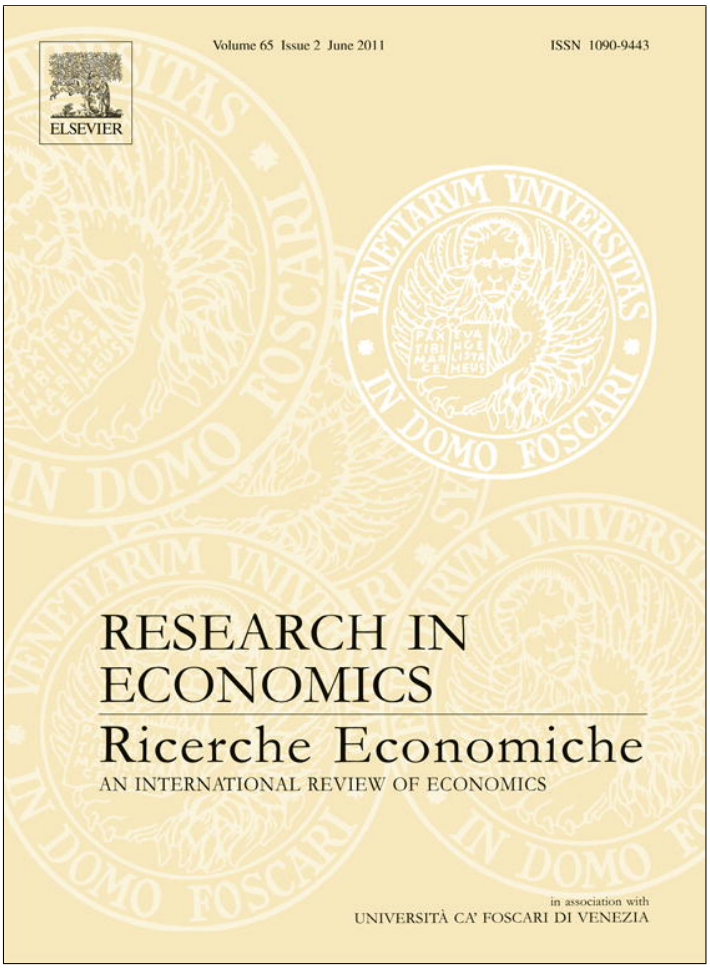

Research in Economics 65 (2011) 100–109

Contents lists available at ScienceDirect

Research in Economics

journal homepage: www.elsevier.com/locate/rie

The link between exchange rate uncertainty and Israeli exports to the US: 2SLS and cointegration approaches☆

Yaron Zelekha [a,*], Ohad Bar-Efrat [b,1]

[a] Ono Academic College, 14 Hagaon Eliyahu St., Ramat Gan, Israel
[b] Bank of Israel, Israel

ARTICLE INFO

Article history:
Received 22 May 2009
Accepted 16 September 2010

Keywords:
Uncertainty
Export

ABSTRACT

Although the effect of uncertainty on economic behavior is of primary concern to both economists and policymakers, its theoretical and empirical treatment in the literature has led to inconclusive results. Indeed, the results of the various empirical studies are highly dependent on the statistical method employed and the proxy used for uncertainty. Using quarterly data for the period 1997–2010:1, this study examines the effect of exchange rate uncertainty on Israeli exports of goods to the US and finds support for the hypothesis that uncertainty has a negative and dominant effect on exports, in both the short run and the long run. Two important contributions are made to the empirical literature: the use of 2SLS in order to address the problem of simultaneity between the exchange rate and exports in this context and the testing of three uncertainty proxies. The use of Israeli data is also relevant to the empirical evidence for developed countries, since Israeli exports of goods to the US consist primarily of products with high value added in production. Contrary to theoretical claims in the literature, having a large proportion of high-value-added goods does not appear to significantly reduce the negative effect of uncertainty.

1. Background

Uncertainty in economic variables that influence output decisions is a subject of great importance to both economists and policymakers. However, the theory and empirical evidence in the literature on the effect of uncertainty on exports is inconclusive.

On the theoretical side, De Grauwe (1988) claimed that positive income effects – which dominate negative substitution effects – are likely to have a net positive effect on exports. The substitution effect is a result of the preference for shifting production to the local market when there is risk of a low exchange rate in the future, while the income effect is a result of the desire to increase the quantity of exports in order to compensate for possible erosion in the exchange rate.

Asseery and Peel (1991) and others describe trade as an option whose value increases with exchange rate uncertainty, thus increasing the supply of exports.

Tavlas and Swamy (1997) claim that a higher level of exchange rate uncertainty will lead to an accumulation of expertise among exporters with respect to movements in exchange rates. This expertise is likely to become an additional source of profit for them, which reinforces the positive effect of uncertainty on exports.

☆ We would like to thank the anonymous referee for his/her important and valuable comments.
* Corresponding author. Tel.: +972 506909000.
E-mail address: yaronzl@013.net.il (Y. Zelekha).
1 The views expressed do not necessarily reflect the views of the Bank of Israel.

1090-9443/$ – see front matter © 2011 University of Venice. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.rie.2010.09.001

Doyle (2001) points out that the positive effects of exchange rate uncertainty are related to the multinational character of companies involved in foreign trade. Thus, being a multinational company provides some degree of natural protection against movements in exchange rates through the ability to shift production or exports between subsidiaries in different countries.

Boug and Fagereng (2010) argue that, given the possibilities for currency hedging in the financial markets, exporters are able to reduce exchange rate uncertainty and therefore minimize its negative effects.

On the other hand, Caballero and Corbo (1989) and others claim that the effect of exchange rate uncertainty on exports is related to the intensity of risk aversion, since greater uncertainty leads to higher costs for risk-averse exporters and therefore reduces the volume of exports.

Dixit (1989) suggests that the costs of adjustment resulting from the shift to or from exports are significant and affect the nature of the firm's reaction to exchange rate risk. These costs create a phenomenon of hysteresis or inertia in export flows. Higher uncertainty will lead firms to refrain from investment in export activity, while on the other hand firms that are already producing for export will refrain from exiting (since they are unable to sell off past investment). In this context, Iacovone and Javorcik (2010), using data on Mexican trade under NAFTA, found that new exporters face higher uncertainty and therefore enter foreign markets with a small variety of goods (most of which were previously sold in the home market) and a low initial volume of exports.

Caballero (1991) claims that the contradictory results produced by the various models with respect to the effect of exchange rate uncertainty on exports are the result of various micro and macro factors. The former include the degree of symmetry in the adjustment costs of production lines (i.e., the extent to which adjustment to a decrease in production is more expensive than adjustment to an increase in production of the same magnitude), where symmetry results in a positive effect and asymmetry results in a negative effect, and the existence of declining or fixed returns to scale in the production function, which produces a positive effect. On the macro level, varying the assumptions regarding the degree of competition in the market may produce different results. Thus, the effect of uncertainty on exports can be positive or negative, depending on the degree of competition in the markets and the nature of the production function, as well as the interaction between them. The uncertainty will tend to have a positive effect on investment in the case of greater competition in the markets and closer proximity to fixed returns to scale in production. Caballero concludes that the negative effect of uncertainty is more common than the positive effect.

It should be mentioned in this regard that it is easier for exporters to accumulate greater market power and thus to raise the price of their products when those products have a higher proportion of added value. At the same time, this will make it harder for an exporter to shift his products to the more limited local market. Furthermore, a high proportion of added value is likely to be related to high fixed costs (primarily R&D) and therefore to a high rate of contribution-based costing (i.e., pricing per unit of product, which takes into account only variable costs). In this situation, there is a greater ability to absorb a drop in revenue in terms of the local currency since the effect of small changes will be no higher than the loss in production of the marginal unit. Another explanation may be related to the ability to achieve greater efficiency. Thus, it is reasonable to assume that producers of goods with a high proportion of added value will have greater expertise in streamlining the production process (i.e., increasing productivity) in order to compensate for changes in total revenue.

Barkoulas et al. (2002) suggest that the existence of different types of uncertainty is one of the factors behind the contradictory empirical results. In their view, different types of uncertainty (such as, for example, the structural uncertainty in the local capital market and policy uncertainty) can have an opposite effect on exports.

As in the case of the theoretical debate, the empirical research has also been inconclusive. A number of studies, most of which looked at developing countries, found evidence for a significant negative effect. In this context, Caballero and Corbo (1989), based on data for six developing countries, found that exchange rate uncertainty has a large negative effect on exports. Moreover, they found that the long-run effect of uncertainty is even larger than the short-run effect, and explain this using risk aversion. Similar results, in both the long run and the short run, were obtained by Bahmani-Oskooee (2002), Onafowora and Owoye (2008) and Arize et al. (2008), who used data for eight Latin American countries over a period of 30 years. Arize et al. found that in some countries uncertainty has a larger effect than the relative prices of tradable and nontradable goods. In their opinion, the results show that exchange rate uncertainty has a negative effect on exports not only in countries with low per capita income but even in those with medium per capita income. They also emphasize the importance of testing for the effect of particularly high levels of uncertainty in countries that have moved from a fixed exchange rate to a flexible one, in view of the generally higher volatility under a flexible exchange rate regime.

Findings for developed countries are mixed, and in fact show some support for a positive effect of real exchange rate uncertainty on exports. While Arize (1995), Choudhry (2005), and others report negative effects, Qian and Varangis (1994) and Baum et al. (2004) report a negative effect in some of the countries and a positive one in the rest. Boug and Fagereng (2010) did not find any significant effects in either direction for Norwegian exports. Doyle (2001) reported a positive effect for bilateral trade between Britain and Ireland in most industries (and a negative effect in the rest), and Choudhry (2008) reported a positive effect for trade between Britain on the one hand and Canada, New Zealand, and Japan on the other, in both the short run and the long run, as do McKenzie and Brooks (1997) and others.

In conclusion, the results in the literature seem to indicate a possible link between the stage of a country's development (particularly that of its financial markets, which provides a partial ability to protect against unexpected changes in exchange rates) and the direction of the effect of uncertainty on trade. More importantly, the various studies stress that the results are

highly dependent on the statistical method employed and the proxy for uncertainty (see also McKenzie, 1999; Bahmani-Oskooee and Hegerty, 2007).

The model presented here is innovative in two ways. First, use is made of both ordinary least squares (OLS) and two-stage least squares (2SLS) estimation (for the first time in this context, as far as we are aware) in order to address the issue of simultaneity between the exchange rate and exports (which has been virtually ignored in the literature). Second, three proxies for uncertainty are tested (one of which is used for the first time and another which has only been used once previously). The results show that the negative effect of exchange rate uncertainty on Israeli exports to the US is robust to the statistical methods employed. The use of Israeli data is another important contribution to the empirical literature for developed countries since Israeli exports to the US consist primarily of goods with high added value.

The article is composed of four parts. Section 2 presents the theoretical background, the database, and the statistical issues, while Section 3 presents the results. Section 4 concludes and suggests some policy implications.

2. Theoretical background, the database, and the statistical method

The model used is a slightly modified version of that of De Gregorio and Wolf (1994), which is a good approximation of the small and open Israeli economy. The basic assumptions of the model are a balanced current account and government budget, and therefore it is particularly suited to a long-run analysis, in which the only explanatory factors are related to supply factors, in addition to the terms of trade.

De Gregorio and Wolf's model can easily be expanded through the addition of various components – uncertainty and the related cost of protection in our case – to the cost of labor and of capital within the exporter's production function. It is worth mentioning that this approach is also consistent with the empirical findings reported for other countries, which showed that exporters in developed countries have a greater ability to obtain reasonably priced protection from unexpected changes in the local exchange rate. In other words, the cost of protection is a negative function of a country's level of development. Therefore, the addition of a permanent cost component representing uncertainty is consistent with the accepted theory since it introduces the cost of protection into a firm's production function and therefore is also relevant in the long run.

The export equation was modified in order to take into account the effects of uncertainty, and in its direct form it leads to a linear correlation between exports on the one hand and output and capital on the other. However, a log-linear equation was used which makes it possible to directly examine the relationship between the propensity to export and the variables representing uncertainty. Hence, the following equation for exports was estimated:

$$\ln Ex_t = A + a_1 \ln L_t + a_2 \ln k_{1t}^d + a_3 \ln y_t + a_4 \ln \mathrm{Re}\, r_t + a_5 \phi_t + \varepsilon_t, \tag{1}$$

where

Ex_t is the Israeli exports to the US,
L_t is the workforce in Israel, which is represented by the size of the population (aged 15 and over),
k_{1t}^d is the stock of capital in Israel,
y_t is the demand for Israeli exports, which is represented by total US imports,
$\mathrm{Re}\, r_t$ is the terms of trade, as represented by the real exchange rate ($\mathrm{Re}\, r_t$) and the index of export prices ($\mathrm{Re}\, r_t'$),
ϕ_t is the exchange rate uncertainty, which will be represented by three alternative proxies (see below),
ε_t is the error term.

The empirical analysis involves a number of important statistical issues that need to be clarified prior to the analysis.

The first issue is that of simultaneity between the exchange rate and exports. These two variables influence each other in a way that distorts the standard statistical treatment in a simple OLS regression. The literature has virtually ignored this issue, although some studies have used lagged variables as part of cointegration estimation (which partially addresses the issue). In contrast, the problem can be fully resolved using two-stage least squares (2SLS) estimation, which is used here for the first time as far we are aware and is described in what follows.

In the first stage, the real exchange rate variable (i.e., the nominal dollar/shekel exchange rate deflated by the index of output prices in Israel) is estimated using the instrumental variables method. The equation includes only the conventional variables which do not affect exports, including Israel's import surplus as a percentage of output which represents an expression of individuals' purchasing power and the intensity of local demand pressure on sources, the rate of investment in the economy as a percentage of output, labor-intensive public consumption as a percentage of output (on the assumption that it competes with the business sector with respect to the labor force and wages), and real interest rates in the US. Hence, the following log-linear equation was used to explain the real exchange rate:

$$\ln \mathrm{Re}\, r_t'' = A + a_1 \ln \mathrm{Re}\, r_{t-1t} + a_2 im_{t+} a_3 I_t + a_4 \ln G_t + a_2 \mathrm{rus}_t + \varepsilon_t, \tag{2}$$

where

im_t is the import surplus as a percentage of output,
I_t is the investment as a percentage of output,
G_t is public consumption as a percentage of output,

rus_t is the real US rate of interest as represented by the one-year nominal return on Treasury Bills less the actual change in the US CPI.

The estimation results ($\bar{R}^2 = 0.897$) show that only the lagged real exchange rate and public consumption as a percentage of output variables were significant.

In the second stage, Israeli exports to the US are estimated on the basis of Eq. (1) using the real exchange rate estimated in the first stage.

The second issue relates to the proxies for price uncertainty. The literature describes three methods for including uncertainty that are meant to deal with the problem of serial correlation in the exchange rate standard deviation data (see Jansen, 1989). This serial correlation is a result of the inertia in external noise within daily currency prices, which do not adjust immediately (particularly in the case of white noise related to expectations of policy changes or the analysis of their effect and of changes in the security situation, in the case of Israel). The first and most commonly used method in the literature calls for the inclusion of the moving average of the standard deviation (denoted here as $\phi 2_t$) over an extended period of time. The disadvantage of this method lies in the incomplete elimination of the serial correlation. The second method uses the GARCH model, in which the standard deviation is included in an estimation that derives the trend of the standard deviation from the raw data. The main disadvantage of this method is the excessive elimination of secondary trends, which is likely to neutralize the overall trend and to seriously distort the fluctuations in the data. It should be mentioned that according to Klaassen (2004) the first two methods may even create contradictory estimates of the trend in risk and uncertainty. The third method, which is recommended by Baum et al. (2004), is used here for the first time (as far as we are aware), and involves calculating the standard deviations of the expected exchange rate in the form of one-month-ahead spot prices (denoted here as $\phi 1_t$). Another method, which is not mentioned in the literature, involves the moving average of the standard deviation of export prices (relative to local output prices) denominated in the foreign currency (denoted here as $\phi 3_t$).

In this regard, we should also stress that in order to avoid any possible simultaneity between the uncertainty proxies, $\phi 1_t$ and $\phi 2_t$, and exports, use was made of lagged variables for both proxies. Moreover, $\phi 1_t$ can only be remotely considered as affected by exports, since it involves the expected exchange rate and not the actual, while $\phi 3_t$ can hardly be regarded as affected by Israeli exports since the trade terms are fixed in world markets. Finally, we included an alternative proxy for $\phi 2_t$, constructed from the real exchange rate variable as estimated using the instrumental variables method.

The third issue is related to the composition of the basket of currencies according to which Israel's export prices are weighted. Although the Central Bureau of Statistics publishes a weighted index of export prices, its method of weighting is liable to degrade the quality of the data (in a manner similar to seasonal adjustment). This makes it problematic to use specific exchange rates and the uncertainty attached to them. Therefore, as in most of the studies done in other countries, the empirical estimation is carried out for Israel's exports to a specific country, i.e., the US, which has been Israel's largest trading partner for several decades. The estimation uses both export prices and the real exchange rate of the US dollar against the shekel (deflated by the index of output prices, which was chosen because it more closely represents the profitability of investment in the expansion of production lines than the CPI).

The fourth issue involves unit roots in the variables, and therefore, before choosing the method of statistical estimation, two tests for stationarity (i.e., the unit root problem) were performed on the variables: an Augmented Dickey–Fuller (ADF) test and a Phillips–Perron test (see Table 1).

The ADF test involves the estimation of Eq. (3) in order to obtain the first-order differences of each variable x_t:

$$x_t - x_{t-1} = \alpha + \beta x_{t-1} + U_{(t)}. \tag{3}$$

Since unit roots were found in the errors of the equations, the hypothesis was tested that β is equal to zero for each equation separately. It was found that the variables are not stationary and that their variance is infinite. At the same time, the same test for the first-order differences showed that all the variables are stationary at accepted levels of confidence, apart from the population variable. It is worth mentioning that the large wave of immigration from the former USSR gradually decreased in size over the sample period, and as a result significant changes occurred in the rate of population growth. As a result, the test for stationarity did not show convergence, even in first-order differences. However, there is little doubt that in the long run the population converges, and this is certainly true for the first differences (and this is indeed seen in the tests for stationarity performed on the first differences of population data for other periods), and therefore this variable can be included in the long-run equations. As an alternative, the population variable was replaced by a trend variable (which receives an increasing numerical value for each period) in a way that does not compromise the quality of the estimation. In any case, the results of the test indicate the possibility of first-order integration in the variables. Therefore, a cointegration equation can be created in which the set of variables is stationary, on the condition that the errors in the equation do not reveal a unit root. Ramanathan (1998) recommends an ADF test for the errors and indeed showed that the equations create first-order integration. Therefore, a t-test can validly be used in the estimation of the original variables.

Moreover, the stationarity of the error is meant to express a long-run relationship between the dependent variable and the explanatory variables. However, since the sample is composed of quarterly observations, the results will be interpreted as also reflecting intermediate-run trends. This is also consistent with the history of the Israeli economy whose development continued for a number of decades (and is still ongoing), and therefore short-run dynamics are likely to play a major role over very long periods.

Table 1
Unit root tests.

Variable	Variable test	Difference test	Variable test	Difference test	Critical value (5%)
	Augmented Dickey–Fuller test	Augmented Dickey–Fuller test	Phillips–Perron test	Phillips–Perron test	
Ex_t	−2.217	−8.010	−2.382	−8.071	−2.92
L_t	−1.543	−1.185	−5.889	−1.197	−2.92
y_t	−3.042	−8.586	−3.034	−9.436	−2.92
Re r_t	−0.178	−5.874	−0.081	−5.757	−2.92
Re r_t'	−1.493	−9.436	−1.256	−10.778	−2.92
Re r_t''	−0.216	−6.126	−0.351	−6.062	−2.92
$\phi 1_t$	−2.378	−8.174	−2.406	−8.174	−2.92
$\phi 2_t$	−1.754	−5.797	−2.126	−5.805	−2.92
$\phi 3_t$	−2.808	−8.227	−2.861	−8.455	−2.92
Pr $odIs_t$	−2.496	−7.001	−2.643	−7.001	−2.92
yis_t	−0.486	−4.807	−0.521	−4.863	−2.92
I_t	−2.547	−10.878	−2.322	−13.073	−2.92
G_t	−0.950	−6.039	−1.114	−6.097	−2.92
rus_t	−1.437	−5.625	−2.045	−5.649	−2.92
ris_t	−0.816	−6.518	−0.546	−7.862	−2.92
ECM A3	−7.446	−5.340	−12.665	−23.946	−2.92
ECM B3	−7.108	−5.510	−10.245	−21.093	−2.92
ECM C2	−7.819	−8.210	−14.284	−24.260	−2.92
ECM A7	−7.648	−6.164	−10.479	−25.676	−2.92
ECM B7	−6.877	−6.656	−11.106	−20.481	−2.92
ECM C6	−7.613	−7.355	−17.645	−22.814	−2.92

The Phillips–Perron test (see Phillips and Perron, 1988) builds on the ADF null hypothesis that β is equal to zero. Like ADF, it addresses the issue that the process generating data for x_t may have a higher order of autocorrelation than is modeled in the test equation, which would make x_{t-1} endogenous and thus invalidate the ADF t-test. However, while the ADF test addresses this issue by introducing lags of $x_t - x_{t-1}$ as regressors in the test equation, the Phillips–Perron test makes a nonparametric correction to the t-test statistic. The test is robust with respect to unspecified autocorrelation and heteroscedasticity in the disturbance process of the test equation. In any event, the Phillips–Perron test also shows that a t-test can validly be done and that OLS can be performed on the original variables.

Finally, the model was estimated using data on the volume of Israeli exports of goods to the US for the sample period 1997–2010:1. The estimation was carried out using US data in view of the dominant position of the US in Israel's foreign trade as Israel's largest individual trading partner, as well as its largest source of foreign investment.

3. Results

The estimation results for the equation explaining Israeli exports to the US appear in Tables 2–4. The best-fitting equation in the case of 2SLS estimation was version B-3 in Table 3 with $\bar{R}^2 = 0.960$ ($R^2 = 0.966$) and SE = 0.060 and DW = 1.840 (which indicate the absence of serial correlation), while the best-fitting equation in the case of OLS estimation was version B-7 in Table 3 with $\bar{R}^2 = 0.960$ ($R^2 = 0.966$) and SE = 0.060 and DW = 2.044 (which indicate the absence of serial correlation). The most important variables were found to be significant, stable, and robust, and to have the expected signs. In addition, the estimates had relatively low variances.

In general, the use of 2SLS estimation improved the results in terms of significance and elasticity, although the differences between the 2SLS and OLS coefficients were negligible.

The relative price variable was represented in all the versions by both the real exchange rate and the index of export prices (adjusted for the change in output prices). The elasticities were found to be positive and close to one (0.944 for the real exchange rate variable and 0.998 for the index of export prices; see version B-3 in Table 3), as expected.

The workforce in Israel, which is represented by the size of the population aged 15 and over, was found to be significant in all the versions, and its elasticity reached a level of 3.656 (see version B-3 in Table 3). This result is explained by the continuous upward trend in population growth throughout the sample period. When we included a time trend variable instead of population, the results remained unchanged. In other words, population behaved like a trend variable while the other variables remained stable. It is worth mentioning that there was an expansion of exports during the sample period with fluctuations around an upward trend, and it may be that the factors which determine this trend (which is characterized by a time component) should include the globalization process and the increasing openness of the Israeli economy.

The business sector capital stock variable was found not to be significant in any of the versions. This might be due to the fact that most of the business sector capital stock that appears in the figures of the Central Bureau of Statistics in fact belongs to the nontradable goods sector (which includes transportation), and therefore is only weakly correlated with the capital stock of the tradable goods sector.

The demand for Israeli exports, which is represented by total US imports, was found to be significant in most of versions, and its elasticity reached a level of 0.246 (see version B-3 in Table 3).

Table 2
Estimation of equations explaining Israeli exports to the US for the period 1997–2010:1 using the standard deviation of the expected exchange rate (as represented by spot prices)[a].

Variable	Coefficients of long-run equation A-1	Coefficients of long-run equation A-2	Coefficients of long-run equation A-3	Coefficients of long-run equation A-4 with time trend	Coefficients of long-run equation A-5	Coefficients of long-run equation A-6	Coefficients of long-run equation A-7
Estimation method	2SLS	2SLS	2SLS	2SLS	OLS	OLS	OLS
Constant	−16.617	−19.387	−29.450	−1.177	−16.579	−20.517	−22.650
	(−4.260)	(−5.173)	(−20.047)	(−0.707)	(−4.403)	(−5.320)	(−6.201)
L_t	1.970	2.331	3.816	0.011	1.985	2.587	2.896
	(3.613)	(4.469)	(19.511)	(4.081)	(3.708)	(4.662)	(5.510)
y_t	0.137	0.201	0.238	0.204	0.144	0.116	0.165
	(1.540)	(2.349)	(3.289)	(2.274)	(1.640)	(1.394)	(2.087)
Re r_t	0.730	0.865	0.857	1.003	0.732	0.612	0.688
	(3.678)	(4.547)	(5.009)	(4.631)	(3.892)	(2.711)	(4.001)
Re r'_t	0.620	0.686	0.815	0.749	0.623	0.734	0.769
	(1.894)	(2.252)	(2.807)	(2.414)	(1.944)	(2.408)	(2.717)
$\phi 1_t$	−1.367	−1.123	−0.789	−1.021	−1.329	−0.950	−0.711
	(−3.194)	(−2.764)	(−1.939)	(3.933)	(−3.143)	(−2.239)	(−1.768)
Ex_{t-1}	0.488	0.354	–	0.429	0.463	0.326	0.207
	(4.265)	(3.046)		(3.933)	(4.019)	(2.711)	(1.735)
Pr $odIs_t$	–	0.0119	0.013	0.010	–	–	0.010
		(2.885)	(4.005)	(2.617)			(2.883)
Dwc_t	–	–	−0.192	–	–	−0.147	−0.154
			(−3.976)			(−2.608)	(−2.939)
R^2	0.951	0.959	0.963	0.957	0.953	0.959	0.965
$\bar{R}^2$	0.945	0.953	0.958	0.950	0.946	0.952	0.959
S.E.	0.070	0.065	0.061	0.066	0.069	0.065	0.061
D.W.	2.043	2.093	1.915	2.140	2.039	2.087	2.185

[a] The equations are in log-linear form, and therefore variables are expressed in natural logarithms, except for $\phi 1_t$, Pr $odIs_t$ and Dwc_t. t-values appear in parentheses.

Table 3
Estimation of equations explaining Israeli exports to the US for the period 1997–2010:1 using the moving average of the standard deviation of the exchange rate[a].

Variable	Coefficients of long-run equation B-1	Coefficients of long-run equation B-2	Coefficients of long-run equation B-3	Coefficients of long-run equation B-4 with time trend	Coefficients of long-run equation B-5	Coefficients of long-run equation B-6	Coefficients of long-run equation B-7
Estimation method	2SLS	2SLS	2SLS	2SLS	OLS	OLS	OLS
Constant	−16.815	−21.088	−29.120	−2.045	−16.548	−19.492	−23.385
	(−4.123)	(−5.491)	(−20.933)	(−1.271)	(−4.231)	(−5.242)	(−6.338)
L_t	1.843	2.430	3.656	0.011	1.843	2.284	2.921
	(3.375)	(4.713)	(20.351)	(3.238)	(3.446)	(4.463)	(5.603)
y_t	0.155	0.232	0.246	0.229	0.160	0.217	0.183
	(1.697)	(2.753)	(3.504)	(2.577)	(1.774)	(2.563)	(2.303)
Re r_t	0.864	1.013	0.944	1.132	0.850	0.929	0.768
	(4.222)	(5.396)	(5.628)	(5.206)	(4.407)	(5.190)	(4.402)
Re r'_t	0.874	0.936	0.998	0.976	0.859	0.874	0.915
	(2.572)	(3.077)	(3.520)	(3.107)	(2.589)	(2.866)	(3.238)
$\phi 2_t$	−2.553	−2.494	−1.995	−2.194	−2.443	−2.346	−1.571
	(−2.868)	(−3.133)	(−2.616)	(−2.721)	(−2.792)	(−2.916)	(−1.987)
Ex_{t-1}	0.463	0.276	–	0.370	0.440	0.292	0.165
	(3.771)	(2.270)		(3.238)	(3.568)	(2.376)	(1.354)
Pr $odIs_t$	–	0.013	0.014	0.011	–	0.011	0.011
		(3.543)	(4.511)	(3.174)		(3.083)	(3.284)
Dwc_t	–	–	−0.170	–	–	–	−0.151
			(3.517)				(−2.923)
R^2	0.950	0.950	0.966	0.958	0.951	0.959	0.966
$\bar{R}^2$	0.943	0.943	0.960	0.951	0.944	0.953	0.960
S.E.	0.071	0.071	0.060	0.066	0.071	0.065	0.060
D.W.	1.818	1.818	1.840	1.962	1.828	1.857	2.044

[a] The equations are in log-linear form, and therefore variables are expressed in natural logarithms, except for $\phi 1_t$, Pr $odIs_t$ and Dwc_t. t-values appear in parentheses.

Table 4
Estimation of equations explaining Israeli exports to the US for the period 1997–2010:1 using the moving average of the standard deviation of export prices (relative to local output prices)[a].

Variable	Coefficients of long-run equation C-1	Coefficients of long-run equation C-2	Coefficients of long-run equation C-3 with time trend	Coefficients of long-run equation C-4	Coefficients of long-run equation C-5	Coefficients of long-run equation C-6
Estimation method	2SLS	2SLS	2SLS	OLS	OLS	OLS
Constant	−13.280	−19.970	−1.023	−13.095	−19.794	−21.730
	(−3.427)	(−5.015)	(−0.601)	(−3.153)	(−5.108)	(5.870)
L_t	1.371	2.418	0.012	1.379	2.416	2.723
	(2.633)	(4.339)	(4.149)	(2.692)	(4.390)	(5.155)
y_t	0.153	0.120	0.139	0.156	0.123	0.165
	(1.598)	(1.383)	(1.553)	(1.654)	(1.444)	(2.019)
Re r_t	0.779	0.604	0.791	0.771	0.604	0.683
	(3.701)	(3.084)	(3.660)	(3.860)	(3.243)	(3.860)
Re r'_t	0.742	0.853	0.902	0.732	0.847	0.841
	(2.129)	(2.711)	(2.845)	(2.142)	(2.740)	(2.905)
$\phi 3_t$	−1.358	−1.231	−1.330	−1.231	−1.134	−0.509
	(−1.969)	(−1.984)	(−2.098)	(−1.803)	(−1.846)	(−0.820)
Ex_{t-1}	0.587	0.359	0.418	0.563	0.342	0.228
	(5.158)	(2.953)	(3.695)	(4.892)	(2.810)	(1.870)
Pr $odIs_t$	–	–	–	–	–	0.010
						(2.690)
Dwc_t	–	−0.188	−0.171	–	−0.186	−0.184
		(−3.461)	(−3.205)		(−3.447)	(−3.645)
R^2	0.945	0.957	0.956	0.946	0.957	0.963
$\bar{R}^2$	0.938	0.950	0.949	0.939	0.951	0.957
S.E.	0.075	0.067	0.068	0.074	0.066	0.062
D.W.	2.036	2.160	2.193	2.026	2.154	2.181

[a] The equations are in log-linear form, and therefore variables are expressed in natural logarithms, except for $\phi 1_t$, Pr $odIs_t$ and Dwc_t. t-values appear in parentheses.

The three proxies for uncertainty were all found to be significant, with a high negative elasticity. It appears that the lagged five-quarter moving average of the standard deviation of the exchange rate and the lagged standard deviation of the expected exchange rate in the form of one-month-ahead spot prices were better proxies, both in the 2SLS and OLS estimations, than the moving average of the standard deviation of export prices (relative to local output prices). The elasticity reached the level of −1.995 for the five-quarter moving average of the standard deviation of the exchange rate and −0.789 for the standard deviation of the expected exchange rate (see versions B-3 in Table 3 and A-3 in Table 2, respectively).

In order to examine the nature of the relationship between exports and uncertainty we added two tests. First, a dummy variable for the symmetry of the elasticities was added, and it was found to be negative though insignificant (i.e., the elasticity for an increase in uncertainty is higher than that for a decrease in uncertainty). Second, a variable equal to the square of each uncertainty proxy was added to capture a possible nonlinearity affect. Although the square of the lagged five-quarter moving average of the standard deviation of the exchange rate was found to be insignificant, the squared standard deviation of the expected exchange rate was found to be negative and significant (with an elasticity of −5.374 and replacing the original proxy). This result indicates a possible symmetric nonlinearity effect, though one that is not robust to all specifications.

Regarding the possibility of simultaneity between the uncertainty proxies and exports, as mentioned, we included an alternative proxy for $\phi 2_t$, constructed from the estimator for the real exchange rate variable as estimated using the instrumental variables method. The results (see Table 5) show that the significant negative elasticity of uncertainty is robust, with no indications for simultaneity between the uncertainty proxies which were used and exports.

In addition, exports lagged by one period were also found to be significant and positive in some of the versions (with an elasticity of 0.276; see version B-2 in Table 3) although their inclusion in the estimation did not change the results significantly.

In order to examine the robustness of the results, various control variables were added to the estimation which were thought to be important in the determination of Israeli exports to the US. Thus, since the high-technology sector accounts for a significant proportion of Israeli exports of goods to the US (80% of industrial exports and 50% of total exports), variables such as R&D expenditure (both its level and its proportion of output) were added, though they were not found to be significant. Productivity in Israeli industry was found to be significant (while US productivity was not), with a positive elasticity that reached the level of 0.014 (see version B-3 in Table 3). However, its inclusion did not change the results significantly (see, for example, version B-1 in Table 3).

The second group of control variables reflected the security situation in Israel. These included, among others, defense expenditure (both its level and as a proportion of output) and casualties in terrorist attacks; however, none of them reached significance (defense expenditure reached an elasticity of 0.388 with only 10% significance).

Table 5
Estimation of equations explaining Israeli exports to the US for the period 1997–2010:1 using the moving average of the standard deviation of the exchange rate as estimated using the instrumental variables method[a].

Variable	Coefficients of long-run equation B-8	Coefficients of long-run equation B-9
Estimation method	2SLS	2SLS
Constant	−15.372	−19.141
	(−3.768)	(−4.814)
L_t	1.700	2.174
	(3.044)	(4.075)
y_t	0.194	0.256
	(1.975)	(2.783)
Re r_t	0.841	0.971
	(4.005)	(4.935)
Re r'_t	0.712	0.769
	(2.078)	(2.446)
$\phi 2_t$	−0.436	−0.367
	(−2.298)	(−2.092)
Ex_{t-1}	0.526	0.365
	(4.389)	(3.015)
Pr $odIs_t$	–	0.012
		(3.133)
R^2	0.947	0.956
$\bar{R}^2$	0.940	0.949
S.E.	0.074	0.067
D.W.	1.983	2.016

[a] The equations are in log-linear form, and therefore variables are expressed in natural logarithms, except for $\phi 1_t$ and Pr $odIs_t$. t-values appear in parentheses.

The third type of control variable was a dummy variable for the global financial crisis, which affected the Israeli economy from the last quarter of 2008 until the end of the sample period. The dummy variable was found to be negative, as expected, but reached accepted levels of significance only in some of the versions. In any case, its inclusion in the estimation did not significantly change the results.

Finally, we examined the relationship between uncertainty and exports in the long run, relative to the short run, using an error correction model (ECM). According to Ramanathan, if the system of variables forms a first-order cointegration equation, then there exists a variable that represents the correction of the error, which can be included in the two-stage estimation and will distinguish between short-run effects and the effects in long-run equilibrium. In the first stage, the cointegration equation is estimated, and in the second stage a first-differences equation is estimated, which includes the error obtained in the first stage lagged by one period. This error represents the ECM factor, which is meant to absorb the deviation from equilibrium in the short run and which causes the other coefficients in the equation to represent long-run effects. The results of the estimation are presented in Table 6. It is worth mentioning that the model illustrates the fact that the standard deviation of the expectations variable, which is used as an estimator of expected inflation uncertainty, has an effect in both the short run and the long run. The ECM factor was found to be negative, as expected, and statistically significant at a level close to −1. The negative correlation implies that convergence to equilibrium can be expected after a random deviation. In other words, following a period in which a deviation from equilibrium occurs in one direction, a correction in the opposite direction and a return to equilibrium can be expected (in our case after about one quarter).

4. Summary and conclusions

The theory and empirical evidence in the literature on the effect of uncertainty on exports is inconclusive. In fact, various studies have shown that empirical results are highly dependent on the statistical method used and the proxy chosen for uncertainty.

Using quarterly data for the sample period 1997–2010:1, the effect of exchange rate uncertainty on the Israeli export of goods to the US was tested, and support was found for the hypothesis that uncertainty has a negative and dominant effect on exports, in both the short run and the long run. Moreover, these results are robust with respect to the estimation method, the proxy for uncertainty, and the inclusion of control variables.

The estimation of the model has introduced two innovations into the empirical literature. First, use was made of the 2SLS method, for the first time as far as we are aware, in addition to OLS, thus addressing the simultaneity problem between the exchange rate and exports, which has been virtually ignored in the literature, and second, three different proxies for uncertainty were tested.

The use of Israeli data is also relevant to the empirical literature on uncertainty and exports in the developed countries, since Israeli exports have a high proportion of goods with high value added in production. However, contrary to the theoretical claims appearing in the literature, it was found that having a large proportion of high-value-added goods does not seem to significantly reduce the negative effects of uncertainty.

Table 6
Estimation of short-run equations explaining Israeli exports to the US for the period 1997–2010:1 using an error correction model (ECM)[a].

Variable	Coefficients of short-run equation A-3	Coefficients of short-run equation B-3	Coefficients of short-run equation C-2	Coefficients of short-run equation A-7	Coefficients of short-run equation B-7	Coefficients of short-run equation C-6
Estimation method	2SLS	2SLS	2SLS	OLS	OLS	OLS
Constant	−0.040	−0.049	0.001	0.017	0.013	0.005
	(−1.137)	(−1.435)	(0.070)	(1.966)	(1.774)	(0.560)
L_t	10.143	11.827	–	–	–	–
	(1.557)	(1.910)				
y_t	0.289	0.289	0.272	0.252	0.273	0.265
	(4.149)	(4.383)	(3.459)	(3.366)	(4.117)	(3.696)
Re r_t	0.715	0.653	0.591	0.647	0.712	0.797
	(2.756)	(2.217)	(2.073)	(2.537)	(3.134)	(3.305)
Re r'_t	0.499	0.578	0.750	0.716	0.628	0.503
	(1.800)	(2.217)	(2.390)	(2.333)	(2.347)	(1.718)
ϕ_t	−0.390	−3.214	−1.671	−0.831	−3.085	−0.692
	(−1.054)	(−3.660)	(−2.677)	(−2.104)	(−3.467)	(−1.247)
Ex_{t-1}	–	–	–	0.479	0.276	0.394
				(3.476)	(2.420)	(3.160)
Pr $odIs_t$	0.012	0.015	–	–	0.014	0.012
	(3.079)	(3.941)			(3.710)	(2.959)
Dwc_t	–	–	–	–	–	−0.080
						(−1.389)
ECM	−1.048	−0.991	−1.300	−1.310	−1.232	−1.335
	(−7.498)	(−7.283)	(−6.440)	(−6.775)	(−7.083)	(−7.345)
R^2	0.670	0.700	0.570	0.599	0.693	0.667
$\bar{R}^2$	0.618	0.652	0.512	0.545	0.644	0.605
S.E.	0.054	0.052	0.062	0.059	0.052	0.055
D.W.	1.892	1.892	2.061	1.866	1.988	2.026

[a] The equations are in log-linear form, and therefore variables are expressed in natural logarithms, except for $\phi 1_t$, Pr $odIs_t$ and Dwc_t. t-values appear in parentheses. All the variables, apart from the ECM factor, are expressed as first-order differences.

In this context, and under the assumption that in the long run demand in foreign markets for the majority of Israeli export goods is completely elastic at a fixed price in foreign currency, the quantity of exports will be determined primarily by supply factors. And indeed, in this study, the factors that were found to affect Israeli exports to the US in the long run were supply factors (including the real exchange rate and the terms of trade, the size of the workforce and local productivity), as well as an uncertainty variable that captures either a long-run effect or a short-run effect, depending on the model being used.

It may be that the negative effect of uncertainty found here is evidence that, among other things, Israel's economy is still "emerging" to some extent, despite its relatively large high-technology sector. Although the Israeli capital market has developed to a considerable extent in recent years, it has not reached the point where long-run protection against foreign currency movements relative to the shekel can be obtained for large amounts and/or for long periods, and certainly not at a low cost (for example, only recently have conditions been created in which the government can carry out SWAP transactions of dollar-denominated debt into shekels in quantities of several hundred million dollars and for periods of several years).

The findings have important policy implications for both Israel and the US. With respect to Israel, they point to the importance of encouraging the development of Israeli multinational corporations that invest in a number of markets and thus are able to diversify risk. In this context, the trend in recent years to reduce barriers to Israeli investment abroad is encouraging. As a result, Israeli companies will be able to more broadly diversify risk and more easily purchase protection against changes in export prices in local terms. The findings also indicate the importance of a focused and consistent policy to accelerate the development of financial markets in Israel in general and their globalization in particular. As part of this effort, emphasis should be placed on the development of liquid and stable markets that can offer derivative financial instruments of various types. With respect to the US, the findings indicate that globalization, which is increasing the efficiency of financial markets in developing countries that trade with the US, is having a significant and positive effect on US imports.

References

Arize, A.C., 1995. The effects of exchange rate volatility on US exports: an empirical investigation. Southern Economic Journal 62, 34–43.
Arize, C., Osang, T., Slottje, D., 2008. Exchange rate volatility in latin America and its impact on foreign trade. International Review of Economics and Finance 17, 33–44.
Asseery, A., Peel, D.A., 1991. The effects of exchange rate volatility on exports: some new estimates. Economics Letters 37, 173–177.
Bahmani-Oskooee, M., 2002. Does black market exchange rate volatility deter the trade flows? Iranian experience. Applied Economics 34, 2249–2255.
Bahmani-Oskooee, M., Hegerty, S., 2007. Exchange rate volatility and trade flows: a review article. Journal of Economic Studies 34 (3), 211–255.
Barkoulas, T., Baum, F., Caglayan, M., 2002. Exchange rate effects on the volume and variability of trade flows. Journal of International Money and Finance 21, 481–496.

Baum, F., Caglayan, M., Ozkan, N., 2004. Nonlinear effects of exchange rate volatility on the volume of bilateral exports. Journal of Applied Econometrics 19, 1–23.
Boug, P., Fagereng, A., 2010. Exchange rate volatility and export performance: a cointegrated VAR approach. Applied Economics 42, 851–864.
Caballero, R.J., 1991. On the sign of the investment—uncertainty relationship. American Economic Review 81, 279–288.
Caballero, R.J., Corbo, V., 1989. The effect of real exchange rate uncertainty on exports: empirical evidence. The World Bank Economic Review 3, 263–278.
Choudhry, T., 2005. Exchange rate volatility and the United States exports: evidence from Canada and Japan. Journal of the Japanese and International Economies 19 (1), 51–71.
Choudhry, T., 2008. Exchange rate volatility and United Kingdom trade: evidence from Canada, Japan and New Zealand. Empirical Economics 35 (3), 607–619.
De Grauwe, P., 1988. Exchange rate volatility and the slowdown in growth of international trade. IMF Staff Papers 35. pp. 63–84.
De Gregorio, J., Wolf, H., 1994. Terms of trade, productivity and demand shocks and Asia–Pacific real exchange rate. National Bureau of Economic Research Discussion Paper No. 6108.
Dixit, A., 1989. Entry and exit decisions under uncertainty. Journal of Political Economy 97 (3), 620–638.
Doyle, E., 2001. Exchange rate volatility and Irish–UK trade, 1979–1992. Applied Economics 33, 249–265.
Iacovone, L., Javorcik, B., 2010. Multy-product exporters: product churning, uncertainty and export discoveries. The Economic Journal 120, 481–499.
Jansen, D.W., 1989. Does inflation uncertainty affects output growth? Further evidence. The Federal Reserve Bank of St. Louis Review. July–August. pp. 43–54.
Klaassen, F., 2004. Why is it so difficult to find an effect of exchange rate risk on trade? Journal of International Money and Finance 23 (5), 817–839.
McKenzie, M., 1999. The impact of exchange rate volatility on international trade flows. Journal of Economic Surveys 13, 71–106.
McKenzie, M., Brooks, R., 1997. Exchange rate volatility and international trade on German–US trade flows. Journal of International Financial Markets Institutions and Money 7, 73–87.
Onafowora, O., Owoye, O., 2008. Exchange rate volatility and export growth in Nigeria. Applied Economics 40, 1547–1556.
Phillips, P.C.B., Perron, P., 1988. Testing for a unit root in time series regression. Biometrika 75, 335–346.
Qian, Y., Varangis, P., 1994. Does exchange rate volatility hinder export growth? Empirical Economics 19, 371–396.
Ramanathan, R., 1998. Introductory Econometrics with Applications, 4th ed. The Dryden Press.
Tavlas, G.S., Swamy, P.A., 1997. Macroeconomic policies and world financial integration. In: Fratianni, M.U., Salvatore, D., Von Itazen, H. (Eds.), Macroeconomic Policy in Open Economics. Greenwood Press, Westport, Connecticut, USA, pp. 248–280.