Demand for Imports, Supply of Exports and Technical Progress: Results from a GNP Function Estimate for Switzerland

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1. INTRODUCTION

International Trade is considered to be a major determinant of economic growth in an open economy. Of course, there is the well-known traditional argument of export-led growth which is based on the foreign trade multiplier in demand oriented open economy macromodels. However, it seems more promising to consider the supply effects of international trade in order to understand its influence on growth. In this context, we may argue that the volume and the competition on markets for internationally traded goods lead to an acceleration of technical progress which allows strong output growth. Indeed, there are attempts to formulate recent theoretical models of endogenous growth in open economies which analyze this issue theoretically [e.g. GROSSMAN and HELPMAN (1991), BALDWIN (1992)]. To a certain extent, the influence of international trade on growth in a small open economy can be analyzed empirically using the GNP-Function approach to modeling the determination of the volume of imports and exports introduced by KOHLI (1978) and BURGESS (1974a,b). In this framework, a small open economy is considered as a firm producing several outputs, say exports and domestic sales, using a variable input (imports) and two fixed inputs (labour and capital). Thereby, we can allow for technical progress which is not Hicks-neutral, i.e. the production of exports and the use of imports as input may be subject to a higher rate of technical progress than the production for the domestic market. This approach may be easily implemented using a translog approximation to the GNP-Function. This paper applies this analysis to annual data covering the years 1960-1988 for a highly open small economy, namely Switzerland.

2. THE GNP-FUNCTION AND ITS TRANSLOG APPROXIMATION

Before turning to a brief formal presentation of the model, some remarks concerning its general underpinnings are worth making. First, there is the treatment of imports as an input which should be motivated. International trade covers a lot of intermediate goods for which this approach is obviously adequate. In addition, imports of finished goods do not reach final demand directly but use domestic resources (services) to reach final demand. Second, exports and imports are modeled under the assumption that the small

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open economy is a price taker on the international market. Thus, there is a demand for imports and supply of exports given their prices. This approach stands in contrast to the conventional export function estimates which consider exports of a country to be determined by world demand. The latter approach is, however, seriously flawed as argued convincingly by KOHLI (1978).

Now, let us define a vector of \( I = 3 \) outputs produced in the economy \( y' = \begin{bmatrix} -M, X, DS \end{bmatrix} \), where \( M, X \) and \( DS \) are the columns of imports, exports and domestic sales, respectively. Note that the variable input \( M \) is treated as a negative output. To correspond to this, we define a vector of prices \( p' = \begin{bmatrix} P_M, P_X, P_{DS} \end{bmatrix} \). There are \( J=2 \) primary inputs which are fixed in the short run, namely labour (\( L \)) and capital (\( K \)) which are collected in the vector \( x' = \begin{bmatrix} L, K \end{bmatrix} \).

Of course, there is a vector of prices for primary inputs \( w' = \begin{bmatrix} w_L, w_K \end{bmatrix} \). We assume that the aggregate technology linking outputs and inputs satisfies constant returns to scale and non-increasing marginal rates of substitution and transformation as well as profit maximization and competitive markets. Under these conditions, we can represent the technology by the restricted profit or GNP-Function \( \pi(p, x, t) \), which is linearly homogeneous and convex (concave) in prices (primary inputs). Moreover, it is non-decreasing (non-increasing) in prices of outputs (variable inputs) and increasing in primary inputs.

This function determines output quantities such that profit is maximized given output prices, endowments of primary inputs and the available technology, which is represented by the time index \( t \). Assuming differentiability and using Hotelling’s lemma, we obtain output supply functions by differentiating \( \pi \) partially with respect to the components of \( p \) and we get inverse primary input demand functions by the marginal product condition \( w = \frac{\partial \pi}{\partial x}(p, x, t) \).

In order to implement this concept empirically, we have to choose a functional form for \( \pi(p, x, t) \). Following KOHLI (1978), we use the well-known flexible translog functional form:

\[
\ln \pi = \alpha_0 + \sum \alpha_i \ln p_i + \sum \beta_j \ln x_j + \frac{1}{2} \sum \sum \gamma_{ij} \ln p_i \ln p_h + \\
\sum \sum \delta_{ij} \ln p_i \ln x_j + \frac{1}{2} \sum \sum \phi_{jk} \ln x_j \ln x_k + \alpha_t + \\
\sum \gamma_i \ln p_i t + \sum \phi_i \ln x_j t + \frac{1}{2} \gamma_t t^2.
\] (1)
In our context, the subscript t coefficients are of special interest. If \( \gamma_1 = \gamma_2 = \gamma_3 = \phi_1 = \phi_2 = 0 \), technical progress is Hicks-neutral. If some of these coefficients are not equal to zero, technical change is biased. The bias is in favour of output (variable input i) when \( \gamma_1 \) is greater (smaller) than zero. Of course, \( \phi > 0 \) says that technical change is in favour of primary input j.

Logarithmic differentiation provides us with output supply functions and inverse factor demand functions in value share form:

\[
\begin{align*}
  v_i &= \frac{\partial y_i}{\pi} = \alpha_i + \sum_{h=1}^{I} \gamma_{ih} \ln p_h + \sum_{j=1}^{J} \delta_{ij} \ln x_j + \gamma_{it} t \\
  u_j &= \frac{w_j x_j}{\pi} = \beta_j + \sum_{i=1}^{I} \delta_{ij} \ln p_i + \sum_{k=1}^{I} \phi_{jk} \ln x_k + \phi_{jt} t
\end{align*}
\]

\( i = 1, \ldots, I \quad j = 1, \ldots, J. \)

Obviously, the intercepts(slopes) of 2 and 3 add up to one(zero) across the equations. Moreover, the matrix of the \( \gamma \) and \( \phi \) coefficients is symmetric. Thus we have to account for cross equation restrictions and the adding up property calls for dropping one equation in (2) and (3), respectively, (in our application the I'th and J'th equation) before estimation.

The \((I+J)\) dimensional quadratic matrix \( \Sigma \) of transformation and substitution elasticities of is easily calculated in the framework of a translog function. The curvature properties of the GNP-Function imply that \( \Sigma_{pp} \), the I-dimensional matrix of partial transformation elasticities, is positive semi-definite and \( \Sigma_{xx} \), the J-dimensional matrix of inverse partial elasticities of substitution, is negative semi-definite. These conditions have to be checked after estimating the model for the entire sample.

Partial price and quantity elasticities of the variable quantity supply function and the inverse primary input demand function can be easily calculated as \( E_{ij} = \sigma_{ij} S_j \), (i,j = 1,2 \ldots, I+J), where \( S = [v_1, v_2, v_3, u_1, u_2] \) and \( \sigma_{ij} \) are the elements of \( \Sigma \).

3. EMPIRICAL RESULTS

The model outlined in Section 2 is estimated using annual data for Switzerland covering the period 1960-1988. The data for imports (M), exports (X) and domestic sales (DS: private and public consumption and investment) and its deflators are taken from the national account. The capital stock was constructed using private and public investment and assuming a depreciation rate of 5\%. A starting value for \( K \) was obtained by assuming
a capital-output ratio of 3 in the year 1948 which is the starting date of national account
data in Switzerland. However, varying the capital-output ratio and the depreciation rate
did not change the results essentially. N is the total employment and the prices of L and
K were calculated indirectly by the nominal labour and capital income of the national
account.¹

Table 1 contains the 3SLS estimation results obtained with these data.² In contrast to
the model outlined before, we allowed a trend break in 1975. This is, of course, motivated
by the tremendous increase in the prices of oil and other raw materials which took place
in 1973/74. The coefficients of the corresponding dummy trend variable are denoted by
γt75 and φt75. Now, let us turn to the results in some detail. First of all, we are interested
in the estimates for the technical change coefficients. The estimates for γt1, γt2, and φt1
are all statistically significantly different from zero at conventional significance levels.
Thus, technical progress is not Hicks-neutral. We note the strongest non-neutrality with
respect to imports. The non-neutrality with respect to exports is less striking and the
coefficient which can be calculated for domestic sales γ = -(γt1 + γt2), whose estimate
equals 0.0037(0.0018), is only marginally lower than the export coefficient.

Thus, our estimates indicate that the use of imports affects technical progress strongly,
whereas the role exports and domestic sales play does not seem to be very different in
this respect. In addition, we observe no statistically significant break of technical
progress for the variable quantities, but this is not true for the primary inputs. The
non-neutrality in favour of capital is reduced in the mid-70’s.

Table 2 reports the estimated elasticities of variable quantities and primary input prices
with respect to output prices and primary input quantities for the year 1980. Before
discussing these results, we have to mention that the curvature conditions (Σpp positive
semi-definite, Σxx negative semi-definite) holds for all observations. The own price
elasticity of import demand ranges between -0.5 and -0.8. Similar absolute values were
obtained for the export supply own price elasticities (0.65 - 0.85). The supply of domestic
sales is definitely less price elastic and is mainly driven by primary inputs. An increase
in capital has strongly positive effects on imports and exports, whereas a partial increase
in labour hardly affects imports and even has a negative impact on exports. The inverse
own and cross price elasticities of demand for labour and capital are in the range of 0.7
to 0.8 in absolute value. Interestingly, the price of labour is hardly affected by increases
in import and export prices, but the prices of domestic sales have a very strong impact
on it. The reaction of the price of capital is, however, similar to all variable quantity
prices.

¹. Data source is “Die Volkswirtschaft”, several issues.
². In addition, first differences of p and x, as well as AR(1) error terms are considered in order to account
for the short run dynamics of the variables. In order to fulfill the adding up restrictions the AR-coefficients are
equal across (2) and (3).
Table 1: Three-Stage Least Squares Estimates of Translog GNP-Function Parameters, Switzerland, 1960-1988

\[ y = [ -M, X, DS ]' \quad x = [ L, K ]' \]

Estimated Standard Errors in Parentheses

| \( \alpha_1 \) | -0.557 (0.087) | \( \gamma_{t1} \) | -0.0077 (0.0020) |
| \( \alpha_2 \) | 1.027 (0.102) | \( \gamma_{t175} \) | -0.00071 (0.00059) |
| \( \beta_1 \) | 0.863 (0.045) | \( \gamma_{t2} \) | 0.0040 (0.0019) |
| \( \gamma_{11} \) | -0.232 (0.109) | \( \gamma_{t275} \) | 0.43 \cdot 10^{-4} (0.00049) |
| \( \gamma_{12} \) | -0.039 (0.099) | \( \phi_{t1} \) | -0.0036 (0.00056) |
| \( \gamma_{22} \) | 0.447 (0.134) | \( \phi_{t175} \) | 0.00086 (0.00013) |
| \( \phi_{11} \) | -0.096 (0.014) | & | & |
| \( \delta_{11} \) | 0.143 (0.023) | & | & |
| \( \delta_{21} \) | -0.286 (0.030) | & | & |

Table 2: Price and Quantity Elasticities for 1980

\[ [ -M, X, DS, w_L, w_K ] \]

with respect to

\[ [ P_M, P_X, P_{DS}, L, K ] \]

| \( E_{11} \) | -0.79 | \( E_{31} \) | -0.13 | \( E_{51} \) | -0.72 |
| \( E_{12} \) | 0.45 | \( E_{32} \) | -0.044 | \( E_{52} \) | 1.04 |
| \( E_{13} \) | 0.34 | \( E_{33} \) | 0.17 | \( E_{53} \) | 0.68 |
| \( E_{14} \) | 0.22 | \( E_{34} \) | 0.72 | \( E_{54} \) | 0.81 |
| \( E_{15} \) | 0.78 | \( E_{35} \) | 0.28 | \( E_{55} \) | -0.81 |
| \( E_{21} \) | -0.50 | \( E_{41} \) | -0.15 | & | & |
| \( E_{22} \) | 0.63 | \( E_{42} \) | -0.15 | & | & |
| \( E_{23} \) | -0.13 | \( E_{43} \) | 1.29 | & | & |
| \( E_{24} \) | -0.24 | \( E_{44} \) | -0.59 | & | & |
| \( E_{25} \) | 1.24 | \( E_{45} \) | 0.59 | & | & |
4. CONCLUSION

The hypothesis suggested by recent developments in international trade and growth theory, namely that foreign trade is an important source of growth, is, to a certain extent, supported by our GNP function analysis of Swiss data. There seems to be a strong non-neutrality of technical change in favour of imports, whereas this cannot be said for exports in comparison with domestic sales. This result supports the theoretical model of BALDWIN (1992), which focuses on the innovation implementation effect in the domestic economy caused by import competition. However two caveats have to be mentioned. First, in our modeling framework technical progress is non-neutral but exogenous. Thus the model may only describe growth arising from foreign trade but does not explain it. Second, technical progress is modeled in a sense residually. That is for instance import growth which can not be explained by prices of variable quantities and quantities of primary inputs is interpreted as technical change. Of course, liberalization of international trade during the sample has the same effect and cannot be distinguished from technical change in our framework.

REFERENCES

SUMMARY

The application of the translog GNP function approach to Swiss data indicates that imported inputs seem to be the most important channel for technical change, whereas the production of exports and domestic sales does not seem to be strongly different with respect to the implementation of technical change.

ZUSAMMENFASSUNG

Die Schätzung einer Translog-BSP-Funktion für die Schweiz führte zum Ergebnis, dass eine starke Nichtneutralität des technischen Fortschrittes zugunsten importierter Inputs vorliegt. Hingegen konnten keine Hinweise für einen entsprechenden Unterschied bezüglich der Inland- und Exportproduktion gefunden werden.

RESUME

L’application d’une fonction translog pour le PNB Suisse indique que l’importation de biens productifs est une déterminante importante pour le progrès technologique tandis que le secteur de production pour l’exportation et celui pour le marché interne ne semble pas trop différer en ce qui concerne l’implémentation du progrès technologique.