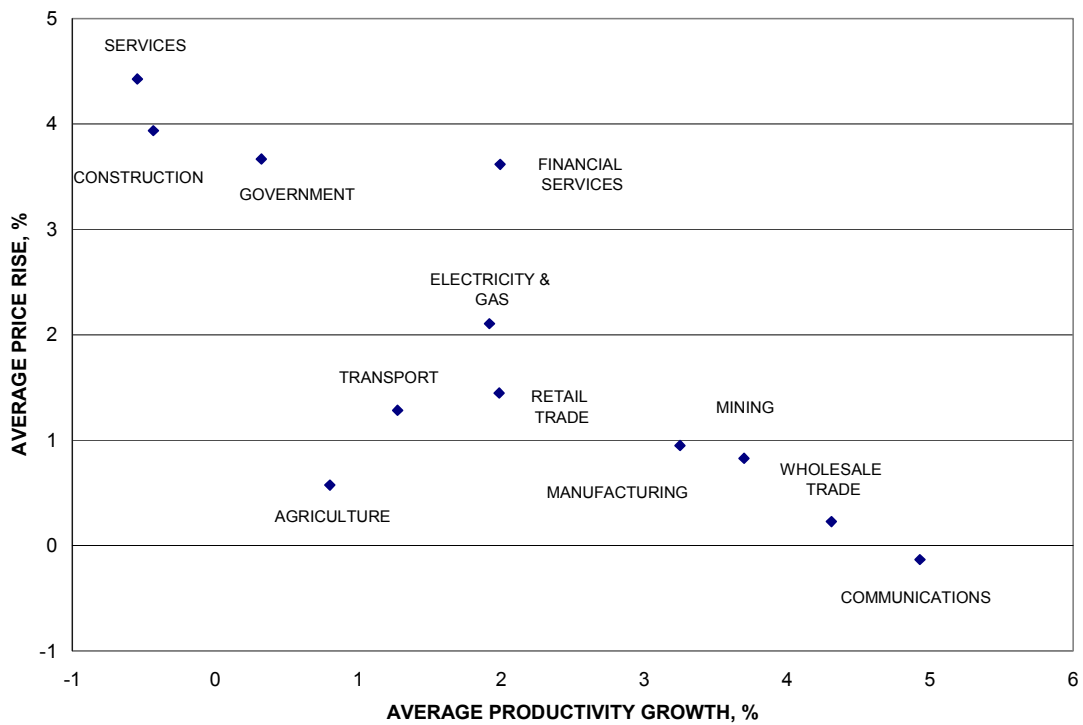
Source: CBS and Bank of Israel, US Department of Labor BLS, author's calculations.

Legend:

Per capita growth – year-on-year volume change, Israel minus US.

Productivity Differentials – the difference between annual percentage change of output per labor hour in manufacturing and non-farm business, Israel minus US.

Figure 5. Productivity and price rise by principal industry in US, average in 1986-2001



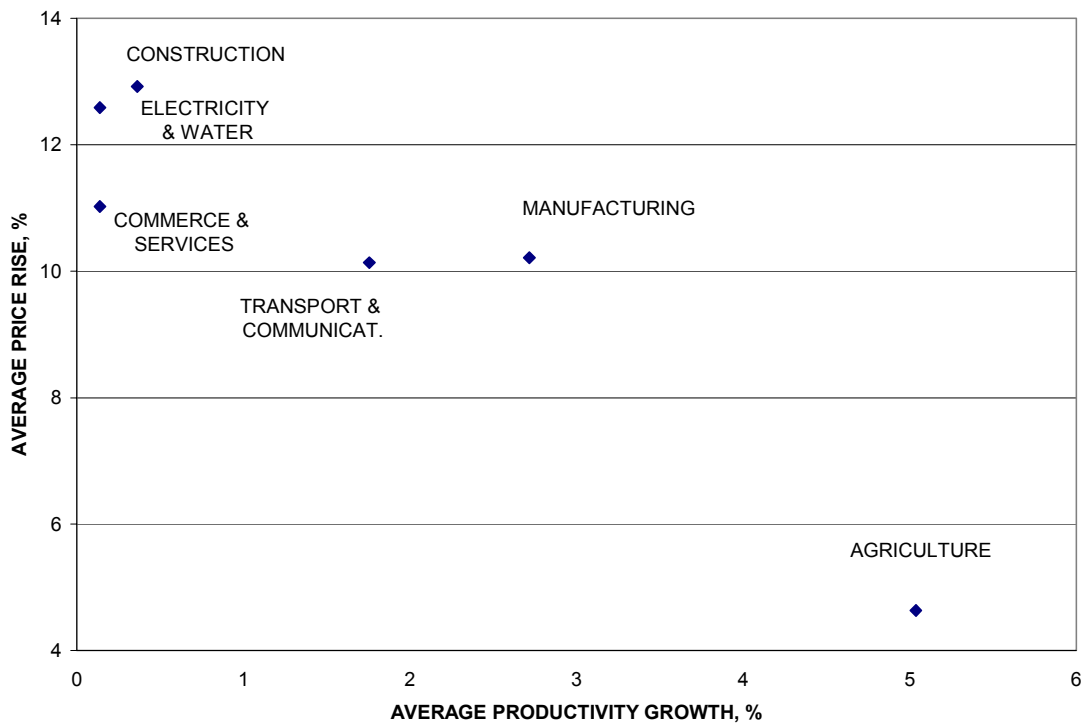
Source: US Department of Commerce BEA, author's calculations.

Legend:

Productivity – gross domestic product originating by industry per full-time equivalent employee by industry.

Price rise – implicit price deflator for gross domestic product by industry.

Figure 6. Productivity and price rise by principal industry in Israel, average in 1986-2002



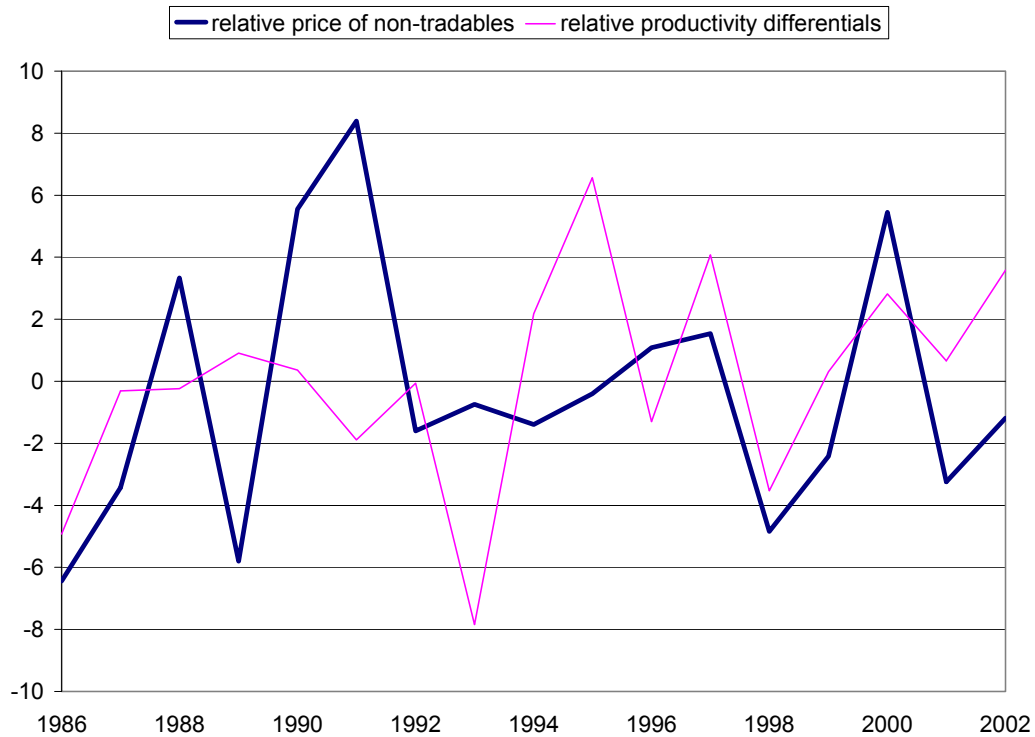
Source: CBS and Bank of Israel, author's calculations.

Legend:

Productivity – average labor productivity (see legend of Figure 3) by industry.

Price rise – implicit price deflator for net domestic product at factor prices by industry.

Figure 7. Relative price of nontradables and productivity differentials, 1986-2002, percent change



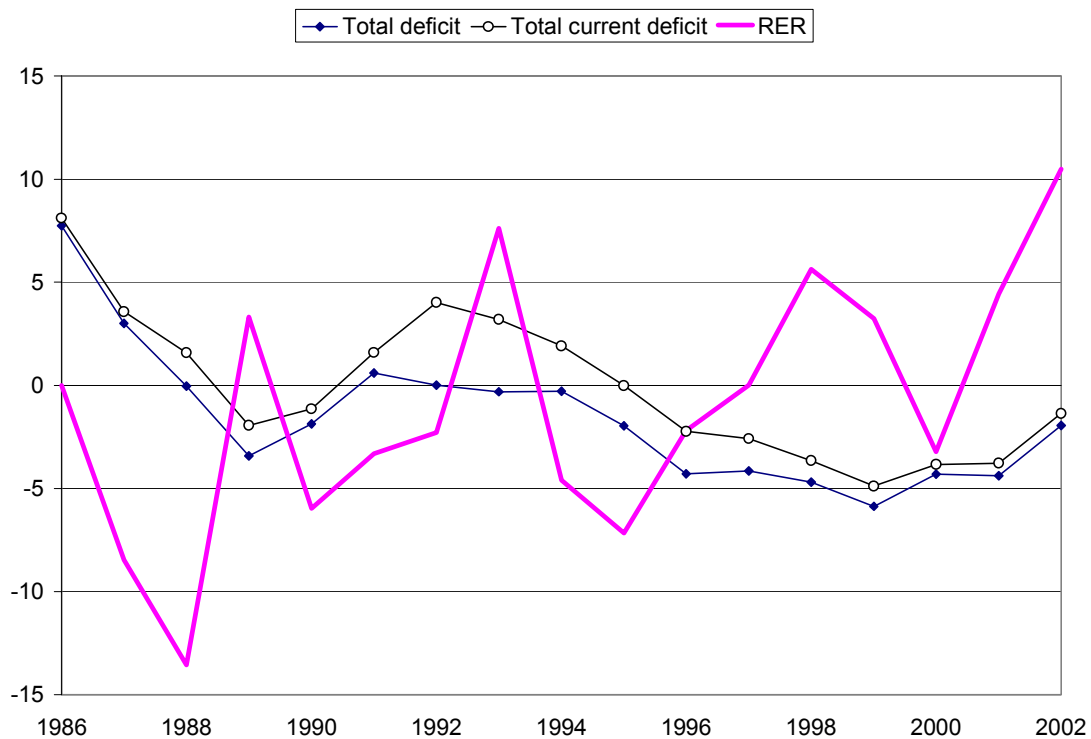
Source: CBS and Bank of Israel, US Department of Commerce BEA, author's calculations.

Legend:

Relative price of nontradables: for Israel – the difference between annual percentage change of implicit business-sector deflator at factor prices and average implicit price deflator of agriculture and manufacturing (1993 SIC), weighted by net product; for the U.S. – the difference between annual percentage change of implicit price deflator of private industries gross domestic product and average implicit price deflator of agriculture, forestry and fishing, mining and manufacturing of durable and nondurable goods (1987 SIC), weighted by gross domestic product.

Relative productivity differentials – rate of change in ALP in tradable sector minus that in nontradable sector, differenced between Israel and US.

Figure 8. Relative government deficit and real exchange rate, 1986-2002



Source: CBS and Bank of Israel, US Department of Commerce BEA, author's calculations.

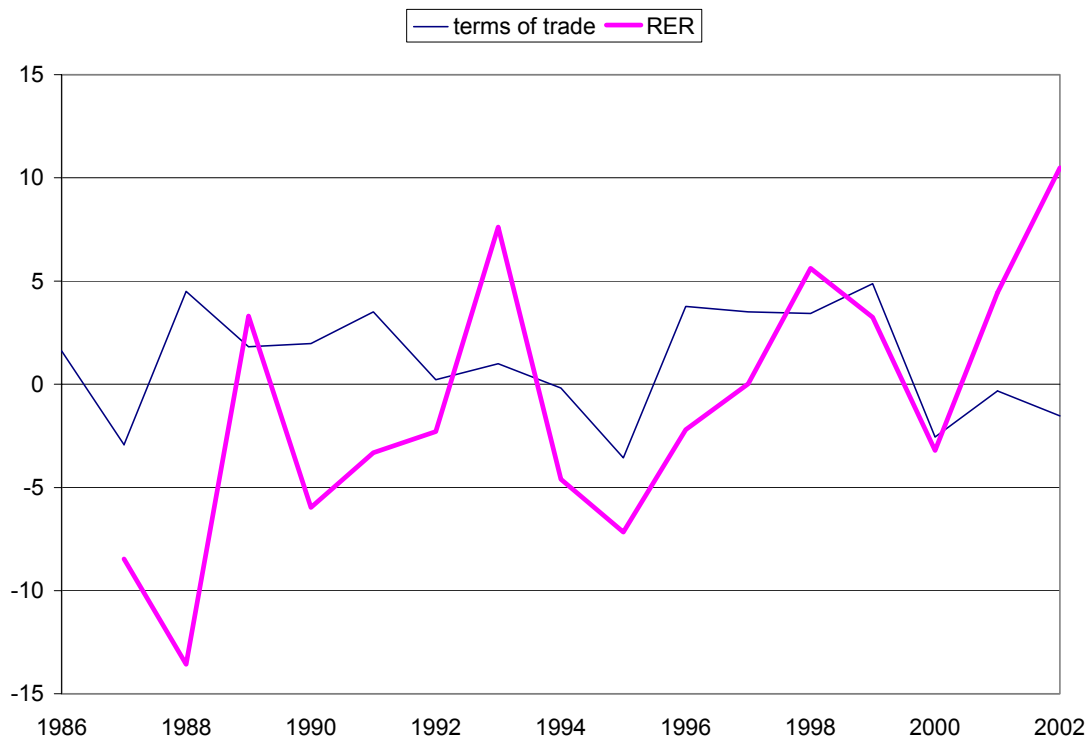
Legend:

Total deficit – the difference between the ratio of total deficit (-) of general government to GDP in Israel and the ratio of total current deficit of general government (federal, state and local) to GDP in the US.

Total current deficit – the difference between the ratio of total current deficit (-) of general government to GDP in Israel and the ratio of total current deficit of general government (federal, state and local) to GDP in the US.

RER – nominal exchange rate (NIS per USD) deflated by the ratio implicit GDP deflators in US and Israel.

Figure 9. Terms of trade and real exchange rate, 1986-2002, percent change



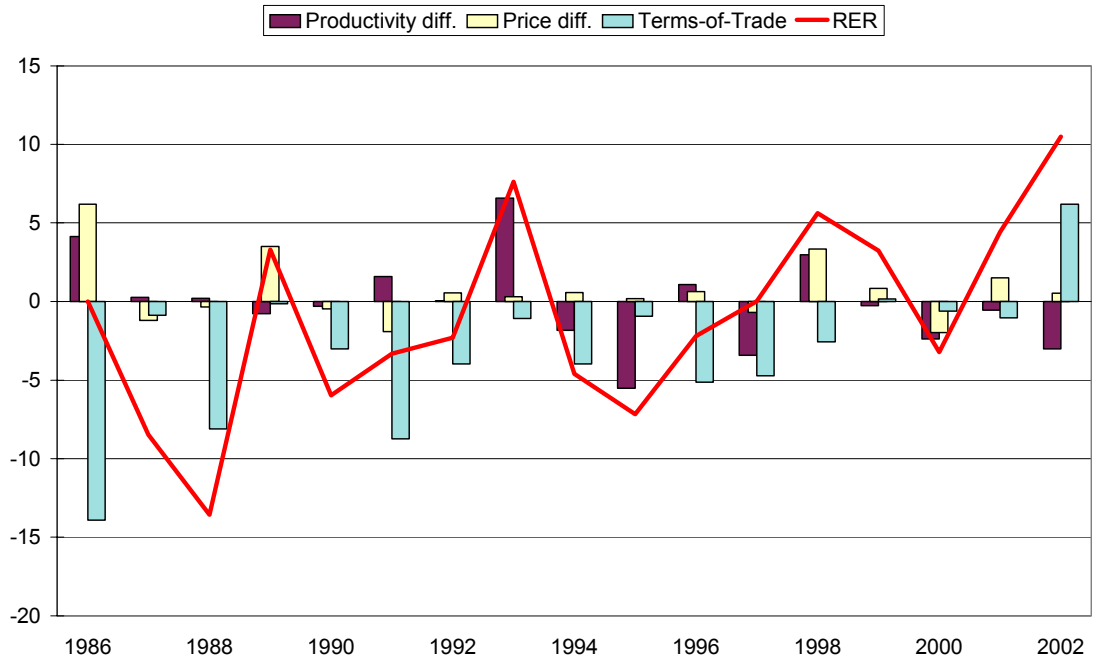
Source: CBS and Bank of Israel, author's calculations.

Legend:

Terms of trade – the difference between annual percentage change of implicit exports deflator and implicit civilian imports deflator.

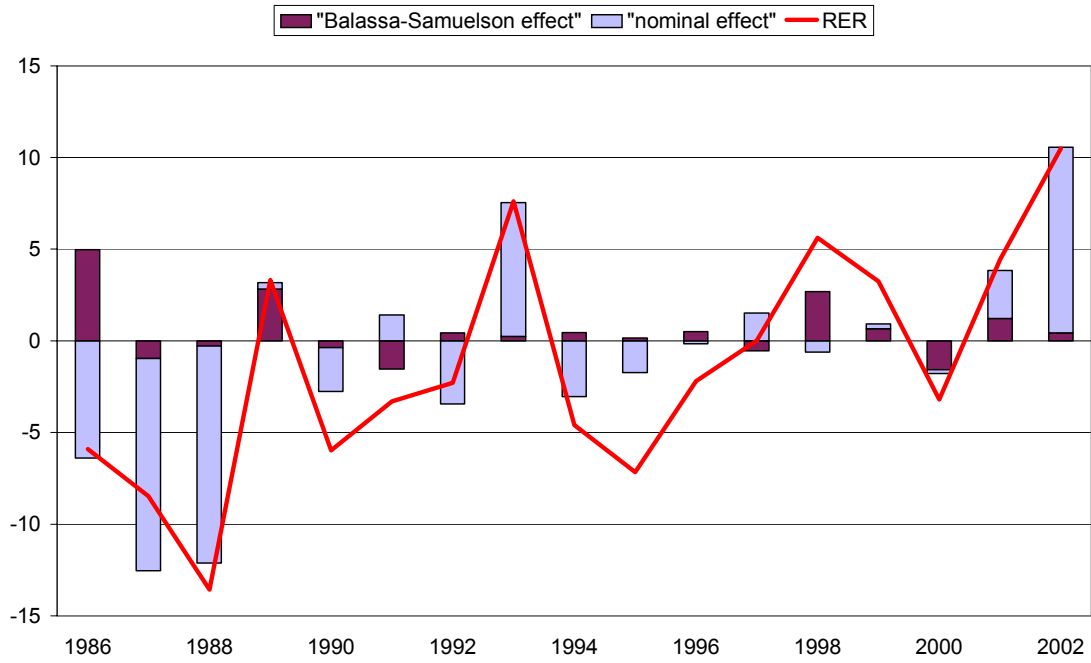
RER – nominal exchange rate (NIS per USD) deflated by the ratio of US and Israel implicit GDP deflators.

Figure 10. Contributions of terms of trade, productivity and price differentials to RER change, 1986-2002, percent



Source: Table 1, Model E.

Figure 11. Contributions of Balassa-Samuelson effect and nominal effect to RER change, 1986-2002, percent



Source: Table 3, Model 2.