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PRICE AND VOLUME ELASTICITIES OF BRAZILIAN FOREIGN TRADE: A PROFIT FUNCTION APPROACH

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By Luiz de Mello and Mauro Pisu

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ABSTRACT/RÉSUMÉ

Price and volume elasticities of Brazilian foreign trade: A profit function approach

Brazil, like other natural resource-exporting countries, has benefited from a sharp increase in commodity prices over the last few years. To investigate the possible impact of terms-of-trade gains on the real economy, this paper estimates normalised quadratic input demand and output supply functions for the Brazilian economy during 1997-2008. Technological change is modelled in a flexible manner through the inclusion of quadratic splines in the profit function. The paper contributes to the literature by using nonlinear seemingly unrelated regression techniques to estimate the input demand and output supply functions and by disaggregating exports and imports into capital, consumption and intermediate goods. Improvements in the terms of trade due to rising export prices and/or falling import prices are associated with hikes in export volumes on the back of rising import demand and some labour shedding in the sectors using imported capital goods. The direct impact of terms-of-trade changes on domestic consumption and investment is comparatively modest, possibly due to the fact that the Brazilian economy remains relatively closed to trade.

JEL classification: F10; F14; F43
Keywords: terms of trade; profit function; seemingly unrelated regression; NQQS

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Les élasticités des prix et volumes du commerce extérieur brésilien : Une approche de fonction de profit

Le Brésil, comme les autres pays exportateurs de matières premières, a bénéficié d'une forte augmentation des prix des ces matières au cours de ces dernières années. Ce document estime des fonctions quadratiques normalisées de demande des inputs et d'offre des outputs pour analyser l'impact des gains du terme de l'échange sur l'économie réelle sur la période de 1997 a 2008. Le changement technologique est modélisé d'une manière flexible en introduisant des splines quadratiques sur les régressions. Des techniques de régression non linéaire *seemingly unrelated* ont été utilisées pour estimer les fonctions de demande et d'offre. Les exportations et les importations ont été désagrégées en biens de capital, de consommation et intermédiaires. Les principaux apports de ce document sont que les variations du terme de l'échange à cause d'une augmentation du prix des exportations et/ou d'une baisse du prix des importations sont associées à une hausse du volume des exportations, à une augmentation des importations et à une réduction de l'emploi dans les secteurs utilisant des biens de capital importés. L'impact direct de l'évolution du terme de l échange sur la consommation intérieure et l'investissement est comparativement faible, peut-être à cause du fait que l'économie brésilienne reste relativement fermée.

JEL classification : F10 ; F14 ; F43
Mots-clés : Termes de l'échange ; fonction profit ; régression *seemingly unrelated* ; NQQS

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Price and volume elasticities of Brazilian foreign trade: A profit function approach

Luiz de Mello and Mauro Pisu,[1]

1. Introduction

Brazil, like other natural resource-exporting countries, has benefited from a sharp increase in commodity prices over the last few years. The country's terms of trade, which had been stagnant since the late 1990s, rose by some 10% between mid-2005 and end-2008. This improvement is not as impressive as the 30% rise that took place during 1990-98 but has rekindled interest among researchers and practitioners in how changes in relative prices are likely to affect domestic demand. Episodes of large terms-of-trade gains have been associated with exchange-rate appreciations that have taken their toll on export performance and created income effects that have fuelled import growth and investment.

This paper sheds additional light on the links between changes in the terms of trade and domestic demand by estimating output supply and input demand functions using quarterly national-accounts data spanning the period 1997 through 2008. We employ the gross national product approach originally developed by Kohli (1978). We estimate a set of input demand and output supply equations using a variant of the symmetric normalised quadratic functional form proposed by Diewert and Wales (1987 and 1988), which is more flexible than the translog function and allows for global curvature conditions to be imposed without comprising functional flexibility. The advantage of this approach is that the own- and cross-price elasticities of the various inputs and outputs can be estimated with a minimal set of assumptions based on profit maximisation only. To our knowledge, this methodology has not yet been applied to Brazilian data. The bulk of the empirical literature on trade elasticities in Brazil focuses instead on the estimation of conventional import and export equations (see Fullerton *et al.*, 1999, for a survey).

Our basic specification considers a profit function that includes three inputs and three outputs. Labour and imports are treated as time-varying inputs, whereas capital is assumed to be in fixed supply in the short run. The outputs are domestic consumption, exports and investment. We also estimate a more detailed specification, which disaggregates exports and imports into capital, consumption (durables and non-durables) and intermediate goods. This disaggregation, which to our knowledge is novel in the empirical literature, sheds additional light on the scope for substitution and complementary among the various inputs and outputs. We model technological change in a flexible manner through the inclusion of quadratic splines in the production function and show that this specification fits the data considerably better than a more traditional treatment based on quadratic time trends.

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1. This paper was written as background material for the OECD *Economic Survey of Brazil*, published in July 2009 under the authority of the Secretary General of the OECD and discussed at the Economic and Development Review Committee (EDRC) on 4 June 2009. The views expressed in this paper do not necessarily reflect those of the OECD and its Member countries. Special thanks are due to Anne Legendre for research assistance and Mee-Lan Frank for excellent technical assistance.

Our main findings are as follows. *First*, terms-of-trade gains are associated with changes in the demand for inputs, with rising imports and some labour shedding, at least in the case of capital goods. By contrast, labour demand rises with falling prices of imported consumption and intermediate goods, which suggests that employment is complementary with these imports.

Second, the effect of terms-of-trade changes on the supply of outputs is relatively modest, at least in the case of domestic consumption and investment. This is not surprising given that Brazil is a relatively closed economy; therefore, income and production substitution effects caused by changes in the terms of trade are most probably lower in magnitude than in more open economies. In addition, exports are sensitive to changes in the price of imports, particularly in the case of shipments of consumption goods.

The paper is structured as follows. Section 2 describes the methodology for estimating the input demand and output supply functions. We briefly review the empirical literature in Section 3 and describe the data in Section 4. The results of the empirical analysis are reported and discussed in Section 5. Section 6 concludes.

2. The methodology

The gross national product methodology developed by Kohli (1978) can be summarised as follows. Technology uses inputs to produce net output $y \equiv [y_i]$, such that $y_i > 0$ ($y_i < 0$) implies that the *i*-th good is an output (input). Prices are denoted by $p \equiv [p_i]$. Assuming the supply of capital to be fixed in the short run (at time *t*), a unit profit function can be defined as $\pi(p,t) = p \cdot y$, which can be interpreted as the return to one unit of fixed capital in period *t*. By Hotelling's lemma, it follows that the net output vector divided by capital equals the vector of price derivatives of the unit profit function, such that $\frac{y}{k} = \nabla_p \pi(p,t)$, where $\nabla_p \pi(p,t) \equiv \partial \pi(p,t) / \partial p_i$.

The first consideration when applying this methodology concerns the choice of an appropriate functional form for $\pi(p,t)$. Early applications modelled the profit function using the translog specification (*e.g.* Kohli, 1978; Jorgenson and Fraumeni, 1981; Charos and Simos, 1988; Kohli, 1990), which is flexible and does not require any pre-defined elasticity of substitution to be imposed among the inputs, unlike the Cobb-Douglas and CES specifications. However, the curvature conditions required for the profit function to be convex in prices are seldom borne out by the data and need to be imposed.[2] Several options have been proposed to do so, although often at the cost of flexibility in the functional specification of the profit function. Diewert and Wales (1987 and 1988) put forward two new families of flexible functions for cost and expenditure equations (the normalised quadratic and symmetric normalised quadratic forms) that allow for curvature restrictions to be imposed without undermining functional form flexibility.[3]

2. This requirement is not met in Charos and Simos (1988), whereas it is satisfied only locally in Kohli (1990). The methodology proposed by Lau (1978) and Wiley *et al*. (1973) allows for the curvature conditions to be imposed locally in a translog setting, although they may still be violated globally. An alternative methodology proposed by Jorgenson and Fraumeni (1981) has the drawback of restricting the substitution possibilities among inputs and outputs, as noted by Diewert and Wales (1987), which undermines the flexibility of the translog functional form.

3. The main difference between these specifications is that the normalised quadratic form selects one component for asymmetric treatment, whereas the symmetric normalised quadratic form treats all variables symmetrically. Diewert and Ostensoe (1988) extended the use of the normalised quadratic form in the case of variable profit functions.

In the estimations below, we employ a variant of the flexible functional forms proposed by Diewert and Wales (1992) – the symmetric normalised quadratic variable unit profit function – which can be written as follow:

$$\pi(p,t) \equiv a\cdot p + (1/2)(\alpha\cdot p)^{-1} p\cdot Bp + b\cdot pt + (1/2)c(\alpha\cdot p)t^2, \quad (1)$$

where $a \equiv [a_i]$ and $b \equiv [b_i]$ are unknown parameter vectors with $\sum b_{ij} = 0$ and $\sum \alpha_i = 1$, by assumption;[4] $B \equiv [B_{ij}]$ is an unknown positive-definitive symmetric matrix of parameters; c is an unknown scalar; and $\alpha \equiv [\alpha_i]$ is a vector of pre-specified parameters.

The unit profit function is convex in prices if matrix B is positive-definite.[5] The output supply and input demand functions, as well as the rate of technological change, can be obtained from the first derivatives of the profit function with respect to p and t, respectively:

$$\nabla_p \pi(p,t) \equiv a + (1/2)(\alpha\cdot p)^{-1}Bp - (1/2)(\alpha\cdot p)2p\cdot Bp\alpha + bt + (1/2)c\alpha t2, \text{and} \quad (2)$$

$$\nabla_t \pi(p,t) \equiv b\cdot p + c(\alpha\cdot p)t. \quad (3)$$

Although this normalised quadratic setting is flexible, it may not fit the data well, because technological progress is treated too simplistically. Inclusion of a time trend in the estimating equations provides only a crude approximation of the effects of technological progress on output supply and input demand. To overcome this weakness, Diewert and Wales (1992) proposed the use of quadratic splines, so that each input demand and output supply equation features a number of separate linear trends. Equation (1) can therefore be re-defined to include quadratic splines instead of a single quadratic time trend, such that:

$$\pi(p,t) \equiv a\cdot p + (1/2)(\alpha\cdot p)^{-1} p\cdot Bp + d(p,t), \quad (4)$$

where $d(p,t) \equiv d^1(p,t)$, if $t \leq t_1$; $d(p,t) \equiv d^2(p,t)$, if $t_1 < t \leq t_2$; and $d(p,t) \equiv d^3(p,t)$, if $t_2 < t$, where t_1 and t_2 (with $t_1 < t_2$) are two predetermined cut-offs.

The quadratic spline function $d^i(p,t)$ is defined as:

$$d^1(p,t) \equiv b\cdot p + (1/2)c_1\cdot pt^2,$$

$$d^2(p,t) \equiv d^1(p,t_1) + (t-t_1)\,\partial d^1(p,t_1)/\partial t + (1/2)(t-t_1)^2 p\cdot c_2, \text{ and} \quad (5)$$

$$d^3(p,t) \equiv d^2(p,t_2) + (t-t_2)\,\partial d^2(p,t_2)/\partial t + (1/2)(t-t_2)^2 p\cdot c_3,$$

where b, c_1, c_2 and c_3 are vectors to be estimated, and $\partial d^i(p,t_i)/\partial t$ is the first derivative of $d^i(p,t)$ with respect to time, evaluated at time t_i.

4. These restrictions can be expressed in matrix form as $B\iota = 0$I and $\alpha\cdot\iota = 1$ where ι is a vector of ones.

5. Wiley *et al.* (1973) showed that a sufficient condition for matrix B to be positive-definite is that it be expressed as $B = UUT$, where U is a lower-triangular matrix, $U \equiv [Uij]$, with $Uij = 0$ if $j > i$, and UT is its transpose. Diewert and Wales (1987) showed that this condition is also necessary. To ensure that $B\iota = 0$ holds when imposing convexity, it is required that $U\iota = 0$I or $\sum Uij = 0$.

Equation (4) allows for varying rates of technological progress.[6] In addition, unlike linear splines, the first-order derivatives and second-order cross-derivatives, $\nabla_t \pi(p,t)$ and $\nabla_{pt} \pi(p,t)$, respectively, are continuous at the cut-off points. This property of the functions ensures that the rate of technological progress, input demands and output supplies do not change abruptly across regimes.

3. A brief review of the empirical literature

Empirical evidence based on the production function approach is fairly abundant for the United States. Kohli (1993) estimated a variable profit function for the United States from 1948 to 1988 allowing for two fixed inputs, labour and capital. His estimates indicate that imports are positively associated with wages. Rising import prices are associated with lower exports, investment and, to a lesser extent, consumption. The elasticity of exports with respect to the price of investment is negative, as is the elasticity of consumption with respect to exports and investment.

The more recent literature focuses on the substitution effect that may exist between imports, including from developing countries, employment and wages. It appears that such a substitution is not very strong for the United States. For example, Sharma (2002) estimated a variable profit function for the period 1974-95 using a translog functional form and treating capital as fixed, whereas Tombazos (2003) treated both capital and labour as fixed. Sharma (2002) finds that the demand for labour increases when the price of imports falls. Also, falling import prices are associated with rising exports and, to a lesser extent, investment and domestic consumption. Among the outputs, the estimated elasticities are such that terms-of-trade gains arising from rising export prices are associated with higher exports and employment, as expected, but lower investment. Tombazos (2003) focuses on the effects of imports on wages and shows that falling import prices push wages upward for both skilled and unskilled labour. This finding suggests that inputs purchased from abroad do not have a detrimental effect on labour income.

Empirical evidence for other countries is rather limited. Diewert and Wales (1992) used Japanese data from 1955 to 1987 to estimate a variable profit function assuming that capital is fixed. They find that a positive shock to the terms of trade is detrimental to the supply of consumption goods and investment. They also find that investment is complementary to, and exports are substitutable for, private and government consumption. Among inputs, labour is complementary with imports and inventories but substitutable for machinery and equipment. These cross-price elasticites are nevertheless very small.

4. Data

We use quarterly seasonally-adjusted chain-linked national-accounts data for consumption, investment (gross fixed capital formation), imports and exports for a period spanning 1997Q1 through 2008Q3 available from IBGE. The corresponding prices are the national-accounts deflators for consumption, gross fixed capital formation, imports and exports. Data on the capital stock and employment are available from IPEA on a monthly basis. The price of labour is the average nominal wage in manufacturing, available from the Monthly Employment Survey (PME). Disaggregated data on the volumes and prices of the components of exports and imports are available from IPEA. Basic descriptive statistics are reported in Table 1.

6. This methodology allows for an arbitrary number of cut-offs. Selection of the breaks is flexible, and the number of cut-offs depends on judgement and the length of the time series used in the estimations.

Table 1. Descriptive statistics, 1997Q1-2008Q3[1]

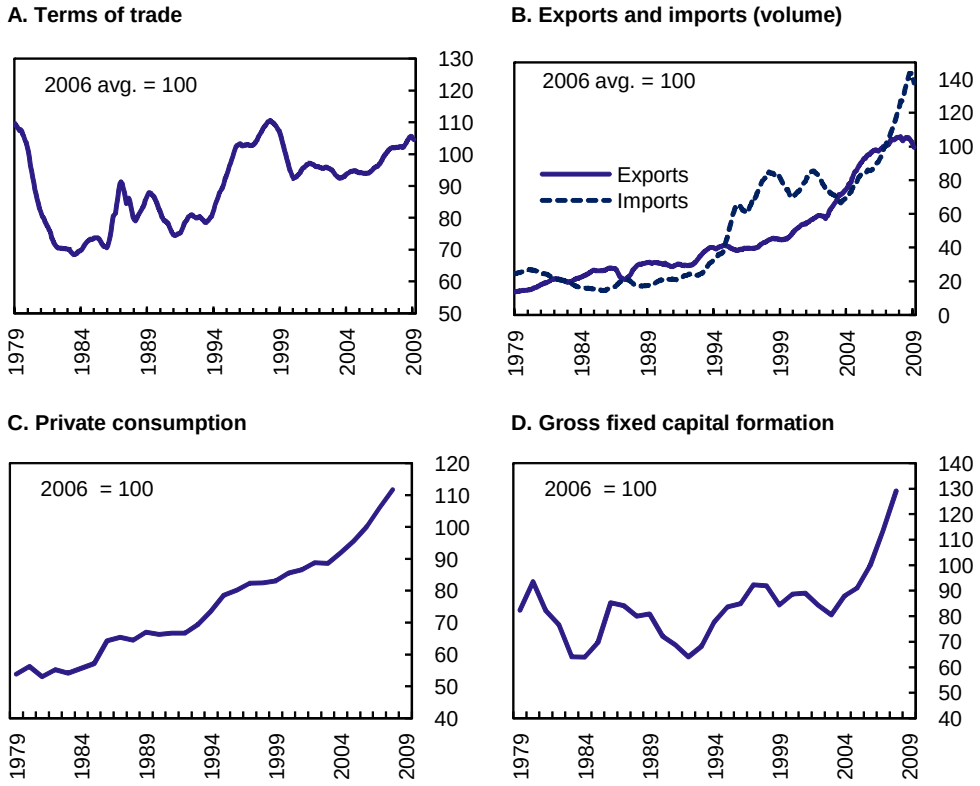
	Mean	Standard deviation	Min.	Max.
Consumption	99.33	9.73	88.72	123.41
Exports	14.83	4.4	8.9	21.73
of which:				
Consumption goods	2.55	0.85	1.3	3.76
Capital goods	1.52	0.72	0.69	2.95
Intermediate goods	6.41	1.75	4.02	9.18
Imports	15.14	3.66	11.55	26.72
of which				
Consumption goods	1.11	0.37	0.73	2.22
Capital goods	1.73	0.56	0.99	3.68
Intermediate goods	5.37	1.59	3.4	9.74
Investment	22.6	3.18	18.62	33.48
Employment	18.32	1.87	16.07	21.73
Capital	3 021.29	223.25	2 656.37	3 516.11

1. All values are in billions of *reais* in 2000Q1 prices. Employment is in millions.

Source: IBGE, IPEA and authors' calculations.

Visual inspection of the input and output series suggests that import volumes and investment, and to a much lesser extent consumption, have tended to move in tandem with the terms of trade, especially since the mid-1990s and for import volumes and gross fixed capital formation (Figure 1). These co-movements suggest the presence of income effects associated with fluctuations in the terms of trade, which would affect the demand for imports and investment goods.

Figure 1. **Trends in terms of trade, trade volumes, consumption and investment, 1979-2009**



Source: IBGE, IPEA and authors' calculations.

5. Main findings

The baseline results with aggregate exports and imports

We started by estimating two sets of output supply and input demand functions derived from the normalised quadratic (NQ) and normalised quadratic with quadratic splines (NQQS) models. The estimated elasticities suggest that curvature conditions required for a well-behaved profit function to be defined are not met. These conditions were therefore imposed globally following Wiley *et al*. (1973) on the basis of a technique that nevertheless renders the output supply and input demand equations nonlinear in the parameters. The equations were therefore estimated as nonlinear seemingly unrelated regressions. We followed Kohli (1993) and Diewert and Wales (1992) and set the elements of α in Equation (4) equal to the fixed weights of a Laspeyre price index, such that condition $\sum\alpha_i = 1$ is met.[7] The break points for the NQQS model were set by splitting the sample period in three parts of equal length.

The results reported in Table 2 show that the NQQS specification fits the data better than NQ. The R-squared of the import, investment and employment equations improve markedly when quadratic splines are used to model technological change. The increments in the R-squared statistics are still positive, albeit smaller in magnitude, for the consumption and export equations. We also tested the null hypothesis that $c_1 = c_2 = c_3$, which implies that $d^1(p,t) = d^2(p,t) = d^3(p,t)$ and that the NQQS and the NQ versions of the profit function are equivalent. The $\chi^2(10)$ statistic strongly rejects the null hypothesis.

Table 2. **Profit functions: NQ and NQQS models, 1997Q1-2008Q3**

	NQ	NQQS
Log-likelihood	594.85	-234.18
Number of parameters	21	35
Break points	None	2000Q3 and 2004Q2
Centered R-squared		
Consumption	0.87	0.87
Exports	0.91	0.96
Imports	0.54	0.88
Investment	0.56	0.89
Employment	0.61	0.95
H_0: $c_1 = c_2 = c_3$		253.4
(*p*-value)		(0.00)

Source: Data available from IBGE and IPEA, and authors' estimations.

The own and cross-price elasticities derived from the estimation of the NQQS model are reported in Table 3 for four different points in time. The own-price elastacities are correctly signed: they are positivie for all outputs (consumption, exports and investment) and negative for the inputs (employment and imports) throughout the sample. This means that the estimated profit function is globally convex in prices, as implied by theory. As regards the magnitudes (in absolute value) of the estimated parameters, imports have the highest own-price elasticity (at or above 0.5 for most of the sample period), almost double that of exports. The price sensitivity of the demand for imports increases from the beginning of the sample through its midpoint and decreases afterwards, whereas that of the supply of exports trends downwards. The other own-price elasticities are low and below 0.1.

7. Diewert and Wales (1992) cannot reject the null hypothesis that the elements of α are equal to the fixed weights of a Laspeyre price index in the NQQS model. Previous studies have used different techniques to compute the value of α. For example, Diewert and Wales (1987) used the sample means, and Diewert and Wales (1987 and 1988) assumed it to be a vector of ones.

Table 3. **Price elasticities, 1997Q1-2008Q3**

	1998Q4	2001Q4	2004Q4	2007Q4
Elasticity of consumption with respect to the price of:				
Consumption	0.037	0.052	0.050	0.035
Exports	-0.012	-0.015	-0.014	-0.012
Imports	-0.014	-0.034	-0.034	-0.016
Investment	-0.001	0.004	0.004	0.000
Labour	-0.011	-0.007	-0.006	-0.007
Elasticity of exports with respect to the price of:				
Consumption	-0.208	-0.142	-0.092	-0.104
Exports	0.251	0.273	0.184	0.141
Imports	-0.220	-0.271	-0.188	-0.125
Investment	0.102	0.092	0.067	0.059
Labour	0.075	0.049	0.030	0.029
Elasticity of imports with respect to the price of:				
Consumption	0.204	0.374	0.349	0.167
Exports	0.188	0.310	0.278	0.157
Imports	-0.591	-0.977	-0.903	-0.490
Investment	0.183	0.254	0.243	0.155
Labour	0.016	0.040	0.033	0.012
Elasticity of investment with respect to the price of:				
Consumption	-0.003	0.021	0.022	0.000
Exports	0.030	0.049	0.049	0.031
Imports	-0.063	-0.118	-0.120	-0.065
Investment	0.024	0.035	0.037	0.025
Labour	0.012	0.013	0.012	0.009
Elasticity of employment with respect to the price of:				
Consumption	0.055	0.045	0.041	0.049
Exports	-0.022	-0.031	-0.029	-0.023
Imports	0.009	0.026	0.025	0.010
Investment	-0.012	-0.016	-0.016	-0.014
Labour	-0.026	-0.021	-0.017	-0.019

Source: Data available from IBGE and IPEA, and authors' estimations.

Of particular interest is the effect of terms-of-trade fluctuations on the supply of outputs and the demand for inputs. The cross-price elasticities show that export price gains are associated with rising exports and imports and, to a much lesser extent, an increase in investment and a decline in the supply of consumption goods and employment.[8] Likewise, rising import prices are associated with a reduction in exports and imports and, to a much lesser extent, a decline in investment and consumption, along with an increase in employment. This suggests that gains in the terms of trade caused by rising export prices or falling import prices encourage Brazilian firms to export. To do so, they change the input mix in favour of imports and, to a much lesser extent, invest and shift production away from the domestic market (at least in the case of rising export prices). This finding suggests that the production of exportables is more import intensive than that of goods produced for domestic consumption. Nevertheless, the price-elasticity of exports with respect to imports has fallen over the sample period, suggesting that exports have become progressively less sensitive to changes in import prices over time.

8. These findings are in contrast with those reported by Sharma (2002) and Kohli (2003) for the United States, who find a negative elasticity between exports and investment. Also, the substitutability between imports and labour is contrary to the findings reported by Tombazos (2003), Sharma (2002) and Kohli (1993) for the United States.

Disaggregating import and export components

The elasticities reported in Table 3 might still mask substantial variation among the different components of inputs and outputs, such as consumption, capital and intermediate goods. To shed light on this issue, we re-estimated the NQQS model with disaggregated data on exports and imports of consumption, capital and intermediate goods.

Table 4 reports the results of the estimation of a nine-equation nonlinear output supply and input demand system, still including quadratic splines to capture technological change and two break points. Convexity in prices is imposed following the methodology of Wiley *et al*. (1973). The R-squared statistics are still above 0.90 for all equations, except for exports of capital goods and domestic consumption. The NQ specification is rejected on the basis of a chi-squared statistic in favour of the specification with quadratic splines.

Table 4. **Profit functions with disaggregated exports and imports: NQQS models, 1997Q1-2008Q3**

	NQQS
Log-likelihood	-4014.99
Number of parameters	81
Break points	2000Q3; 2004Q2
Centred R-squared	
Consumption	0.89
Exports of consumption goods	0.95
Exports of capital goods	0.89
Exports of intermediates	0.94
Imports of consumption goods	0.95
Imports of capital goods	0.92
Imports of intermediates	0.94
Investment	0.90
Employment	0.95
H_0: $c_1 = c_2 = c_3$	539.63
(*p*-value)	(0.00)

Source: Data available from IBGE and IPEA, and authors' estimations.

Table 5 reports the estimated elasticities. Again, all own-price elasticities are correctly signed, although they are much higher in magnitude than those reported in Table 3.[9] In addition, the effects of terms-of-trade fluctuations on the supply of inputs and the demand for inputs are consistent with those estimated above using aggregate export and import data. Terms-of-trade gains arising from export price hikes and/or falling import prices prop up exports on the back of rising imports and some labour shedding. But important findings emerge from the use of disaggregated data for imports and exports:

First, there is strong complementarity among the export components, as well as substitution between imports of capital and consumption goods. The cross-price elasticities are all positive, suggesting that all export components are complementary with each other. Exports of capital goods are particularly sensitive to variations in the prices of the other export categories, followed by consumption and intermediate goods.

9. Diewert and Lawrence (2002) have also found higher elasticities than those usually reported in the literature when using a large set of inputs and outputs. Thus, it would seem that low elasticities are, at least in part, the result of aggregation bias. Decomposing exports and imports into three different components helps to reduce this source of bias, while keeping the number of parameters to be estimated manageable and the estimation computationally feasible.

As for imports, however, there is some complementarity between consumption and intermediate goods, whereas imported capital goods substitute for the other inputs purchased from abroad.

Second, fluctuations in the terms of trade have a modest effect on investment, consumption and employment, as in the analysis based on aggregate data. But the substitution between imports and labour is driven essentially by imports of capital goods. By contrast, labour demand rises with imports of consumption and intermediate goods, suggesting complementarity among these inputs. In addition, the point estimates of the elasticity of employment with respect to the price of imported capital goods are low in magnitude. Employment therefore appears to be more strongly related to changes in the price of imports of consumption and intermediate goods. Moreover, the detrimental effect of import-price hikes on exports is particularly strong for consumption goods, with the cross-elasticity ranging from -0.3 to -0.9 over the sample period under examination.

Finally, rising labour costs are particularly detrimental to export growth, although they encourage imports of capital goods, in line with the substitution effect noted above. Investment and consumption are significantly less sensitive to fluctuations in labour costs. This result is in contrast with the positive association between wages and aggregate exports reported in Table 3.

Table 5. Price elasticities with disaggregated exports and imports, 1997Q1-2008Q3

	1998Q4	2001Q4	2004Q4	2007Q4
Elasticity of consumption with respect to the price of:				
Consumption	0.0576	0.069	0.0577	0.0413
Exports of consumption goods	0.0067	0.0031	0.0017	0.0011
Exports of capital goods	-0.0039	-0.0149	-0.0087	-0.0059
Exports of intermediate goods	0.0119	0.007	0.007	0.0057
Imports of consumption goods	-0.0084	-0.0081	-0.007	-0.0037
Imports of capital goods	0.0053	0.0068	0.0057	0.0048
Imports of intermediate goods	-0.0357	-0.0434	-0.0401	-0.0227
Investment	0.0019	0.0008	0.0004	-0.0033
Employment	-0.0354	-0.0201	-0.0167	-0.0173
Elasticity of exports of consumption goods with respect to the price of:				
Consumption	0.5088	0.1222	0.053	0.0433
Exports of consumption goods	1.4232	1.1596	0.7341	0.6445
Exports of capital goods	0.4972	0.5708	0.2658	0.1891
Exports of intermediate goods	0.339	0.2785	0.2032	0.1688
Imports of consumption goods	-0.3873	-0.3384	-0.2003	-0.1452
Imports of capital goods	-0.914	-0.8697	-0.4826	-0.3151
Imports of intermediate goods	-0.283	-0.269	-0.182	-0.1275
Investment	0.255	0.136	0.093	0.0925
Employment	-1.440	-0.791	-0.484	-0.5504
Elasticity of exports of capital goods with respect to the price of:				
Consumption	-0.555	-1.126	-0.384	-0.4301
Exports of consumption goods	0.924	1.086	0.386	0.3424
Exports of capital goods	1.497	2.537	0.660	0.4755
Exports of intermediate goods	1.0671	1.3329	0.5522	0.4635
Imports of consumption goods	-0.8575	-1.0977	-0.3621	-0.2663
Imports of capital goods	-0.8214	-1.1464	-0.3545	-0.2343
Imports of intermediate goods	-1.2883	-1.7788	-0.6713	-0.4826
Investment	1.409	1.3464	0.5569	0.5742
Employment	-1.3744	-1.1531	-0.3833	-0.4424

Source: Data available from IBGE and IPEA, and authors' estimations.

Table 5. **Price elasticities with disaggregated exports and imports, 1997Q1-2008Q3** (*cont*.)

	1998Q4	2001Q4	2004Q4	2007Q4
Elasticity of exports of intermediates with respect to the price of:				
Consumption	0.3245	0.115	0.0837	0.0862
Exports of consumption goods	0.1211	0.1158	0.0795	0.0631
Exports of capital goods	0.2053	0.2912	0.149	0.0957
Exports of intermediate goods	0.607	0.6585	0.5302	0.3984
Imports of consumption goods	-0.1556	-0.1698	-0.1098	-0.0713
Imports of capital goods	0.2248	0.264	0.1605	0.0961
Imports of intermediate goods	-0.7614	-0.8953	-0.6631	-0.4232
Investment	0.2144	0.1585	0.1262	0.1177
Employment	-0.7802	-0.5379	-0.3562	-0.3628
Elasticity of imports of consumption goods with respect to the price of:				
Consumption	0.7159	0.8741	0.8816	0.3635
Exports of consumption goods	0.4324	0.9148	0.8249	0.3544
Exports of capital goods	0.5154	1.5597	1.0278	0.359
Exports of intermediate goods	0.486	1.1046	1.1555	0.4655
Imports of consumption goods	-0.8327	-1.8837	-1.5795	-0.5667
Imports of capital goods	0.076	0.1811	0.1424	0.044
Imports of intermediate goods	-0.9011	-2.1928	-2.115	-0.7471
Investment	0.4893	0.8424	0.8692	0.4185
Employment	-0.9811	-1.4001	-1.2068	-0.6911
Elasticity of imports of capital goods with respect to the price of:				
Consumption	-0.3416	-0.3538	-0.4596	-0.3665
Exports of consumption goods	0.7784	1.1427	1.2863	0.5994
Exports of capital goods	0.3766	0.7916	0.6514	0.246
Exports of intermediate goods	-0.5357	-0.8346	-1.0926	-0.4891
Imports of consumption goods	0.058	0.088	0.0922	0.0343
Imports of capital goods	-1.4326	-2.408	-2.3714	-0.8286
Imports of intermediate goods	0.5851	0.9673	1.1619	0.4346
Investment	0.3365	0.4405	0.5587	0.2831
Employment	0.1753	0.1662	0.1732	0.0868

Source: Data available from IBGE and IPEA, and authors' estimations.

Table 5. **Price elasticities with disaggregated exports and imports, 1997Q1-2008Q3** (*cont*.)

	1998Q4	2001Q4	2004Q4	2007Q4
Elasticity of imports of intermediates with respect to the price of:				
Consumption	0.9742	0.8665	0.6523	0.4213
Exports of consumption goods	0.1014	0.1349	0.0973	0.0589
Exports of capital goods	0.2491	0.4696	0.2468	0.1231
Exports of intermediate goods	0.7652	1.0819	0.9034	0.5228
Imports of consumption goods	-0.2899	-0.4074	-0.2739	-0.1413
Imports of capital goods	0.2467	0.3698	0.2325	0.1055
Imports of intermediate goods	-1.3083	-1.9546	-1.5124	-0.7627
Investment	0.3845	0.4137	0.3332	0.2269
Employment	-1.123	-0.9745	-0.6792	-0.5545
Elasticity of investment with respect to the price of:				
Consumption	0.0097	0.0042	0.0018	-0.0146
Exports of consumption goods	0.0171	0.0178	0.0153	0.0102
Exports of capital goods	0.0508	0.0921	0.0629	0.0351
Exports of intermediate goods	0.0401	0.0497	0.0528	0.0348
Imports of consumption goods	-0.0293	-0.0406	-0.0346	-0.019
Imports of capital goods	-0.0264	-0.0437	-0.0343	-0.0165
Imports of intermediate goods	-0.0716	-0.1073	-0.1023	-0.0544
Investment	0.0589	0.0663	0.0703	0.0531
Employment	-0.0491	-0.0386	-0.0318	-0.0288
Elasticity of employment with respect the price of:				
Consumption	0.182	0.126	0.113	0.1163
Exports of consumption goods	0.0974	0.1247	0.1073	0.0921
Exports of capital goods	0.0501	0.0956	0.0586	0.0409
Exports of intermediate goods	0.1477	0.204	0.2019	0.1624
Imports of consumption goods	-0.0595	-0.0817	-0.065	-0.0474
Imports of capital goods	0.0139	0.0199	0.0144	0.0076
Imports of intermediate goods	-0.2116	-0.3059	-0.2826	-0.2009
Investment	0.0497	0.0468	0.0431	0.0436
Employment	-0.2698	-0.2295	-0.1908	-0.2145

Source: Data available from IBGE and IPEA, and authors' estimations.

6. Conclusions

This paper reports the results of estimations of input demand and output supply equations for Brazil during the period spanning 1997 through 2008. Nonlinear seemingly unrelated regressions are estimated using the gross national product function approach originally developed by Kohli (1978) and extended by Diewert and Wales (1987 and 1988) and Diewert and Wales (1992) to allow for greater flexibility in the treatment of substitution possibilities among the inputs and the outputs, as well as technological change via quadratic splines.

We estimated two specifications, treating capital as fixed in both. The first includes two variable inputs (labour and imports) and three outputs (domestic consumption, exports and investment). The second specification disaggregates exports and imports into consumption (durables and non-durables), capital and intermediate goods to deal with a possible aggregation bias resulting from heterogeneity among the different factors of productions and outputs. The results of the estimations indicate that terms-of-trade gains are associated with rising exports on the back of increasing imports and some labour shedding in the case of imports of capital goods. The effect of fluctuations in the terms of trade on domestic consumption and investment are comparatively modest.

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