NUS
National University of Singapore

SCAPE

Singapore Centre for Applied and Policy Economics

Modelling Small Economy Exports: The Case of Singapore

by

Tilak Abeysinghe and Keen Meng Choy

Department of Economics
SCAPE Working Paper Series
Paper No. 2005/01 - Apr 2005
http://nt2.fas.nus.edu.sg/ecs/pub/wp-scape/0501.pdf

MODELLING SMALL ECONOMY EXPORTS:
THE CASE OF SINGAPORE

Tilak Abeysinghe* and Keen Meng Choy
Department of Economics, National University of Singapore, AS2, 1 Arts Link, Singapore 117570, Republic of Singapore

December 2004

Abstract

This paper sheds further light on the debate spearheaded by Riedel (1988) on the specification of a small country export function. The theoretical and empirical analyses in the paper show that while the price-taker assumption cannot be rejected, the export function for Singapore should not be construed as a standard export supply equation. As argued by Kapur (1983) instead, it is an export function with both demand and supply factors playing a role. We arrived at the final model specification by taking into consideration changes in the import content of exports over time. The paper also provides a new methodology for deriving a quarterly series of manufacturing net capital stock.

Keywords: price taker, demand constraint, export function, import content, restricted cointegrating space

JEL classification: C32, F14, F41

---

* Corresponding author: Address as above. Email: TilakAbey@nus.edu.sg. The authors would like to thank Chandra Athukorala and Basant Kapur for valuable discussions on the subject matter and Rajaguru Gulasekaran and Ananda Jayawickrama for assistance in the collection of research materials. The first author would also like to thank the National University for research grant R-122-000-010-112 which partially funded this research.

1. Introduction

The form of small open economy export functions is far from known. Early empirical studies focused on estimating single-equation export demand functions and obtained low price elasticities and high income elasticities. The low price elasticity led many researchers to suspect a possible bias in regression estimates that stems from the endogeneity of export prices (Orcutt, 1950; Harberger, 1953; Leamer, 1981). Indeed, Klein (1960) pointed out that there is nothing wrong with the use of ordinary least squares (OLS) techniques if the country concerned is a price-taker in the world market. If that were the case, Klein argued, the country should be viewed as an individual producer facing an infinitely elastic demand curve in a perfectly competitive world market—what needs to be estimated then is an export supply function, not a demand function.

Whilst the price elasticity of exports appeared to be underestimated, the opposite seems to be true of the income elasticity. In particular, a high income elasticity is at odds with the rapid growth of manufactured exports from Newly Industrialized Economies (NIEs) during the 1970s, despite a significant slowing down of income growth in the industrial countries (Riedel, 1984). According to this view, the rapid expansion of NIE exports over the past three decades without a discernible deterioration of their terms of trade is better explained by a continuous expansion of export supply in the face of highly price-elastic demand.

Notwithstanding these observations, the practice of estimating a single-equation export demand function abounds (see some macroeconometric models published in *Economic Modelling*). The preference for an export demand equation has resulted from the ready availability of the required data and the reasonable forecasts that it generated. In contrast, the estimation of an export supply function is hampered by data constraints (Riedel, 1988). An obvious improvement over the single-equation demand model was the simultaneous estimation of both export demand and supply equations by Goldstein and Khan (1978), followed by subsequent papers by the same authors and others. However, in what may perhaps be the first paper to address the issue of the small country assumption, Browne (1982) argued that even the Goldstein-Khan formulation was an inadequate representation for testing the price-taker hypothesis.

Riedel (1988) proposed a model formulation for testing the price-taker assumption explicitly. He specified for the small open economy of Hong Kong an export demand equation with the export price as the dependent variable, an export supply equation with quantity as the dependent variable, and a wage equation. Estimated as a simultaneous system of equations, Riedel observed that the two-stage least squares (2SLS) estimates of the coefficients of the quantity and world income variables in the export demand equation were not significantly different from zero while the coefficient for the price of competing goods in importing countries was non-zero. He claimed that this constitutes prima facie evidence of an infinitely elastic export demand, a characteristic of a price-taking country in the world market. Riedel's study led to a vigorous debate with Nguyen (1989, 1996), Faini et al. (1992), Muscatelli (1995a, 1995b) and Muscatelli et al. (1992, 1994, 1995a, 1995b), all of whom contested his model formulation and results. Although the debate and subsequent responses in Athukorala and Riedel (1991, 1994, 1996) did not produce a consensus, Riedel's exercise alerted researchers to the inherent theoretical inconsistency in estimating an export demand equation under the assumption of price-taking behaviour.

The objective of the present study is to shed further light on this debate from the perspective of another small and very open economy—the city-state of Singapore. With a dominance of foreign multinationals (MNC) in the export sector, Singapore is an archetypal example of what Lloyd and Sandilands (1986) called a "re-export economy", or an economy in which imported inputs are intensively used in the production of exports for world markets. As such, Singapore makes for an instructive case study that calls attention to the need to look beyond traditional demand-supply specifications of export functions.

We begin the empirical analysis of the paper by formally testing various export hypotheses on Singapore data. These standard hypotheses are all rejected, motivating us to formulate an alternative model of export determination based on the dynamic production theory of the firm. Guided by this model, we arrived at long-run and short-run export functions for Singapore by taking into consideration changes over time in the import content of exports. The theoretical and empirical analyses in the paper show that while the price-taker assumption cannot be rejected, the final model specification is not a standard export supply equation. As argued by Kapur (1983), it is an export function with both demand and supply factors playing a role.

2. Testing Export Hypotheses

Consider the following log-linear export demand and supply equations:

Demand: $$x = \alpha_0 + \alpha_1 p^x + \alpha_2 p^w + \alpha_3 y^w \qquad (1)$$

Supply: $$x = \beta_0 + \beta_1 p^x + \beta_2 p^{rm} + \beta_3 p^d + \beta_4 k \,. \qquad (2)$$

In (1) and (2), lower case letters refer to the logarithms of economic variables: x is the export volume, p^x is the price of exports, p^w is the price of competing goods in the importing countries, y^w is the aggregate real income of the importing countries, p^{rm} is the price of imported raw materials, p^d is the price of domestic inputs, and k represents production capacity.

If p^w, y^w, p^{rm}, p^d, and k are assumed to be exogenously given, (1) and (2) jointly determine x and p^x. This is the standard model adopted for countries with some price-setting power. When a country is a price-taker, p^x is also exogenously determined. In this case, one has to choose between estimating (1) or (2). As stated earlier, many applied researchers have chosen the export demand function because of the ready availability of data. Theoretically speaking, however, one should be estimating the export supply equation.

Riedel (1988) has attempted to show that export prices are exogenously determined by estimating the demand equation with p^x as the dependent variable, wherein the coefficients of both x and y^w turned out to be statistically insignificant. His findings led to a debate—which subsequently came to be known as the "normalization paradox"—on the interpretation of the price equation as an inverse demand function (see the references cited earlier). With regard to this apparent paradox, two points are noteworthy. First, it is well-known that normalization cannot convert a non-zero estimate to a zero coefficient if the conditioning variable set remains the same. Second, if Equation (1) is the correct specification, then the regression with price as the dependent variable suffers from endogeneity bias because of the correlation between exports and the error term.

The above problems do not arise in a cointegration framework, especially when the sample size is large. We therefore employ Johansen's (1995) methodology to test alternative empirical specifications of the export function for the Singapore economy. Let z_t be an $(n \times 1)$ vector of variables that enter both the demand and supply equations. For the specifications in (1) and (2),

$$z_t = (x, p^x, p^w, y^w, p^{rm}, p^d, k)' . \qquad (3)$$

The vector autoregression (VAR) for z_t can be written in vector error-correction model (VECM) format as

$$\Delta z_t = \alpha\beta' z_{t-1} + \sum_{j=1}^{p-1}\Gamma_j \Delta z_{t-j} + \Gamma_0 + \varepsilon_t \qquad (4)$$

where $\beta' z_{t-1}$ consists of r ($< n$) cointegrating relationships. For $r = 2$, we have:

$$\beta' = \begin{pmatrix} \beta_{11} & \beta_{21} & \beta_{31} & \beta_{41} & \beta_{51} & \beta_{61} & \beta_{71} \\ \beta_{12} & \beta_{22} & \beta_{32} & \beta_{42} & \beta_{52} & \beta_{62} & \beta_{72} \end{pmatrix}$$

We shall impose restrictions on the columns of β to test a number of hypotheses commonly encountered in the applied literature on modelling exports. The forms of the β vectors corresponding to these hypotheses are given below.

Hypothesis 1:

The country has an influence on price and hence, both demand and supply equations need to be estimated:

$$\beta' = \begin{pmatrix} 1 & \beta_{21} & \beta_{31} & \beta_{41} & 0 & 0 & 0 \\ 1 & \beta_{22} & 0 & 0 & \beta_{52} & \beta_{62} & \beta_{72} \end{pmatrix}$$

Under this hypothesis, the first cointegrating vector corresponds to the demand equation and the second to the supply equation.

Hypothesis 2:

The country is a price-taker and has an infinitely elastic supply curve:

$$\beta' = \begin{pmatrix} 1 & \beta_{21} & \beta_{31} & \beta_{41} & 0 & 0 & 0 \\ 0 & 1 & \beta_{32} & 0 & 0 & 0 & 0 \end{pmatrix}$$

In this case, the first cointegrating vector represents demand and the second assumes that p^x is proportional to p^w.

Hypothesis 3:

The country is a price-taker and faces an infinitely elastic demand curve:

$$\beta' = \begin{pmatrix} 1 & \beta_{21} & 0 & 0 & \beta_{51} & \beta_{61} & \beta_{71} \\ 0 & 1 & \beta_{32} & 0 & 0 & 0 & 0 \end{pmatrix}$$

The first vector here represents the supply function while the second vector assumes that p^x is proportional to p^w, as in Hypothesis 2 above.

The validity of these hypotheses can be tested using Johansen's likelihood ratio (LR) test. The constraints imposed on the cointegrating vectors under each hypothesis are all of the exclusion type and they represent over-identifying restrictions, as can be verified by checking the order condition for identification, which states that at least $r - 1$ restrictions must be imposed on the parameters for a cointegrating vector to be identified. The LR test statistic has an asymptotic χ^2 distribution with degrees of freedom equal to the number of over-identifying restrictions imposed (Johansen, 1995).

The variables and quarterly data we use for testing the hypotheses are described in the Appendix. We confine our attention to the main export category in Singapore—non-oil domestic exports (NODX), which accounts for more than 70% of Singapore's total direct exports of goods and services (the rest is made up of oil exports and re-exports). As for the price of competing goods, we use an index based on US producer price data, denoted by p^{us}, instead of the commonly used p^w index. The estimation period is 1981Q1–2003Q4, with pre-sample values coming from 1980. Standard ADF tests of unit roots show that the variables in logarithms are best characterized as $I(1)$ processes. The optimal VAR specifications for the seven variables in (3) chosen by the SBC and AIC criteria are VAR(1) and VAR(2) respectively. We decided to proceed with the VAR(2) model because the Johansen cointegration procedure is well-known to be very sensitive to the choice of the lag order;

under-specification in particular is known to produce misleading results (Harris, 1997; Maddala and Kim, 1998).

Table 1 presents the results of Johansen's trace test for cointegration rank (r) of the seven variables and Table 2 shows the LR test outcomes for different demand and supply specifications. The results indicate the presence of two cointegrating vectors at the 5% level and one vector at the 1% level. Under the assumption of two cointegrating vectors, the traditional demand-supply model in Hypothesis 1 faces a marginal rejection at the 5% level. Although one may be tempted to proceed further with this hypothesis, the coefficients of p^x and p^{us} are wrongly signed in the demand equation, and so is the coefficient of p^x in the supply equation. Taken together, the results suggest that the demand-supply model that jointly determines export price and quantity is not suitable for Singapore.

Hypotheses 2 and 3 are also soundly rejected by the LR test, the main reason for this being the lack of cointegration between p^x and p^{us}. Despite the tendency for these two price series to co-move together (Fig. A1), both the Johansen trace test and the residual-based ADF test clearly indicate that the two variables are not cointegrated. However, an OLS regression of p^x on p^{us} produces a coefficient of one and furthermore, only p^{us} and lagged p^x are significant in a dynamic regression of p^x on all the variables in the model plus an additional variable representing the nominal effective exchange rate. When we carried out the same exercises using first differences, the only variable that remained significant was p^{us} (or p^w if it was used in place of p^{us}). This assures us that export prices in Singapore are exogenously determined, and the lack of cointegration between p^x and p^{us} simply indicates that the latter does not fully measure the price of goods competing with Singapore's exports.

====================

Insert Tables 1 & 2

====================

We are thus led to consider two further hypotheses based on the assumption of a single cointegrating vector, labelled as H4 and H5 in Table 2. Hypothesis 4 is a pure demand specification while Hypothesis 5 is a pure supply specification. As with the preceding hypotheses, however, both H4 and H5 are rejected by the LR test while p^x and p^{us} carried the wrong signs in the demand equation. Note also the unusual magnitudes of the coefficients of the supply equation in Hypothesis 5, a common problem resulting from misspecification of the Johansen procedure. In summary, we conclude that neither a standard demand or supply equation, nor a simultaneous demand-supply system, provides an adequate model for Singapore's exports.

3. An Alternative Theoretical Formulation

In the light of the rejections of the standard export hypotheses, we shall depart from the traditional demand-supply specifications in modelling the export sector in Singapore. Imagine an MNC that has established a manufacturing facility in Singapore for the purpose of exporting to world markets. Even though such an enterprise is compelled to adopt price-taking behaviour on account of the small size of the Singapore economy, its ability to export to world markets depends vitally on the width of firm-specific marketing channels, which are in turn influenced by external demand conditions at any one time.[1]

We present here a theoretical model of export production that is inspired by the pioneering work of Holt et al. (1960) on the dynamic optimizing behaviour of a firm that takes the demand for its product, the product price and input prices as given. To keep the exposition simple, it is assumed that the firm produces solely to meet new export orders and does not maintain finished goods inventories. Furthermore, it is assumed that the firm can

[1] The arguments in this paragraph are due to Kapur (1983), though he did not derive his postulated export function from firms' optimizing behavior, which we do here.

predict sales with certainty and maximizes the discounted sum of present and future profits given by

$$\sum_{i=0}^{\infty}(1+\rho)^{-i}\left\{P_{t+i}Q_{t+i}-c_1Q_{t+i}^2-c_2\left(U_{t+i}-c_3N_{t+i}\right)^2\right\} \tag{5}$$

subject to

$$U_t = U_{t-1} + N_t - Q_t \tag{6}$$

where ρ is the discount rate, P_t is the product price, Q_t is output, N_t denotes demand in terms of new orders received and U_t is the quantity of unfilled orders. c_1 and c_2 are cost parameters that depend on, *inter alia*, prevailing input prices, wages, recruitment costs, and tangible and intangible costs associated with unfulfilled orders (for notational simplicity, we do not attach time subscripts to c_1 and c_2). The second squared term in (5) introduces a departure from the standard cost function faced by a price-taking firm. The firm decides on the level of unfilled orders U_t relative to a target level $U_t^* = c_3N_t$, where c_3 is a firm-specific constant. Deviations of U_t from the target level due to fluctuations in N_t brings additional costs to the firm in terms of lost sales or service deficiencies. The constraint in (6) states that the change in unfilled orders from one period to the next must be equal to the difference between new orders received and current production.

Owing to the constraint on demand, the export firm in this model confronts a slightly different optimization problem from the usual one faced by a profit-maximizing firm. This requires the firm to make a decision every period for all time periods on the amount of output to produce (and implicitly on the quantities of factor inputs to use) by balancing at the margin the costs of changing output against those of letting orders go unfilled, in the face of demand fluctuations. Substituting the constraint (6) into the profit function (5) and differentiating the resulting expressions with respect to Q_t and U_t, we obtain the following first-order conditions:

$$(c_1 + c_2)Q_t - c_2 U_{t-1} - c_2(1-c_3)N_t = \frac{P_t}{2} \tag{7}$$

$$-U_{t-1} + \left[1 + (1+\rho)^{-1} + \frac{c_2}{c_1}\right]U_t - (1+\rho)^{-1}U_{t+1} - \left[1 + \frac{c_2 c_3}{c_1}\right]N_t + (1+\rho)^{-1}N_{t+1} = 0 \tag{8}$$

The solution to the difference equation in (8) is:

$$U_t = \lambda U_{t-1} + \sum_{i=0}^{\infty}\left[\lambda(1+\rho)^{-1}\right]^{i+1}\left[(1+\rho)\left(1 + \frac{c_2 c_3}{c_1}\right)N_{t+i} - N_{t+1+i}\right]$$

where λ is the smallest root of the characteristic equation given by $\lambda^2 - \left[2 + \rho + (1+\rho)(c_2 / c_1)\right]\lambda + (1+\rho) = 0$. Using this solution for unfilled orders and (7), we can solve for the optimal level of output as follows:

$$\begin{aligned} Q_t = {} & \lambda Q_{t-1} + \frac{P_t}{2(c_1 + c_2)} - \frac{\lambda P_{t-1}}{2(c_1 + c_2)} + \frac{c_2\{1 - c_3 - \lambda(1-\rho)^{-1}[1 + \lambda(1 + c_2 c_3 / c_1)]\}}{c_1 + c_2}N_t \\ & + \frac{c_2 \lambda c_3 (1 + c_2 / c_1)}{c_1 + c_2}N_{t-1} + \frac{c_2[\lambda(1 + c_2 c_3 / c_1) - 1]}{c_1 + c_2}\sum_{i=1}^{\infty}\left[\lambda(1+\rho)^{-1}\right]^{i+1} N_{t+i} \end{aligned} \tag{9}$$

The last term in (9) that involves the discounted present value of future *N* can be proxied by production capacity (K_t) because firms are very likely to expand their production capacity only if they expect a permanent increase in future demand. If c_1 and c_2 move over time in such a way that $c_2 /(c_1 + c_2)$ is approximately constant, then (9) can be treated as a dynamic linear regression model of Q_t on Q_{t-1}, P_t / C_t, P_{t-1} / C_{t-1}, N_t, N_{t-1}, and K_t, where C_t represents a composite cost variable. Moreover, if c_2 is zero or negligibly small, the model reverts to the standard long-run supply function with quantity as a function of product price and input prices. This means that in the absence of a demand constraint, the coefficients of the demand and production capacity variables should be jointly zero.

We derived (9) assuming a quadratic cost function primarily to show how demand forces enter the production decision process of a price-taking firm. The general situation can be pictured in terms of standard average and marginal cost curves faced by a firm operating in a perfectively competitive market, with the price level determined by the intersection of world demand and world supply curves. The cost curves are drawn for a given level of *U*. A drop in world income shifts the world demand curve to the left and lowers *N* and *P* for the firm. This would increase the cost of holding the original level of *U* and also the cost of lowering *U* due to the narrowing of marketing channels. As a result the firm's AC and MC curves shift upward and lower the production level further. Overall, the world supply curve also shifts to the left resulting in a further drop in world production and an increase in the price level. The opposite occurs in the case of a rise in world income. At the aggregate level, therefore, we get an export supply function of the form $Q_t = f(P_t, C_t, Y_t^w, K_t)$. The most appropriate empirical representation of this function is best determined by the data.

4. Estimating the Export Function

The model formulated in the previous section is particularly relevant for a small country like Singapore whose export sector is dominated by MNCs that produce to order for world markets. Under such circumstances, it makes little sense to estimate a pure demand or a pure supply equation—as we demonstrated empirically in Section 2. Instead, it is more meaningful to estimate an export function in the form of Equation (9) that has the usual price and cost arguments found in the supply function (i.e. p^x, p^{rm} and p^d), and also depends on variables representing current and expected future demand (y^w and k respectively).

In terms of Johansen's framework laid down in Section 2, we specify the following cointegrating vector to represent such an export function for Singapore:

$$\beta' = \begin{pmatrix} 1 & \beta_{21} & 0 & \beta_{41} & \beta_{51} & \beta_{61} & \beta_{71} \end{pmatrix}$$

with the expected signs $\beta^*_{21}, \beta^*_{41}, \beta^*_{71} > 0$ and $\beta^*_{51}, \beta^*_{61}, < 0$, where $\beta^*_{j1} = -\beta_{j1}$. The parameter β_{31} is set to zero on account of price-taking behaviour on the part of firms. The estimated cointegrating vector is shown in Table 2 under the column denoted H6. In stark contrast to the hypotheses considered earlier, the estimated coefficients have the correct signs and the LR test strongly supports the zero restriction on the coefficient of p^{us}.

Having established a valid cointegrating vector, we can revert to OLS estimation and proceed to obtain a more refined export function.[2] We found in preliminary experiments that the coefficient estimate of k is very sensitive to variations in the sample size as a result of its high collinearity with y^w, but a robust estimate can be obtained by using Δk in the regression instead.[3] Replacing k with Δk, the static export function can be written as:

$$x = \beta_0 + \beta_1 y^w_t + \beta_2 \Delta k_t + \beta_3 p^x_t + \beta_4 p^{rm}_t + \beta_5 p^d_t + u_t \,. \qquad (10)$$

Except for the coefficient on Δk, the OLS estimates of (10) given below are similar to the Johansen estimates in Table 2 (t-statistics are in parentheses):

$$\begin{aligned} \hat{x}_t = &-5.63 + 3.49 y^w_t + 2.87 \Delta k_t + 0.99 p^x_t - 0.97 p^{rm}_t - 0.27 p^d_t, \;\; R^2 = 0.997 \\ &(-6.45)\;(82.0)\quad\;(7.62)\qquad\;(11.8)\;(-6.93)\quad(-3.00) \end{aligned} \,. \qquad (11)$$

Next, we impose the homogeneity restriction with respect to output price and input prices $\beta_3 + \beta_4 + \beta_5 = 0$ by rewriting (10) as[4]

[2] OLS estimates are known to be more stable than Johansen's maximum likelihood estimates (see Maddala and Kim, 1998, Chapters 5 and 6). Phillips (1994) has also shown that the Johansen estimator has a Cauchy-type distribution which tends to produce outliers.

[3] With the short sample period we have, it is difficult to detect whether Δk is $I(0)$ or $I(1)$ although the ADF test supports the former. We repeated the tests in Tables 1 and 2 with Δk in place of k. This does not affect the findings we reported earlier except that an extra cointegrating vector has to be allowed for to account for this apparently stationary variable.

[4] Estimating (10) in dynamic form with one lag of each variable and testing the homogeneity restriction yields a Wald statistic of 1.02 with a chi-square p-value of 0.313. Thus, the restriction is not rejected by the data. Without a dynamic specification, the Wald test may be invalid (Sims, Stock and Watson, 1990).

$$x = \beta_0 + \beta_1 y_t^w + \beta_2 \Delta k_t + \beta_4 (p^{rm} - p^x)_t + \beta_5 (p^d - p^x)_t + u_t \qquad (12)$$

This formulation was basically what Kapur (1983) had postulated for Singapore's exports, although his idea went largely unnoticed. Kapur went on to argue that an appreciation of the domestic currency would hurt exports, as can be seen by plugging into (12) the equation $p^i = p^{if} + e \; (i = x, rm)$, where e is the logarithm of the exchange rate (Singapore dollars per unit of foreign currency) and p^{if} is the logarithm of the relevant price index expressed in foreign currency units. A currency appreciation (fall in e) has the effect of lowering import prices measured in domestic currency and *pari passu* the domestic price of exports, which leave export volumes unaffected, but it also increases the real cost in foreign currency terms of domestic inputs employed in the export sector, thereby curtailing exports.

Abeysinghe and Tan (1998) have shown, however, that the effect of a currency appreciation on exports depends on the import content of exports. To incorporate this idea, we reformulate the export function in (12) as:

$$x_t = \beta_0 + \beta_1 y_t^w + \beta_2 \Delta k_t + \gamma c_t + u_t \qquad (13)$$

where $c_t = \theta_t (p^{rm} - p^x)_t + (1 - \theta_t)(p^d - p^x)_t$ represents the weighted sum of the costs of imported and domestic inputs, both relative to the export price, and the weight θ_t $(0 \le \theta_t \le 1)$ measures the imported input content of exports. It should be noted that this formulation allows β_4 and β_5 in (12) to vary over time. Given that $\gamma < 0$, (13) shows that the impact of exchange rate changes on exports depends critically on import content. When domestic inputs are negligible (θ is close to unity), a currency appreciation has virtually no effect; conversely, when domestic inputs are dominant (θ is close to zero), appreciation has its full impact as measured by γ. It follows that a pure entrepôt or "re-export" economy (Lloyd and Sandilands, 1986) would have a very high θ. The specification in (13) therefore results in a very parsimonious model with a concomitant reduction in multicollinearity between regressors.

The key question is how to estimate θ. A continuous time series on the import content of exports is not available but annual data on manufacturing output and value-added are published. Since more than 60 percent of Singapore's domestically produced manufactured output is exported, one minus the ratio of value-added to output should yield a reasonable estimate of the proportion of intermediate imports in exports. Reflecting Singapore's re-export economy status, θ was 77% in the early 1980s by our calculation, but this figure fell to about 74% after the severe recession in 1985–86. In the aftermath of the 1997 Asian financial crisis, the import content dropped further to 73%. To account for these shifts and also to allow θ to change gradually, we first converted the annual estimates of import content to quarterly figures through a univariate interpolation method (the spline method in SAS) and then took a 12-quarter moving average.

We report below the long-run solutions to dynamic specifications of the export functions in (12) and (13) with one lag of each variable:

$$\begin{aligned} \hat{x}_t = &-7.2 + 3.59 y_t^w + 3.26 \Delta k_t - 0.79 (p_t^{rm} - p_t^x) - 0.28 (p_t^d - p_t^x) \\ &(-18.9)\ (42.8) \quad\ (4.29) \quad (-4.92) \qquad\qquad (-2.36) \end{aligned} \tag{14}$$

$$\begin{aligned} \hat{x}_t = &-7.1 + 3.56 y_t^w + 2.70 \Delta k_t - 1.01 c_t \\ &(-22.3)\ (51.6) \quad\ (3.88) \quad (-6.35) \end{aligned} \tag{15}$$

The coefficients in (15) are virtually the same as those from a static OLS regression. Moreover, the recursive estimates of these coefficients are highly stable over time, a virtue due in no small part to the allowance for time-varying import content. This is not exactly so for the specification in (14). Although we cannot test the validity of the import content restriction directly because of a changing θ, an F-test based on the R^2 of the dynamic regressions produces a statistic of 3.276 with a p-value of 0.074, hence indirectly supporting the restriction at the 5% level. For the purpose of estimating a short-run export function for Singapore, we define the error-correction term derived from (15) as $ec_t = x_t - 3.5y_t^w - 2.7\Delta k_t + c_t$.[5]

Equation (15) predicts the long-run movements of exports very tightly but it does not fully capture the short-run turning points. The missing variable is the demand for electronics, fluctuations in which have translated into dramatic expansions and contractions in the exports and outputs of Singapore and other Asian countries who depend heavily on electronics exports (Abeysinghe, 2001). The best proxy indicator of the electronics cycle is global semiconductor sales. Unfortunately, a consistent data series on this variable begins only from 1989, so the estimation period had to be truncated to 1989Q1–2001Q4, the last eight quarters in the sample period being retained for dynamic forecasting.

A general-to-specific search led us to the following error-correction model (ECM) for explaining short-run fluctuations in exports:

$$\begin{array}{l} \widehat{\Delta x_t} = -2.35 - 0.35 ec_{t-1} + 0.32 \Delta chip_t + 0.14 \Delta chip_{t-1},\ R^2 = 0.52 \\ \quad (-3.43)\ (-3.45) \qquad (3.47) \qquad\quad (1.48) \end{array} \tag{16}$$

where *chip* is the logarithm of global chip sales. The estimated model suggests that the transitory dynamics in Singapore's non-oil domestic exports are strongly influenced by the world electronics cycle and deviations from the long-run equilibrium. The adjustment coefficient on the disequilibrium term is statistically significant at the 1% level and the model passes all the diagnostic and misspecification tests (including the Chow test) computed by the

[5] As a matter of preference, we chose rounded figures for the error-correction term. These are kept constant over different sample periods.

PcGive econometrics package (Hendry and Doornik, 2001).[6] We retained the relatively insignificant lag of chip sales in (16) because recursive estimates show that this coefficient is very stable and helps to improve the performance of out-of-sample forecasts of exports. Fig. 1 plots these dynamic forecasts together with the actual and fitted values from the ECM. For a variable as volatile as exports, the estimated model produces impressive results.

=================

Insert Fig. 1 & Table 3

=================

Further insight into the Singapore export function can be gained by extracting dynamic elasticities from the final model specification in (16). These are shown in Table 3. There are two main determinants of export performance on the demand side—the income of Singapore's major trading partners and global chip sales. A 1% growth in foreign income boosts export growth by 1.2% within the same quarter (the impact elasticity) and achieves its full impact of 3.5% after nine quarters (the long-run elasticity). These estimates are not only statistically significant but also robust to alternative specifications of the export function, and serve to highlight the strong dependence of the Singapore economy on global economic growth. By contrast, global chip sales create a transitory effect, peaking after one quarter (0.35%) and then tapering off over about eight quarters. Despite these relatively smaller

[6] Curiously, despite using seasonally adjusted data, the residuals contain a seasonal effect at lag four. This appears to be noise rather than a signal.

magnitudes of elasticities, wide swings in the electronics cycle produce large cycles in exports.

Recall that the capital stock in our model is a proxy for expected future demand, and not a measure of production capacity as in the standard export supply equation.[7] Exports have been very responsive to growth in the manufacturing sector capital stock. Our econometric estimates suggest that a 1 percentage point increase in the growth rate of the capital stock leads to an increase in export volumes of 2.7% in the long run. This relatively large estimate suggests that the phenomenal expansion of Singapore's exports during the last four decades has been partly driven by huge foreign direct investment (FDI) inflows attracted by the prospects of selling to world markets and government-sponsored tax incentive schemes.

Turning to the supply-side variables, the long-run export price elasticity implied by the final model specification is unity. By fixing the value of θ at 0.74, we are also able to compute elasticities for imported raw material costs ($p^{rm}-p^x$) and domestic input costs (p^d-p^x), with the latter further sub-divided into labour costs ($ulc-p^x$) and non-labour costs ($nlc-p^x$) categories.[8] The estimated magnitudes in Table 3 indicate that, compared to domestic costs, imported raw material prices are a bigger drag on export production. The immediate effect of a 1% increase in the relative price of imported inputs is −0.26% and this rises to −0.74% in the long run. Correspondingly, the impact effect of domestic input costs is only −0.09% while the long-run effect is −0.26%. Breaking these estimates down into their labour costs and non-labour costs components shows that, quite contrary to the popular

[7] We note incidentally that the capital stock has no place in a long-run supply function since all factors of production are variable at long horizons.

[8] Note that P^d, as proxied by unit business costs, is derived by the statistical authorities as an arithmetic average of *ULC* and *NLC*, the latter being made up of services costs and government rates and fees. Assuming that this formula holds approximately for a geometric average, we can write $\ln(P^d / P^x)$ = $\alpha \ln(ULC / P^x) + (1-\alpha)\ln(NLC / P^x)$, where $\alpha = 0.464$ is the weight.

perception, the effect of rising real wage costs on Singapore's exports—due either to rising nominal wages or currency appreciation—has been rather mild.[9]

5. Implications

We shall now summarise the implications of our theoretical and empirical analyses. First and foremost, our findings contradict the Riedel (1988) hypothesis that world income is irrelevant to export growth. Like Muscatelli et al. (1995), we found a relatively high long-run income elasticity for export volumes in Singapore. With regard to the price elasticity, we took as our point of departure Riedel's assumption of price-taking behaviour and confirmed that this hypothesis cannot be rejected for Singapore. However, we departed from previous studies on small open economies by estimating an export function for Singapore that takes into consideration the import content of exports. Such a function should not be construed as a standard supply equation—it is derived instead from an alternative theoretical model of export determination where both demand and supply factors have a role to play.

The final model specification we arrived at provides an alternative explanation of why export expansion has occurred in Singapore without a deterioration in the terms of trade. In particular, the negative effect of an appreciating domestic currency on export volumes has been limited by the relatively low proportion of domestic inputs in exports and by the same token, rising business costs in Singapore did not have a significant impact on exports. In any event, whatever effects these cost variables might have had were more than offset by the growth in external demand.

[9] Domestic input costs rose because of higher unit business costs and currency appreciation prior to 1997 and a fall in the foreign price of exports after 1997. To assess whether the exchange rate has an independent impact on exports, we re-ran the earlier regressions with $\ln(NEER)$ or $\Delta\ln(NEER)$ as an additional variable but found that the effect was statistically insignificant.

Finally, our results are also indicative of a link between the accumulated capital stock and export volumes. But unlike in Muscatelli et al. (1995) and traditional supply specifications where the accumulated capital stock represents the total resource base of an economy or productive capacity, the capital stock in our model acts as a proxy for future demand. We nevertheless found evidence to support the new theories of trade and product differentiation emphasized by Muscatelli et al. (1995) to be the reason behind the NIEs' export success. This evidence took the form of an estimated long-run elasticity of greater than unity for global semiconductor demand, thus suggesting that Singapore diversified successfully into the electronics industry with increased penetration of world markets.

Appendix: Variables and Data Sources

Export Volumes, Prices and Foreign Income

In our empirical model, P^x is the Singapore dollar export price index for NODX, P^{rm} is the imported raw material price index also denoted in Singapore dollars, and P^d is the unit business cost index of the manufacturing sector in Singapore. Real variables are measured in constant 1990 prices and the base year for price indices is also 1990.

Export volumes and prices, import prices and unit business cost series are from the Singstat Time Series (STS) database of the Singapore Department of Statistics. Exchange rates are from the Federal Reserve Bank of St Louis website. A price index for imported raw material (P^{rm}) is not directly available in Singapore. This index was computed as a weighted average of the import price indices for machinery and transport equipment, mineral fuel, and chemical and chemical products. The weights chosen are the same as those used by the Singapore Department of Statistics for computing the import price index.

Following a common practice in the literature, we initially computed P^w as an export share-weighted average of producer price indices (PPIs) or wholesale price indices in Singapore dollars of eleven major trading partners of Singapore. We found this to be a poor proxy for the prices of goods competing with Singapore's exports, however. The PPIs of the trade partners include diverse products ranging from aircraft and heavy machinery to agricultural products, many of which are absent in Singapore's exports. Ideally, we should select only the most relevant sub-categories of the PPIs and then compute an average index to represent P^w. Unfortunately, except for the US, detailed breakdowns of the price indices are not available for all the countries.

The US being the major export destination for Singapore's exports, we decided to use seven relevant sub-categories of the US PPI to proxy P^w and denote this as P^{us}. The categories are processed food (WPU02), textile products and apparel (WPU06), chemicals and allied products (WPU06), general purpose machinery (WPU114), electrical machinery and equipment (WPU117), electronic components and accessories (WPU1178), and medical surgical and personal aid devices (WPU156), all of which were downloaded from the Bureau of Labor Statistics website. P^{us} is an export-share weighted geometric average, with the shares computed from Singapore's exports to the US in the year 2000. The above seven categories account for about 95% of Singapore's non-oil exports to the US with electronics receiving the largest weight of 55%. Figure A1 shows that P^{w} has departed substantially from P^{x} since 1998.

================

Insert Fig. A1

================

Our foreign income variable Y^{w} is an export-share weighted geometric average of the real GDPs of the ASEAN4 countries (Indonesia, Malaysia, Philippines, Thailand), NIE3 economies (Hong Kong, South Korea, Taiwan), China, Japan, US, and the rest of OECD as one group. The share of exports going to each foreign country is a 12-quarter moving average. By allowing the export shares to vary over time, our measure of world income reflects changes in the country composition of Singapore's trade. Computational details for GDP and the export shares are given in Abeysinghe and Forbes (2001). The global chip sales series is from the Semiconductor Industry Association (SIA) website.

Manufacturing Net Capital Stock

The last variable used is the stock of fixed capital (*K*). A lack of data on this stock in Singapore and the unsatisfactory nature of the perpetual inventory method led us to devise a new method for computing a capital stock time series for the manufacturing sector.

The Report of the Census of Industrial Production published annually by the Economic Development Board of Singapore provides annual (year-end) data on the value of gross fixed assets and net fixed assets. The former is the accumulated cost of capital expenditures and the latter is that net of depreciation. The ratio of the two series shows that the depreciation rate has increased over time. This is quite plausible especially for the electronics sector where product obsolescence has been quite rapid. This also implies that the standard approach of perpetual inventory method that uses fixed depreciation rates to compute capital stock produces misleading estimates of the capital stock. We, therefore, do not use the perpetual inventory method here.

We can easily compute an annual series of net capital stock based on net fixed assets. The annual change of this series represents net investment expenditures. We deflate this series by the deflator for gross fixed capital formation to obtain a constant dollar net investment series. Then using 1990 as the base we computed an annual series of net capital stock. Due to changes in the survey coverage, the annual net capital stock series shows a level shift in 1997 and 2001. To adjust for this we used a regression of capital stock on a trend and dummies and then obtained adjusted growth rates for the two years. Keeping the other growth rates intact, we worked out the series backward to obtain an adjusted series.

The next important question is how to convert the annual series to quarterly figures. For this we could use the Chow-Lin (see Abeysinghe and Gulasekaran, 2004) related series technique that relies on the availability of quarterly data on the variables that may be used to predict the capital stock. To search for such related series we use the following approach.

First order conditions for profit maximization based on Cobb-Douglas production function shows that the log of capital stock is a liner function of log of output and log of real price of capital. Because of the lack of data on the price of capital, we searched for a relationship by regressing log of capital stock (k^*) on log of output represented by direct exports (excluding re-exports) which account for about 60% of manufacturing output (q), log of manufacturing employment (l) and time t. The latter two turn out to be insignificant and k^* on q and lagged k^* produces a highly stable significant relationship. The presence of lag k^* makes the direct application of the Chow-Lin procedure difficult. We, therefore, follow the approach in Abeysinghe (1998).

Let the regression for quarterly data be written as

$$k_t^* = \beta_0 + \beta_1 q_t + \lambda k_{t-1}^* + u_t \qquad \text{(A1)}$$

The transformation given in Abeysinghe (1998) enables us to estimate the quarterly model from annual data on k^* and quarterly data on q. The transformed model is

$$k_t^* = \beta_0(1+\lambda+\lambda^2+\lambda^3) + \beta_1(q_t + \lambda q_{t-1} + \lambda^2 q_{t-2} + \lambda^3 q_{t-3}) + \lambda^4 k_{t-4}^* + v_t \qquad \text{(A2)}$$

This model can be estimated by non-linear OLS. The estimation results based on data over 1978-2002 produce the following results, where the numbers in parentheses are t-statistics:

$\hat{\beta}_0 = 0.6411$ (9.25)
$\hat{\beta}_1 = 0.0469$ (5.40)
$\hat{\lambda} = 0.8944$ (62.61)

$R^2 = 0.99$, Durbin $h = 1.17$.

Plugging these estimates into (A1) we can generate quarterly k^* using the year-end k^* of each year as the starting value. This step is the same as the Chow-Lin method because of the serially uncorrelated errors. However, a minor adjustment was needed to remove some spikes that occurred in fourth quarter growth rates. This was easily achieved through small adjustments to the third and fourth decimal places of the AR parameter estimate $\hat{\lambda}$ = 0.8944 and keeping it constant at the adjusted value until the next adjustment was necessary. This procedure provided us the quarterly net capital stock series used in the study.

References

Abeysinghe, T. (1998) "Forecasting Singapore's quarterly GDP with monthly external trade", *International Journal of Forecasting*, 14, 505–513.

Abeysinghe, T. (2001) "Electronics and growth cycles in Singapore", *Applied Economics*, 32, 1657-1663.

Abeysinghe, T. and Gulasekaran, R. (2004) "Quarterly real GDP estimates for China and ASEAN4 with a forecast evaluation", *Journal of Forecasting*, 23, 431–447.

Abeysinghe, T. and Tan, L.Y. (1998), "Exchange rate appreciation and export competitiveness", *Applied Economics,* 30, 51–55.

Athukorala, P. and Riedel, J. (1991) "The small country assumption: A reassessment with evidence from Korea", *Weltwirtschaftlichess Archiv*, 127, 138-151.

Athukorala, P. and Riedel, J. (1994) "Demand and supply factors in the determination of NIE exports: A simultaneous error-correction model for Hong Kong: A comment", *The Economic Journal*, 104, 1411-1414.

Athukorala, P. and Riedel, J. (1996) "Modelling NIE exports: Aggregation, quantitative restrictions, and choice of econometric methodology", *Journal of Development Studies*, 33, 81-98.

Browne, F. (1982) "Modelling export prices and quantities in a small open economy", *Review of Economics and Statistics*, 64, 346-347.

Faini, R., Clavijo, F., and Senhadji, A. (1992) "The fallacy of composition argument: is it relevant for LDC manufactured exports?" *European Economic Review*, 36, 865-882.

Goldstein, M. and Khan, M.S., (1978) "The supply and demand for exports: A simultaneous approach", *Review of Economics and Statistics*, 60, pp. 275–286.

Harberger, A.C. (1953) "A structural approach to the problem of import demand", *The American Economic Review,* 43, 148-159.

Harris, D. (1997) "Principal components analysis of cointegrated time series", *Econometric Theory*, 13, 529–557.

Hendry, D.F. and J.A. Doornik (2001) *Empirical Econometric Modelling Using PcGive 10: Volume I*, London: Timberlake Consultants Press.

Houthakker, H.S. and Magee, S.P. (1969) "Income and price elasticities in world trade", *Review of Economics and Statistics*, 51, pp. 111–125.

Holt, C.C., Modigliani, F., Muth, J.F. and Simon, H.A. (1960) *Planning Production, Inventories and Work Force*, Englewood-Cliffs, NJ: Prentice Hall.

Johansen, S. (1995), *Likelihood-based Inference in Cointegrated Vector Autoregressive Models*, Oxford: Oxford University Press.

Kapur, B. (1983) "Short-term analytical model of the Singapore economy" *Journal of Development Economics*, 12, 355–376.

Klein, L.R. (1960) "Single equation vs. equation system methods of estimation in econometrics", *Econometrica*, 28, 866-871.

Leamer, E.E. (1981) "Is it a demand curve, or is it a supply curve – Partial identification through inequality constraints" *Review of Economics and Statistics*, 63, 319-327.

Lim, C.Y. et al. (1988) *Policy Options for the Singapore Economy*, Singapore: McGraw-Hill.

Lloyd, P.J. and Sandilands, R.J. (1986) "The trade sector in a very open re-export economy", in C.Y. Lim and P.J. Lloyd (eds.) *Singapore: Resources and Growth*, Singapore: Oxford University Press.

Maddala, G.S. and Kim, I.M. (1998) *Unit Roots, Cointegration, and Structural Change*, Cambridge University Press, UK.

Muscatelli, V.A. (1995a) " NIE export performance revisited: The estimation of export demand elasticities and the role of product differentiation and growth", in D. Vines and D. Currie (eds.) *North-South Linkages and International Macroeconomic Policy*, New York: Cambridge University Press.

Muscatelli, V.A. (1995b) "Demand and supply factors in the determination of NIE exports: A reply", *Economic Journal*, 104, 1415-1417.

Muscatelli, V.A., Srinivasan, and Vines D. (1992) "Demand and supply factors in the determination of NIE exports: A simultaneous error-correction model for Hong Kong", *Economic Journal*, 102, pp. 1467–1477.

Muscatelli, V.A., Srinivasan, and Vines D. (1994) "The empirical modeling of NIE exports: An evaluation of different approaches", *Journal of Development Studies*, 30, 279-302.

Muscatelli, V.A., Stevenson, A.A., and Montagna, C. (1995a) "Modelling aggregate manufactured exports for some Asian Newly Industrialized Economies", *Review of Economics and Statistics,* 77, pp. 147–155.

Muscatelli, V.A., Stevenson, A.A., and Montagna, C. (1995b) "An analysis of disaggregated manufacturing exports of the Asian NIE to EEC, USA, and Japan", *Applied Economics*, 99,

Nguyen, D.T. (1989) "The demand for LDC exports of manufactures: Estimates from Hong Kong: A comment", *Economic Journal*, 99, 461-466.

Nguyen, D.T. (1996) "The debate concerning the demand for NIE exports and the small country assumption: A critical review", *The Singapore Economic Review*, 41, pp. 1–12.

Orcutt, G. (1950) “Measurement of price elasticities in international trade”, *Review of Economics and Statistics*, 32, pp. 117–132.

Phillips, P.C.B. (1994) “Some exact distribution theory for maximum likelihood estimators of cointegrating coefficients in error correction models”, *Econometrica,* 62, 73–93.

Riedel, J. (1984) “Trade as the engine of growth in developing countries, revisited” *Economic Journal*, 94, 56-73.

Riedel, J. (1988) “The demand for LDC exports of manufactures: Estimates from Hong Kong”, *Economic Journal*, 98, 138–148.

Sims, C.A., Stock, J.H., and Watson, M.W. (1990) “Inference in linear time series models with some unit roots”, *Econometrica*, 58, pp. 113–144.

Table 1
Trace test for cointegration rank

H_0:rank≤	0	1	2	3	4	5	6
Trace test	144.9**	97.3*	59.4	36.6	19.3	5.9	0.1
p-value	0.002	0.037	0.254	0.372	0.481	0.712	0.758

Note: ** and * indicate statistical significance at the 1% and 5% levels respectively.

Table 2
Test results for cointegrating vectors

	Two cointegrating vectors						One cointegrating vector		
	H1		H2		H3		H4	H5	H6
	D	S	D	$P^x \propto P^w$	S	$P^x \propto P^w$	D	S	D&S
x	1	1	1	-	1	-	1	1	1
p^x	1.23	-0.69	1.31	1	18.04	1	1.05	-3.90	0.85
P^{us}	-0.16	-	-0.39	0.43	-	-0.37	-0.30	-	-
y^w	3.85	-	3.71	-	-	-	3.70	-	3.20
p^{rm}	-	-6.29	-	-	18.96	-	-	-95.28	-1.04
p^d	-	-2.67	-	-	4.96	-	-	-64.12	-0.17
k	-	0.99	-	-	4.57	-	-	-11.95	0.17
χ^2	8.08		39.45		29.59		10.91	10.96	0.54
p-value	0.045*		0.000**		0.000**		0.012*	0.004**	0.464

Notes: D represents a demand equation and S represents a supply equation. H(*i*) stands for Hypothesis *i* = 1,…,6. A dash in a cell indicates a zero restriction imposed on the cointegrating vector. Non-normalized coefficients are multiplied by –1 for easy comparison with the expected sign, as in a regression model.

Table 3
Dynamic elasticities for exports

Lag (Quarters)	y^w	*chip*	Δk	$p^{rm}-p^x$	p^d-p^x	$ulc-p^x$	$nlc-p^x$
0	0	0.31	0	0	0	0	0
1	1.23	0.35	0.95	-0.26	-0.09	-0.04	-0.05
4	3.09	0.10	2.39	-0.65	-0.23	-0.11	-0.12
8	3.43	0.02	2.64	-0.72	-0.25	-0.12	-0.14
12	3.49	0.00	2.69	-0.74	-0.26	-0.12	-0.14

Note: Variables are in logarithms and *nlc* is non-labour costs.

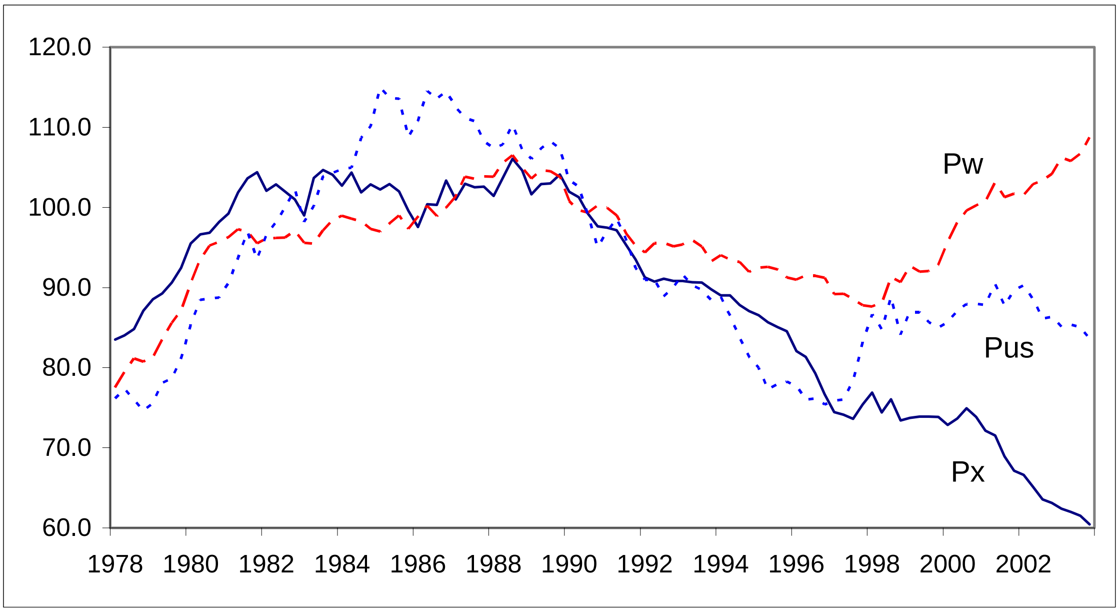

Fig. A1. P^x , P^w, and P^{us}

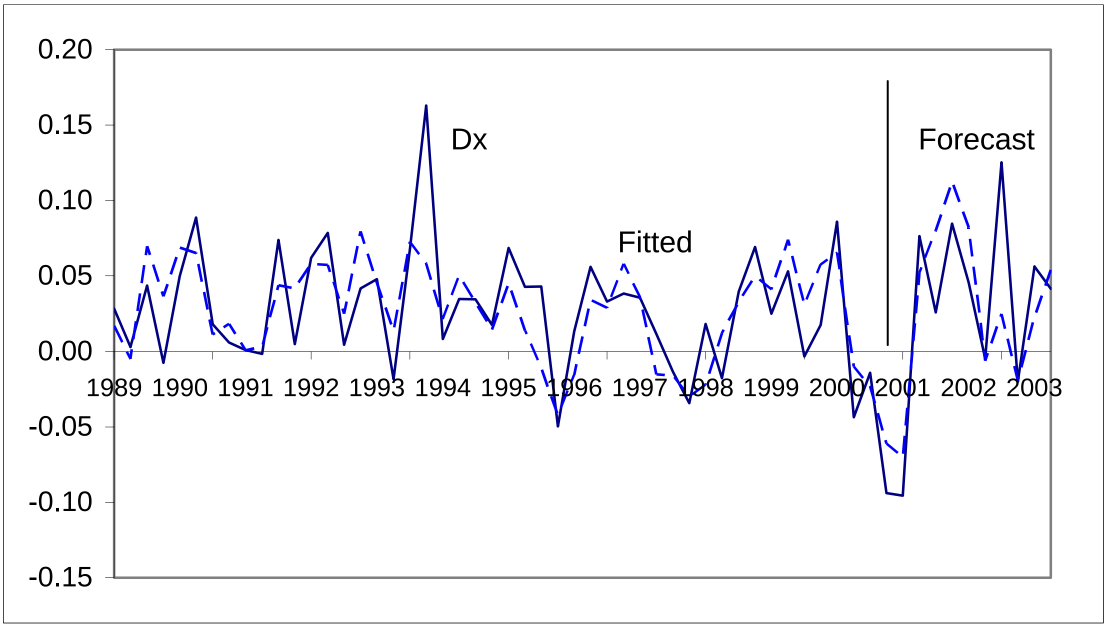

Fig. 1. Actual and fitted growth rates for NODX with forecast over eight quarters