Terms of Trade, Real GDP, and Real Value Added: A New Look at New Zealand's Growth Performance

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Abstract

The conventional measure of real GDP underestimates the growth in real value added when the terms of trade improve. Thus, in New Zealand, where the terms of trade have been improving over the past 15 years, real GDP has underestimated the country's real growth performance by nearly 0.4% per year on average. Our analysis has a solid theoretical foundation, being based on the GDP-function approach to modelling the production sector of an open economy.

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Preamble

Once upon a time there was an island somewhere in the South Seas. The natives spent most of their time fishing. Real GDP in this country was equal to their fish catch. The central bank, by carefully managing the supply of cowry shells, was able to maintain a constant price level. Setting the price level to unity, nominal GDP was thus equal to real GDP.

The natives' fishing boats needed a fair bit of maintenance. This was quite tedious work. Over time, the islanders realised that some of them had a comparative advantage at fixing boats, while others were relatively better at going out to sea. They thus decided that the natural born ship builders would stay on shore, while the others would do the fishing. The catch would then be shared between them all. This reorganisation of production, which involved specialisation with trade, was similar to a technological progress. It led to an increase in the total fish catch, i.e. an increase in real (and nominal) GDP.

The islanders had the choice between two fishing spots, the East Bay and the West Bay. Sometimes the fish were more plentiful in one bay, sometimes in the other. Every morning, the fishermen would randomly select a fishing site. Even though their daily catch fluctuated a fair bit, depending on whether or not they were lucky enough to have chosen the right spot, their annual catch was remarkably stable. Eventually the tribe's elders realised that the fish were mostly in the East Bay when the sky was cloudy, and in the West Bay when it was sunny. Using this new knowledge, the fishermen managed to increase their catch substantially. Thus, this new technological advance led to a further increase in real (and nominal) GDP.

The ocean was actually populated by two types of fish, blue fish and red fish. They were equally easy (or difficult) to catch. The blue fish tended to be found on the north side of the East Bay or of the West Bay, depending on the weather, whereas the red fish seemed to prefer the south side. The islanders were perfectly indifferent between the two kinds of fish. Both fish were therefore selling for the same price, and the composition of production and consumption was totally random.

The islanders knew that they were not alone in the world. There were many other, much larger, islands just beyond the horizon, with very similar economies. The only difference was that in the rest of the world the inhabitants had a very strong preference for blue fish, so much so that the price of blue fish was four times that of red fish. Needless to say, the home fishermen considered going abroad to trade blue fish for red fish, but unfortunately this was not economically feasible, for about half the cargo of fish would rot during a crossing. By shipping one ton of blue fish, only one half would arrive unspoilt. This half-ton of blue fish could then be exchanged for two tons of red fish, half of which would rot on the voyage back. Even though the other transportation costs were insignificant, the operation made no economic sense. Until the day the islanders discovered refrigeration. From that day on, the fishermen specialised in catching blue fish, and by the time they came back to their home port, they were carrying four times the amount of red fish. Real (and nominal) GDP thus quadrupled thanks to this tremendous technological progress.

Let us go back a few steps, and assume for a moment that the price of blue fish was the same as the price of red fish, at home and abroad, and, moreover, that refrigeration had been around for a long time. Since relative prices would then be the same in both regions, there would be no incentive to trade, even in the absence of transportation costs. Assume next that, for whatever reason, the price of blue fish quadrupled in the rest of the world. Trade suddenly becomes highly profitable for the home country. The fishermen harvest blue fish exclusively, and by the time they return to port, they carry four times the amount of red fish. The improvement in the terms of trade has led to a spectacular increase in real value added. What will the island's national accountant have to say about this? Although nominal GDP has quadrupled, he or she will argue that real GDP has not changed. It therefore must be the GDP deflator that has been multiplied by four, irrespective of the fact that the domestic price of fish has remained constant.

Even though the consequences of the improvement in the terms of trade here are perfectly analogous to those following the discovery of refrigeration in the previous example, the treatment of these two events by the national accounts differs radically. The former is viewed as a price effect, while the latter is viewed as a real effect. The national accounts take a very narrow view of production when it comes to international trade, even though *domestic* specialisation and *domestic* trade enter the calculation of real value added. Domestic production involves the transformation of inputs into outputs. International trade involves additional transformations. By excluding terms-of-trade effects from the calculation of an economy's real value added, one omits an important source of transformation. In most industrialised nations, services, rather than manufacturing, account for the bulk of economic activity. Many services, such as wholesaling, retailing, and banking, involve trades. The trader's markup is a measure of his or her value added. It makes little sense to handle domestic and foreign trades differently, just as it makes little sense to treat terms-of-trade effects and technological changes unevenly. The asymmetrical treatment of terms-of-trade improvements and technological progress is all the more problematic as in many cases it may not be possible to distinguish between the two. A drop in the price of imports could be caused equally well by an improvement in the terms of trade or by technological progress in the shipping industry.

1. Introduction

As shown by Figure 1, New Zealand's terms of trade have improved by approximately 24% over the past 15 years.[1] They have increased very strongly in the late 1980s, only to fall back in the early 1990s, before resuming their increase, at a more moderate pace, for the remainder of the decade. This average improvement in the terms of trade should have been a blessing for New Zealand. As any student of international trade theory knows, this must have led to an increase in real income and welfare. Yet, this improvement in New Zealand's terms of trade has, *ceteris paribus*, reduced its real GDP as it is conventionally measured.

[Figure 1 about here]

An improvement in the terms of trade means that, for a given trade balance position, the country can either import more for what it exports, or export less for what it imports. Simply put, it gets more for less. This is almost identical to a technological improvement. Both events imply an increase in real value added and in economic welfare.[2] Yet, the national accounts treat these two phenomena very differently. A technological change is considered as a real occurrence, and, for given factor endowments, it leads to an increase in the conventional measure of real GDP. An improvement in the terms of trade, on the other hand, is treated as a price phenomenon, and it enters the calculation of the GDP deflator. A drop in the price of imports, for instance, will, other things equal, lead to an increase in the GDP price deflator. This is because, GDP being defined as gross output minus imports, import prices enter the calculation of the GDP deflator with a *negative* weight.[3] Given that a change in the terms of trade is treated by the national accounts as a price — rather than as a real — phenomenon, one might expect the drop in import prices to leave real GDP unchanged. However, it turns out that it actually leads to a *decline* in the conventional (Laspeyres) measure of real GDP, even though the lower price of imports must unambiguously lead to an increase in real value added, in real

[1] The terms of trade are obtained by dividing the export deflator by the import deflator. All the years refer to the years ending on March 31. See Section 7 below for a description of the data and the actual series.

[2] Although real value added and economic welfare are clearly very different concepts, it is the case that, other things equal, an increase in real value added allows, other things equal, for an increase in welfare.

[3] See expression (14) for details.

domestic income, and in welfare.[4] The reason for this perverse result again has to do with the definition of real GDP. The drop in import prices will typically lead to more imports. This larger amount of imports then gets subtracted from gross output to get real GDP, without any adjustment being made for their new lower price.

A change in the price of traded goods relative to the price of domestic sales is likely to trigger welfare effects as well. A small equiproportionate increase in the price of imports and exports will tend to raise export revenues and the import bill. In case of a trade surplus, the former effect will dominate, thus making the country better off, while the reverse is true in case of a trade deficit. Figure 2 shows the path of the price of exports relative to the price of domestic sales for the period 1986-2001. One sees that this price was far from constant. In fact, it fell quite steeply until 1998, before recovering somewhat.[5]

[Figure 2 about here]

2. A Simple Description of the Aggregate Technology

Throughout this paper, we treat imports as an input to the technology. This treatment is consistent with the fact that most of world trade is in raw materials and intermediate products, and that even most so-called "finished" products must still transit through the production sector — where they are combined with domestic value added — before reaching final demand. Furthermore, this treatment of imports is consistent with the national accounts framework where imports are treated as a negative output.

We begin with a very simple description of the aggregate technology, similar to the one used by Kohli (1983). Thus, we assume that gross output is produced by a domestic composite factor of production (an aggregate of labour and capital) and imports. For the time being, we assume a single output that can be either absorbed at home or exported to the rest of the world to pay for imports. In accordance with standard trade theory, we view the endowment of the composite factor and the prices of goods as exogenous. We denote the quantity of imports at

[4] See Kohli (1983, 2003). Although most statisticians are well aware of the difference between real GDP and real domestic income, this distinction is generally overlooked in practice. Thus, Prescott (2002), who describes New Zealand as a depressed economy, focuses exclusively on real GDP and never even mentions terms-of-trade changes.

[5] The price of domestic sales (p_S) is computed as a Törnqvist index of the deflators of consumption expenditures, investment, and government purchases.

time t by $q_{M,t}$, the endowment of the domestic aggregate factor by x_t, and the quantity of gross output by $q_{Y,t}$. The technology can be described by the following aggregate production function:

(1) $$q_{Y,t} = f(q_{M,t}, x_t) \ .$$

We assume that $f(\cdot)$ is twice continuously differentiable, increasing, linearly homogeneous, and quasi-concave. The competitive equilibrium can be described as the solution of maximising GDP, subject to the technology, the domestic factor endowments, and the prices of goods. This leads to the following first-order condition:

(2) $$f_M(q_{M,t}, x_t) = \frac{p_{M,t}}{p_{Y,t}} \ ,$$

where $f_M(\cdot) \equiv \partial f(\cdot)/\partial q_{M,t}$; $p_{M,t}$ is the price of imports, and $p_{Y,t}$ is the price of output. Condition (2) can be solved for $q_{M,t}$ to yield the import demand function:

(3) $$q_{M,t} = q_M(p_{M,t}, p_{Y,t}, x_t) \ .$$

Quasi-concavity and linear homogeneity of the production function imply that the demand for imports is decreasing in its own price; linear homogeneity implies that the demand for imports is homogeneous of degree one in x_t; profit maximisation, finally, guarantees that the demand for imports is homogeneous of degree zero in prices. Assuming that the aggregate domestic factor is mobile between firms, its competitive rental price (w_t) will be equal to the value of its marginal product:

(4) $$w_t = p_{Y,t} f_x(q_{M,t}, x_t) = p_{Y,t} f_x\left[q_M(p_{M,t}, p_{Y,t}, x_t)\right] = w(p_{M,t}, p_{Y,t}, x_t) \ ,$$

where, naturally, $f_x(\cdot) \equiv \partial f(\cdot)/\partial x_t$.

As an alternative to the production function, we can also use the country's GNP/GDP function to describe its technology.[6] This will prove very useful later on when we generalise the model and increase the number of inputs and outputs. The GDP function is defined as follows:

(5) $$\pi(p_{M,t}, p_{Y,t}, x_t) \equiv \max_{q_M, q_Y} \{p_{Y,t} q_Y - p_{M,t} q_M : q_Y = f(q_M, x_t)\} \ ,$$

for $p_{M,t}, p_{Y,t} > 0, x_t \geq 0$. As shown by Diewert (1974), given the assumptions made on $f(\cdot)$, this function is linearly homogeneous and convex in prices, linearly homogeneous in the endowment of the domestic factor, nondecreasing in $p_{Y,t}$ and nonincreasing in $p_{M,t}$. Moreover, Hotelling's Lemma implies that import demand function (3) can be obtained directly by differentiation of the GDP function:

[6] See Kohli (1978, 1991), Woodland (1982).

(6) $$q_M(p_{M,t}, p_{Y,t}, x_t) = -\frac{\partial \pi(\cdot)}{\partial p_{M,t}} .$$

Similarly, the supply of gross output can be obtained as:

(7) $$q_Y(p_{M,t}, p_{Y,t}, x_t) = \frac{\partial \pi(\cdot)}{\partial p_{Y,t}} ,$$

whereas the competitive return to the domestic factor is given by:

(8) $$w(p_{M,t}, p_{Y,t}, x_t) = \frac{\partial \pi(\cdot)}{\partial x_t} .$$

Before we proceed, it is useful to define some additional concepts. *Nominal* GDP measures the value of all final goods and services produced during a given period of time. It is given by the value of the GDP function; in view of (5) it can thus be defined as:

(9) $$\pi_t \equiv p_{Y,t} q_{Y,t} - p_{M,t} q_{M,t} .$$

Next, we define *real value added* (y_t) — or, alternatively, *real net output* — as nominal GDP deflated by the price of output:[7]

(10) $$y_t \equiv \frac{\pi_t}{p_{Y,t}} = \frac{p_{Y,t} q_{Y,t} - p_{M,t} q_{M,t}}{p_{Y,t}} = q_{Y,t} - \frac{p_{M,t}}{p_{Y,t}} q_{M,t} .$$

From the linear homogeneity of the production function, one can see that:

(11) $$p_{Y,t} q_{Y,t} - p_{M,t} q_{M,t} = w_t x_t .$$

Hence, real value added in this model is equal to *real income*, i.e. nominal income deflated by the price of output:

(12) $$y_t = \frac{w_t x_t}{p_{Y,t}} .$$

The conventional measure of *real* GDP (q_t^L) is defined as follows:[8]

(13) $$q_t^L \equiv q_{Y,t} - q_{M,t} .$$

This last definition is of course well known to anyone familiar with the national accounts, where real GDP is defined as the constant-dollar value of gross output minus the constant-dollar value of imports. It is common practice, finally, to divide nominal GDP by real GDP to obtain an average price of GDP, also known as the GDP deflator (p_t^P):

[7] All price and quantity indices are defined relative to a base period, for which prices are typically normalised to one.

[8] Statistics New Zealand has recently switched from a direct (fixed-based) to a chain Laspeyres index of real GDP. This means that expression (13) is only valid for consecutive periods: it is as if one renormalised prices every period. Comparisons over extended periods of time can be made by compounding the yearly changes.

(14) $$p_t^P \equiv \frac{\pi_t}{q_t^L} = \frac{1}{(1+s_{M,t})p_{Y,t}^{-1} - s_{M,t}p_{M,t}^{-1}} ,$$

where $s_{M,t}$ is the GDP share of imports: $s_{M,t} \equiv p_{M,t}q_{M,t}/\pi_t$. It is well known that, given that real GDP as defined by (13) is a Laspeyres quantity index, the implicit GDP deflator as given by (14) has the Paasche form.

3. Graphical Analysis

Figure 3 represents the production function in (q_M, q_Y) space.[9] For given x, the function is increasing and concave in q_M. It need not go through the origin: the distance ***OA*** represents output in autarky. If the relative price of imports (p_M/p_Y) — the inverse of the terms of trade — is given by the slope of line ***BC***, then GDP is maximised at point ***C*** where the marginal product of imports is equal to its relative price. Imports are given by the distance ***OD***, gross output is equal to ***OE***. Real income of the domestic composite factor is equal to ***OB***. This can also be interpreted at domestic real value added or real net output. Under balanced trade, exports are equal to ***BE*** and domestic absorption amounts to ***OB***. Absorption exceeds ***OB*** if there is a trade deficit, or falls short of it if there is a surplus. Assuming that all prices are normalised to one initially, real GDP too is given by the distance ***OB***. Thus, this far, we can interpret real GDP as a measure of real net output, real value added, and real income. Note that the distance ***AB*** can be interpreted as the gains from trade.

[Figure 3 about here]

Consider now the effect of an improvement in the country's terms of trade, i.e. a reduction in the relative price of imports. Assume that the new terms of trade are given by the slope of ***B'C'***. The equilibrium point moves to the northeast, from ***C*** to ***C'***. Imports increase from ***OD*** to ***OD'***, and gross output goes up, from ***OE*** to ***OE'***. Real value added unambiguously increases, from ***OB*** to ***OB'***.[10] What about real GDP? It can easily be seen that real GDP *decreases*, from ***OB*** to ***OF***: ***F*** is the intercept of the line through ***C'*** with a negative unit slope; this slope is minus one because real GDP — as shown by (13) — is evaluated at base-period

[9] The time subscripts are omitted in this section and the next for more clarity.

[10] It is interesting to note that this outcome does not depend on the position of the trade account. That is, since exports are assumed, for the time being, to be perfect substitutes for goods intended for domestic use, the effect of a change in the terms of trade on real value added is independent of the level of exports.

prices.[11] The intuitive explanation of this phenomenon is as follows. When import prices fall, the country can afford to import more. Yet, as shown by (13), real GDP is obtained by subtracting imports valued at their base-period prices. By failing to take into account the lower price of imports, one ends up subtracting too much.

Another way to look at the problem is to consider the effect of a change in the terms of trade on the GDP deflator. As shown by (14), a drop in the price of imports leads, *ceteris paribus*, to an increase in the GDP deflator, even though no price actually increases. This shows that, contrary to common belief, the GDP deflator is a poor index of the general price level. Indeed, the drop in the price of imports has no inflationary effects, quite the contrary. Consequently, if the GDP deflator overestimates the price of value added, real GDP must underestimate its quantity.

If the terms of trade were to worsen, imports, gross output, and real value added would fall. So would real GDP. However, real GDP would tend to underestimate the reduction in real value added. While real GDP will tend to underestimate the negative effect of a deterioration in the terms of trade, the situation is much more serious in the case of an improvement in the terms of trade, since real GDP will move in the *wrong direction*.

While our analysis is based on the GDP-function approach to modelling imports and exports, the same type of bias could be exposed if one used instead the Heckscher-Ohlin-Samuelson model of international trade where imports are treated as final goods. An improvement in the terms of trade relative to the base period, while unambiguously increasing real income, would lead to a reduction in real GDP, i.e. total output minus imports valued at base period prices.[12]

It might be useful to emphasise here that the fact that an improvement in the terms of trade leads to a reduction in the Laspeyres index of real GDP has nothing to do with chaining or the absence of it. The example illustrated by Figure 3 refers to two states — or two periods — only. Hence, there can be no difference between chain and direct indices. Statistics New Zealand has recently moved from a direct (fixed-based) Laspeyres measure of real GDP to a chain Laspeyres index. Although chain indices are to be preferred to direct ones in almost every respect, this switch does not address the problem identified in this paper. The reason why real GDP drops in our example has to do with the functional form that is being used. The Laspeyres quantity index tends to underestimate the aggregate quantity in the context of production

[11] In fact, as noted by Kohli (1983), if the terms-of-trade improvement were sufficiently large, real GDP could become negative!
[12] See Kohli (2003) for additional details.

theory, except in the extreme cases of linear and Leontief aggregator functions. It only provides a linear approximation to what is shown in Figure 3 to be a nonlinear production function. If, instead of the Laspeyres index, one used a quantity index that is exact for the depicted production function,[13] the index of real GDP would remain constant. However, it would still fail to pick up the increase in real value added that results from the drop in import prices.[14]

4. Numerical Example: The Cobb-Douglas Functional Form

How large is the bias illustrated in Figure 3? Some back-of-the-envelope calculations using New Zealand data can be based on the assumption that the technology is Cobb-Douglas. Assume that the production function is given by:

$$(15) \qquad f(q_M, x) = \gamma q_M^{\alpha} x^{(1-\alpha)} \ .$$

The GDP function then is as follows:

$$(16) \qquad \pi(p_M, p_Y, x) = \delta p_M^{1-\beta} p_Y^{\beta} x \ ,$$

where $\delta \equiv (1-\alpha)\alpha^{\alpha/(1-\alpha)}\gamma^{1/(1-\alpha)}$ and $\beta \equiv 1/(1-\alpha)$.[15] The demand for imports, supply of gross output, and domestic factor rental price are obtained by differentiation:

$$(17) \qquad q_M = -\delta(1-\beta) p_M^{-\beta} p_Y^{\beta} x$$

$$(18) \qquad q_Y = \delta \beta p_M^{1-\beta} p_Y^{\beta-1} x$$

$$(19) \qquad w = \delta p_M^{1-\beta} p_Y^{\beta}$$

Consider now the effect of a *large* change in the price of imports, from $p_{M,0}$ to $p_{M,1}$. The changes in the quantity of imports, gross output, and the domestic factor rental price are as follows:

$$(20) \qquad \Delta q_M = -\delta(1-\beta) p_Y^{\beta} x (p_{M,1}^{-\beta} - p_{M,0}^{-\beta})$$

$$(21) \qquad \Delta q_Y = \delta \beta p_Y^{\beta-1} x (p_{M,1}^{1-\beta} - p_{M,0}^{1-\beta})$$

$$(22) \qquad \Delta w = \delta p_Y^{\beta} (p_{M,1}^{1-\beta} - p_{M,0}^{1-\beta}) \ ,$$

where *Δ* is the first-difference operator. Assume that p_Y and p_M are normalized to one initially; (20)-(22) then become:

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[13] Thus, the Törnqvist index is exact for the translog functional form, whereas the Fisher index is exact for the square-rooted quadratic; see Diewert (1976).

[14] The United Sates currently uses a chain Fisher index of real GDP. An improvement in the terms of trade is therefore likely to have little impact on the index of real GDP, although real value added must unambiguously increase.

[15] See Kohli (1991), page 40.

(23) $\Delta q_M = -\delta(1-\beta)x(p_{M,1}^{-\beta} - 1)$

(24) $\Delta q_Y = \delta \beta x(p_{M,1}^{1-\beta} - 1)$

(25) $\Delta w = \delta(p_{M,1}^{1-\beta} - 1)$.

One notes from (25) that an increase (decrease) in the price of imports unambiguously reduces (increases) the return to the domestic factor. Hence, for given factor endowments and a given technology, an improvement in the terms of trade must increase real domestic income, real net output and real value added. The change in real GDP, on the other hand, can be calculated as:

(26) $\Delta q^L = \Delta q_Y - \Delta q_M = \delta x\left[\beta p_{M,1}^{1-\beta} + (1-\beta)p_{M,1}^{-\beta} - 1\right]$.

Using 1986 New Zealand figures, and normalising all 1986 prices to unity, we find that $\beta = 1 + q_M / q_L$ is approximately equal to 1.34. We can interpret δ as the 1986 return to the domestic factor (w), and δx as 1986 real GDP (q^L). From 1986 to 2001, the New Zealand terms of trade improved by about 24%; hence, we can set $p_{M,t}$ to 0.81. Using these figures, we find, on the basis of (26), that a 24% improvement in the terms of trade *reduces* real GDP by about 1.1%, while, judging from (25), it *increases* real value added by about 7.4%. Thus, as a first approximation, we find that the change in real GDP underestimates the increase in real value added that took place between 1986 and 2001 by about 8.5%.

5. Generalisation

The model of the previous sections was rather restrictive. Fortunately, it can easily be generalised to allow for technological change and to allow for many inputs and outputs.[16] Let us assume two outputs, domestic sales (S) and exports (X), as well as two primary inputs, labour (L) and capital (K).[17] Primary input and output (including import) quantities at time t are denoted by $x_{j,t}$ and $q_{i,t}$, respectively, with prices $w_{j,t}$ and $p_{i,t}$ ($j \in \{L, K\}, i \in \{S, X, M\}$). It is again convenient to describe the country's technology by the GDP function that is now defined as:[18]

(27) $\pi(p_{S,t}, p_{X,t}, p_{M,t}, x_{L,t}, x_{K,t}, t) \equiv \max\{p_{S,t}q_S + p_{X,t}q_X - p_{M,t}q_M : (q_S, q_X, q_M, x_{L,t}, x_{K,t}) \in T_t\}$,

[16] This section and the next are based on Kohli (2003) to which we refer the reader for additional details and a proof of the various results.
[17] Domestic sales are an aggregate of consumption expenditures, investment, and government purchases.
[18] See Kohli (1978, 1991), and Woodland (1982).

where T_t is the production possibilities set at time t; it is assumed to be a convex cone. The GDP function is linearly homogeneous and convex in prices, and linearly homogeneous and concave in input quantities.

It is well known that the profit-maximising output supply and import demand functions can be obtained by differentiation:[19]

(28) $$q_{i,t} = \pm \frac{\partial \pi(\cdot)}{\partial p_{i,t}} = q_i(p_{S,t}, p_{X,t}, p_{M,t}, x_{L,t}, x_{K,t}, t) \ , \quad i \in \{S, X, M\} \ ,$$

where the minus sign applies to imports. Moreover, assuming that the domestic factors are mobile between firms, the derivatives with respect to the fixed input quantities yields the competitive domestic factor rental prices:

(29) $$w_{j,t} = \frac{\partial \pi(\cdot)}{\partial x_{j,t}} = w_j(p_{S,t}, p_{X,t}, p_{M,t}, x_{L,t}, x_{K,t}, t) \ , \quad j \in \{L, K\} \ ,$$

For given factor endowments and output prices, the GDP function model is capable of determining the demand for imports and the supply of exports, and hence the position of the trade account. It can explain the adjustment in trade flows that result from changes in relative prices and/or factor endowments, holding other things equal. Nonetheless, the GDP function only deals with the production side of the economy, and it thus remains a partial-equilibrium model. The prices of imports and exports can be viewed as exogenous by invoking the small-open-economy assumption, but the price of domestic sales depends on domestic demand conditions, and thus it is not explained by the model. Similarly, the model does not explain the rate of capital accumulation, or the supply of labour. Monetary variables, such as the exchange rate and the balance of payments, clearly also remain beyond the scope of our model. This should not be viewed as a shortcoming of our approach, however, since we are dealing with measurement issues. We are interested in aggregating observed quantities in way that is coherent with a well-behaved underlying production model, and it is legitimate to take the historical values of prices and factor endowments as given.

In what follows, it will be convenient to define g_t as the inverse terms of trade, and h_t as the relative price of exports where domestic sales are used as the numeraire:

(30) $$g_t \equiv \frac{p_{M,t}}{p_{X,t}}$$

(31) $$h_t \equiv \frac{p_{X,t}}{p_{S,t}} \ .$$

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[19] Again, see Kohli (1978, 1991) and Woodland (1982).

GDP function (27) can then be rewritten as:

(32) $\pi(p_{S,t}, h_t p_{S,t}, h_t g_t p_{S,t}, x_{L,t}, x_{K,t}, t) \equiv \psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)$.

It follows from the properties of $\pi(\cdot)$ that GDP function $\psi(\cdot)$ is linearly homogeneous in $p_{S,t}$. Moreover, one can see from (28)-(29) and (32) that:

(33) $$\frac{\partial \psi(\cdot)}{\partial p_{S,t}} = q_{S,t} + h_t q_{X,t} - h_t g_t q_{M,t}$$

(34) $$\frac{\partial \psi(\cdot)}{\partial h_t} = p_{S,t}(q_{X,t} - g_t q_{M,t})$$

(35) $$\frac{\partial \psi(\cdot)}{\partial g_t} = -p_{X,t} q_{M,t}$$

(36) $$\frac{\partial \psi(\cdot)}{\partial x_{j,t}} = w_{j,t} \ , \quad j \in \{L, K\}$$

(37) $$\frac{\partial \psi(\cdot)}{\partial t} = \frac{\partial \pi(\cdot)}{\partial t} \ .$$

As shown by Diewert and Morrison (1986) in their path-breaking article, the GDP function is a convenient analytical tool to identify the GDP effect of technological progress. The following index indicates the GDP impact of the passage of time, holding all output prices and domestic factor endowments constant:

(38) $$R^L_{t,t-1} \equiv \frac{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t)}{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \ .$$

Note that all output prices and domestic input quantities were held constant at their values in period *t*-1. $R^L_{t,t-1}$ is thus a Laspeyres type of index. Alternatively one could have frozen output prices and fixed input quantities at their period-*t* values to obtain the following Paasche-like index of the GDP effect of technological progress:

(39) $$R^P_{t,t-1} \equiv \frac{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)}{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t-1)} \ .$$

Diewert and Morrison (1986) recommend taking the geometric average of the two indices just defined. This yields the following Fisher-like index of the GDP effect of technological progress:

(40) $$R_{t,t-1} \equiv \sqrt{R^L_{t,t-1} R^P_{t,t-1}} \ .$$

The GDP impact of changes in domestic factor endowments can be defined in a similar way:[20]

(41) $$X_{L,t,t-1} \equiv \sqrt{\frac{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t}, x_{K,t-1}, t-1)}{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \frac{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)}{\psi(p_{S,t}, h_t, g_t, x_{L,t-1}, x_{K,t}, t)}}$$

(42) $$X_{K,t,t-1} \equiv \sqrt{\frac{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t}, t-1)}{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \frac{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)}{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t-1}, t)}} \; .$$

Next, we can define the following GDP terms-of-trade effect:

(43) $$G_{t,t-1} \equiv \sqrt{\frac{\psi(p_{S,t-1}, h_{t-1}, g_t, x_{L,t-1}, x_{K,t-1}, t-1)}{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \frac{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)}{\psi(p_{S,t}, h_t, g_{t-1}, x_{L,t}, x_{K,t}, t)}} \; ,$$

and the GDP trade-balance effect:

(44) $$H_{t,t-1} \equiv \sqrt{\frac{\psi(p_{S,t-1}, h_t, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)}{\psi(p_{S,t-1}, h_{t-1}, g_{t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \frac{\psi(p_{S,t}, h_t, g_t, x_{L,t}, x_{K,t}, t)}{\psi(p_{S,t}, h_{t-1}, g_t, x_{L,t}, x_{K,t}, t)}} \; .$$

Some explanations regarding $H_{t,t-1}$, the GDP trade-balance effect, might be necessary. While an improvement in the terms of trade *ceteris paribus* unambiguously increases real value added and welfare, a change in the price of traded goods relative to the price of domestic expenditures may have real effects as well. Consider a small equiproportionate increase in the prices of imports and exports (as the result of a depreciation of the home currency, for instance), so that the terms of trade remain the same. If trade is balanced, the additional export revenues exactly offset the extra cost of the imports. In case of a trade deficit, however, the higher traded-good prices will make the country worse off, while the reverse is true in the case of a trade surplus. A change in *h* thus triggers a welfare effect, the sign of which depends on the position of the trade balance. The trade account acts somewhat like a lever in this experiment, and it magnifies the change in the relative price of traded goods. This kind of effect is typically buried in the GDP price deflator, but, even though it will generally be small, it is a real effect that needs to be identified and considered separately. Note that this effect vanishes if exports are perfect substitutes for the goods destined for the domestic market. This was the assumption underlying the model of Sections 2-4.

All five effects just defined are real, and thus they contribute to explaining changes in the country's real value added. To square things off, we finally define the GDP effect of domestic price changes:

[20] See Kohli(1990).

$$(45) \qquad P_{S,t,t-1} \equiv \sqrt{\frac{\psi(p_{S,t},h_{t-1},g_{t-1},x_{L,t-1},x_{K,t-1},t-1)}{\psi(p_{S,t-1},h_{t-1},g_{t-1},x_{L,t-1},x_{K,t-1},t-1)}\frac{\psi(p_{S,t},h_t,g_t,x_{L,t},x_{K,t},t)}{\psi(p_{S,t-1},h_t,g_t,x_{L,t},x_{K,t},t)}} \; .$$

6 Measurement

Assume that the GDP function has the following translog form:[21]

$$(46) \qquad \begin{aligned} \ln \pi_t = {} & \alpha_0 + \sum_i \alpha_i \ln p_{i,t} + \sum_j \beta_j \ln x_{j,t} + \frac{1}{2}\sum_i \sum_h \gamma_{ih} \ln p_{i,t} \ln p_{h,t} + \\ & \frac{1}{2}\sum_j \sum_k \phi_{jk} \ln x_{j,t} \ln x_{k,t} + \sum_i \sum_j \delta_{ij} \ln p_{i,t} \ln x_{j,t} + \\ & \sum_i \delta_{iT}\, t \ln p_{i,t} + \sum_j \phi_{jT}\, t \ln x_{j,t} + \beta_T\, t + \frac{1}{2}\phi_{TT}\, t^2 \\ & \qquad i,h \in \{S,X,M\},\; j,k \in \{L,K\} \;, \end{aligned}$$

where:

$$\sum_i \alpha_i = 1, \sum_j \beta_j = 1, \gamma_{ih} = \gamma_{hi}, \phi_{jk} = \phi_{kj}, \sum \gamma_{ih} = \sum \phi_{jk} = \sum_i \delta_{ij} = \sum_j \delta_{ij} = \sum_i \delta_{iT} = \sum_j \delta_{jT} = 0 \; .$$

One can show that if GDP function $\pi(\cdot)$ is translog, then GDP function $\psi(\cdot)$ defined by (32) is translog as well.[22] That is, $\psi(\cdot)$ then provides a flexible representation of the country's technology.

If estimates of the translog GDP function were available, it would be a simple matter to calculate the various effects defined in the previous section.[23] However, it turns out that as long as the true GDP function is translog, all these effects can be calculated from the data alone; that is, without needing to know the values of the parameters of the GDP function. Thus, following in the footsteps of Diewert and Morrison (1986), one can show that:[24]

$$(47) \qquad R_{t,t-1} = \frac{\Pi_{t,t-1}}{P_{t,t-1} \times X_{t,t-1}} \;,$$

where $\Pi_{t,t-1}$ is the growth factor of nominal GDP, $P_{t,t-1}$ is a Törnqvist price index of the GDP output components, and $X_{t,t-1}$ is a Törnqvist quantity index of domestic factor endowments:

$$(48) \qquad \Pi_{t,t-1} \equiv \frac{\psi(p_{S,t},h_t,g_t,x_{L,t},x_{K,t},t)}{\psi(p_{S,t-1},h_{t-1},g_{t-1},x_{L,t-1},x_{K,t-1},t-1)} = \frac{p_{S,t}q_{S,t} + p_{X,t}q_{X,t} - p_{M,t}q_{M,t}}{p_{S,t-1}q_{S,t-1} + p_{X,t-1}q_{X,t-1} - p_{M,t-1}q_{M,t-1}}$$

[21] See Christensen, Jorgenson and Lau (1973) and Diewert (1974). See Kohli (1978) for an early empirical estimation of this function. Estimates for New Zealand can be found in Fox, Kohli, and Warren (2002).
[22] See Kohli (2003).
[23] See Kohli (1990, 1991) for such an econometric approach.
[24] See Kohli (2003).

(49) $$P_{t,t-1} \equiv \exp\left[\sum_i \frac{1}{2}(s_{i,t} + s_{i,t-1}) \ln \frac{p_{i,t}}{p_{i,t-1}}\right], \quad i \in \{S, X, M\}$$

(50) $$X_{t,t-1} \equiv \exp\left[\sum_j \frac{1}{2}(s_{j,t} + s_{j,t-1}) \ln \frac{x_{j,t}}{x_{j,t-1}}\right], \quad j \in \{L, K\} ,$$

where $s_{i,t}$ and $s_{j,t}$ are the GDP shares of output i and primary input j, respectievely: $s_{i,t} \equiv p_{i,t} q_{i,t} / \pi_t$, $s_{j,t} \equiv w_{j,t} x_{j,t} / \pi_t$, $i \in \{S, X, M\}$, $j \in \{L, K\}$. Similarly, it can be shown that:[25]

(51) $$X_{j,t,t-1} \equiv \exp\left[\frac{1}{2}(s_{j,t} + s_{j,t-1}) \ln \frac{x_{j,t}}{x_{j,t-1}}\right], \quad j \in \{L, K\} ,$$

(52) $$G_{t,t-1} \equiv \exp\left[\frac{1}{2}(-s_{M,t} - s_{M,t-1}) \ln \frac{g_t}{g_{t-1}}\right],$$

(53) $$H_{t,t-1} \equiv \exp\left[\frac{1}{2}(s_{B,t} + s_{B,t-1}) \ln \frac{h_t}{h_{t-1}}\right],$$

where $s_{B,t} \equiv s_{X,t} - s_{M,t}$, and:

(54) $$P_{S,t,t-1} = \frac{p_{S,t}}{p_{S,t-1}} .$$

Finally, it can be shown that the six effects that we just defined together give a *complete* decomposition of the growth in nominal GDP:[26]

(55) $$\Pi_{t,t-1} = P_{S,t,t-1} \times H_{t,t-1} \times G_{t,t-1} \times X_{L,t,t-1} \times X_{K,t,t-1} \times R_{t,t-1} .$$

It is noteworthy that the product of the first three terms on the right-hand side of (55) yields the Törnqvist price index defined by (49):

[25] Our measure of the terms-of-trade effect -- see (52) below -- is different from the one proposed by Diewert and Morrison (1986), and which is defined in terms of GDP function (27) directly:

$$A_{t,t-1} \equiv \sqrt{\frac{\pi(p_{S,t-1}, p_{X,t}, p_{M,t}, x_{L,t-1}, x_{K,t-1}, t-1)}{\pi(p_{S,t-1}, p_{X,t-1}, p_{M,t-1}, x_{L,t-1}, x_{K,t-1}, t-1)} \frac{\pi(p_{S,t}, p_{X,t}, p_{M,t}, x_{L,t}, x_{K,t}, t)}{\pi(p_{S,t}, p_{X,t-1}, p_{M,t-1}, x_{L,t}, x_{K,t}, t)}} .$$

Diewert and Morrison (1986) show that, if the true GDP function is translog, $A_{t,t-1}$ can be calculated as:

$$A_{t,t-1} \equiv \exp\left[\sum_i \frac{1}{2}(s_{i,t} + s_{i,t-1}) \ln \frac{p_{i,t}}{p_{i,t-1}}\right], \quad i \in \{X, M\} .$$

There are, however, a couple of difficulties with $A_{t,t-1}$. Thus, if the prices of imports and exports increase in the same proportions (following a devaluation of the national currency, for instance), $A_{t,t-1}$ will register a change unless trade happens to be balanced on average over the two periods, even though the terms of trade clearly do not change in such a case. Put differently, $A_{t,t-1}$ which is meant to measure a real effect, is generally not homogeneous of degree zero in prices. This implies that the element that is supposed to measure the contribution of prices in the GDP growth decomposition will generally not be homogeneous of degree one in prices.

[26] See Kohli (2003) for a proof.

$$P_{t,t-1} = P_{S,t,t-1} \times H_{t,t-1} \times G_{t,t-1} \quad (56)$$

In other words, the remaining three terms together provide a measure of what can be called an implicit Törnqvist index of real GDP:[27]

$$\tilde{Q}_{t,t-1} \equiv X_{L,t,t-1} \times X_{K,t,t-1} \times R_{t,t-1} = \frac{\Pi_{t,t-1}}{P_{t,t-1}} \quad (57)$$

Such an implicit Törnqvist index of real GDP would be preferable to the Laspeyres index commonly used, in that it is a superlative index. Nevertheless, it excludes the terms-of-trade effect and the trade-balance effect that we have repeatedly characterised as real — rather than price — effects. These considerations lead us to define the following implicit Törnqvist index of real value added ($\tilde{Y}_{t,t-1}$) obtained by combining all five real effects contained in (55):

$$\tilde{Y}_{t,t-1} \equiv H_{t,t-1} \times G_{t,t-1} \times X_{L,t,t-1} \times X_{K,t,t-1} \times R_{t,t-1} = \tilde{Q}_{t,t-1} \times H_{t,t-1} \times G_{t,t-1} = \frac{\Pi_{t,t-1}}{P_{S,t,t-1}} \quad (58)$$

It is noteworthy that ($\tilde{Y}_{t,t-1}$), which measures the combined effect of five real forces, can be obtained simply by deflating the change in nominal GDP by the index measuring the change in domestic prices; that is, without needing any data on the inputs of labour and capital. This is quite useful given the difficulties that one generally encounters when one tries to find adequate data on the prices and quantities of domestic primary inputs.

7. Evidence for New Zealand

All the data used in this paper are taken from the New Zealand National Accounts, Tables 1A1 and 2A1. Current dollar figures for GDP (expenditure basis) and its main components are shown in Table 1 for the years 1986-2001. All years refer to the periods ending on March 31. Figures for GNE (gross national expenditure) are also reported. The corresponding quantity series expressed in 1995/96 prices are shown in Table 2, and the implicit price deflators in Table 3. The *v*'s denote nominal values, whereas the *q*'s and the *p*'s are again used for quantities and prices. The labels *C*, *I*, *G*, *X*, *M* stand, respectively, for consumption, investment, government consumption, exports, and imports. Investment is defined as the sum of gross fixed capital formation and changes in inventories. Statistics New Zealand has recently begun to compute real GDP and its components using chain Laspeyres quantity indices. These are

[27] See Kohli (1999).

currently only available for the years since 1988. Figures for the earlier years were obtained by linking the (fixed-weighted) back-series with the revised ones.

[Tables 1, 2, and 3 about here]

It is immediately apparent from Table 3 that, over the entire sample period, the price of imports has increased by less than the price of exports; this merely confirms the upward trend in the terms of trade that was already depicted by Figure 1. Furthermore, one can note that the implicit GNE price deflator has increased by less than its GDP counterpart. This divergence is precisely due to the improving terms of trade, since, as we have seen earlier, a drop in the relative price of imports tends to raise the implicit GDP price deflator, but, being excluded from its calculation, it has no such effect on the GNE deflator. Consequently, if the GDP deflator overestimates price developments, we should expect real GDP to underestimate real growth.

[Figure 4 about here]

We show in Figure 4 the yearly values of $G_{t,t-1}$ and $H_{t,t-1}$ for the period 1987 to 2001. It can be seen that the terms-of-trade effect fluctuates a fair bit. It is greater than one on average, although its contribution to GDP growth was negative in 1991-1992, and in 1998-2000. These were the years when the terms of trade worsened. As to the trade-balance effect, it is very small for most years. It cannot be ignored, however, if one wants the decomposition of GDP growth given by (55) to hold exactly.

[Figure 5 about here]

Figure 5 shows the cumulated paths of our implicit Törnqvist index of real value added and of the official measure of real GDP starting in 1986. As expected, it is apparent that over the past 15 years real value added has increased more rapidly than the real GDP figures suggest. The difference between the two lines reflects mostly the positive average contribution of the terms-of-trade effect.[28] From 1986 to 2001, real GDP has increased by just under 39%. This translates into a yearly average growth rate of 2.22%. Real value added, on the other hand, has increased by a total of close to 47%, or, on average, by about 2.58% annually. Real GDP

[28] It can be seen from Figure 4 that the contribution of the trade-balance effect is negligible in the case of New Zealand. Some of the difference is also imputable to the fact that the official measure of real GDP is a Laspeyres

thus underestimated the growth in real value added by close to 0.4% annually over the past 15 years. The cumulated growth deficit adds up to about 5.43% over the period.[29] Taking 2001 figures, this amounts to about 5.7 billion dollars at 1995/96 prices.

The real growth of the economy is one of the most closely watched statistics, and any deviation from trend can trigger policy responses. It is therefore important to have a reading that is as accurate as possible. Our estimate of a 0.4% annual growth deficit is an average over a long period, and it masks significant yearly discrepancies. We therefore report in Table 4 annual growth rates for the period 1987-2001. The figure in the first column is based on the official measure of real GDP ($Q^L_{t,t-1} \equiv q^L_t / q^L_{t-1}$), while next to it we report the growth rate implied by our implicit Törnqvist index of real value added ($\tilde{Y}_{t,t-1}$). The difference between the two estimates can be substantial. Thus, it exceeds 1 percentage point in absolute value in 5 out the 15 years in the sample. It is as high as 2.2 percentage points (in 1988), and as low as -1.5 percentage points (in 1991). Such large disparities can considerably alter one's perception of the economy's performance.

[Table 4 about here]

In order to obtain our implicit Törnqvist measure of real value added, we have used a Törnqvist price index to deflate nominal GDP. This choice was motivated by the fact that the Törnqvist index is exact for the translog aggregator function. However, other, perhaps more familiar, price indices could be used. Thus, it would make little numerical difference if p_S were calculated as a Fisher index. One could even use a chain Paasche index. Thus, perhaps the simplest measure of real value added in the New Zealand case would be to deflate nominal GDP by the implicit deflator of Gross National Expenditure, an index that is readily available from the New Zealand national accounts (see also Table 3). The growth rate implied by the resulting series ($Y^L_{t,t-1}$) is shown in the last column of Table 4. One can see that it conveys essentially the same information as our Törnqvist index. The difference between the two growth measures never exceeds 25 basis points.

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chain index, whereas our calculations are based on the Törnqvist aggregation, but this effect turns out to be very small as well.

29 This is less than our back-of-the-envelope estimate of Section 4. This is because the Cobb-Douglas functional only provides a first-order approximation (in logarithms) to an arbitrary production function, whereas the translog gives a second-order approximation. Given that the terms-of-trade change that we are dealing with here is quite large, we should not be surprised by this difference.

For simplicity, we have ignored the fact that some domestic factors of production might be foreign owned, and that some national factors of production might be held abroad. That is, we have not made a distinction between GDP and GNP, or between domestic and national income. In New Zealand, production and income defined on a national basis tend to be less than when defined on a domestic basis given that the country is a net debtor. Nonetheless, our discussion applies to both concepts. For a given level of net foreign factor payments, an improvement in the terms of trade will tend to lower real GNP, whereas national income would necessarily increase.[30] We would therefore recommend to deflate nominal GNP by a domestic price level — such as p_S or the implicit GNE price deflator — to get a measure of real national income, rather than relying on real GNP.

8. Concluding Comments

Most economists, when thinking about foreign trade, are used to refer to a framework such as the Heckscher-Ohlin-Samuelson model, and they thus think of traded goods as being final goods. And most would agree that in that case, real GDP is not the same as real domestic income, since trade comes in-between. Things get more interesting, though, if one treats traded goods as intermediate goods, a closer approximation to reality. In that case trade is an intimate part of production. It is no longer possible, then, to argue that production takes place first, that trade follows, and that a change in the terms of trade therefore has nothing to do with production. We have used here the term real value added to emphasise the fact that trade takes place during production, and that an improvement in the terms of trade contributes to the productivity of the domestic factors of production much in the same way as a technological progress.

One could object that even if it is true that real value added and real income increase as a result of an improvement in the terms of trade, this is of limited interest since it does not create a single job. The reason why many economists are interested in GDP figures is because an increase in real GDP is usually associated with the creation of jobs. Even if it were true that an improvement in the terms of trade does not create any jobs, this criticism is beside the point

[30] The impact of the terms-of-trade change on domestic factor rewards is given by expression (29). It could be that the terms-of-trade improvement stongly favours one factor of production over the other -- a type of Stolper-Samuelson situation. If the former factor is mostly foreign owned and the latter mostly nationally held, the terms-of-trade improvement could make the country worse off, but this case seems rather extreme and unlikely.

for several reasons.[31] For a start, as we have shown in Section 3, an improvement in the terms of trade can lead to a meaningless reduction in real GDP. Second, a technological change, which is integrated in the calculation of real GDP, leads to an increase in real GDP without necessarily creating any jobs either. Both phenomena are perfectly similar, and there is no reason to treat them differently. In truth, if one were really interested in the demand for labour, it would be much more sensible to derive it from a GDP function such as (27), instead of relying on a very crude indicator such as real GDP.[32] Finally, one ought to remember that it is real income — and ultimately consumption — that generate utility, rather than work effort, which is usually considered to have a negative marginal utility. Work is a means to an income, it is not a goal in itself.

One could also argue that real GDP attempts to measure a country's production effort — production requires hard work — and that there is little merit in experiencing an "effortless" improvement in the terms of trade. We would strongly disagree with such a narrow view. While an improvement in the terms of trade may indeed be a purely exogenous event, foreign trade is an activity that requires much effort. Importers and exporters must constantly scout world markets in search of better opportunities, and domestic producers must position themselves to take advantage of existing comparative advantages, and always be on the lookout for new ones. Similar considerations apply to technological change. Technological progress too may be the outcome of chance, and it is certainly not true that every invention or innovation is the outcome of a systematic and tiresome research effort. There is therefore no reason to discriminate between these two types of efforts on a *a priori* basis.

Our measure of real value added comes close to what the United States Bureau of Economic Analysis calls "Command-basis GNP".[33] Command-basis GNP, or GDP, is a rather crude attempt to take into account the changing purchasing power of exports when computing a country's real value added. Command-basis GDP ($q_{B,t}$), sometimes also called terms-of-trade adjusted GDP, can be computed as:

$$(59) \qquad q_{B,t} \equiv q_{S,t} + \frac{p_{X,t}q_{X,t} - p_{M,t}q_{M,t}}{p_{M,t}} = q_t^L + q_{X,t}\left(\frac{p_{X,t}}{p_{M,t}} - 1\right).$$

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[31] Note that in the context of the GDP-function model, employment is exogenous; it is the return to labour that is endogenous.

[32] The inverse demand for labour (29) derived from the GDP-function model is much more sophisticated than most specifications commonly used in the literature, and it shows that a change in the terms of trade is likely to affect wages.

[33] See Denison (1981).

Compared to the standard Laspeyres definition of real GDP, one sees that in (59) both components of the trade account are deflated by the same price index, namely the price of imports. While this correction goes in the right direction, the choice of the import price index as the deflator is rather arbitrary. Why the price of imports, instead of, say, the price of exports, or the GDP price deflator? To the extent that trade is nearly balanced, the choice of the common deflator does not matter much, but our analysis based on the GDP-function model nevertheless suggests that the appropriate deflator is the price of domestic sales.

Finally, we would like to emphasise that our argument that the conventional measure of real GDP does not properly incorporate terms-of-trade effects should not be viewed as a criticism of Statistics New Zealand. On the contrary, this agency does a remarkable job with few resources. By recently switching to a chain measure of real GDP, while most other industrialised countries are only just contemplating such a move, Statistics New Zealand has demonstrated that it is at the forefront of good international practices. The fact remains, however, that, in view of the improvement in the terms of trade that New Zealand has enjoyed over the past decade and a half, its growth performance has been underestimated by official real GDP statistics.

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Table 1:

GDP and main components, current dollars (millions)

	v_C	v_I	v_G	v_X	v_M	v_{GDP}	v_{GNE}
1986	28352	12025	7474	14187	15576	46463	47851
1987	33529	13172	9084	15385	15504	55668	55786
1988	36570	13491	11633	16451	15488	62655	61693
1989	39606	13533	12544	17811	15476	68017	65682
1990	42438	16146	13251	18943	18913	71865	71835
1991	44640	14267	14059	19755	19569	73152	72965
1992	44494	11884	14319	21488	19248	72936	70696
1993	45350	13195	14865	23700	21865	75246	73411
1994	47434	16467	15110	25085	22708	81387	79011
1995	51177	18913	15338	26951	25326	87052	85427
1996	54521	21072	16378	27125	26417	92679	91971
1997	57487	21889	17040	27511	27018	96911	96418
1998	59567	21601	18566	28534	28193	100075	99734
1999	61775	19902	18924	30378	30144	100835	100601
2000	64470	22405	20109	33151	34448	105687	106984
2001	67224	22533	20248	41065	39209	111861	110005

Table 2:

GDP and main components, constant 1995/1996 dollars (millions)

	q_C	q_I	q_G	q_X	q_M	q_{GDP}	q_{GNE}
1986	45752	15712	12451	17213	15392	75423	73574
1987	47661	15360	12536	18004	15704	77906	75218
1988	46892	15215	14353	18750	16617	78525	76223
1989	47894	15131	14366	19198	16627	79939	77143
1990	48189	17565	14957	18787	19275	80124	80680
1991	48294	15931	15125	20152	19412	80123	79281
1992	47555	12697	15062	22147	18711	79200	75482
1993	47768	13909	15200	22873	20065	79997	77005
1994	49567	16855	15464	24452	21602	85007	81985
1995	52644	19240	15608	26525	24723	89378	87526
1996	54521	21072	16378	27125	26417	92679	91971
1997	56592	22044	16657	28385	28151	95527	95293
1998	57899	21846	18025	29378	28937	98182	97778
1999	59150	20414	17831	30123	29581	97931	97394
2000	61534	23085	18698	32175	32890	102652	103331
2001	62509	22656	18283	34358	33024	104822	103514

Table 3:

GDP and main components, implicit price deflators

	p_C	p_I	p_G	p_X	p_M	p_{GDP}	p_{GNE}
1986	0.6197	0.7654	0.6003	0.8242	1.0120	0.6160	0.6504
1987	0.7035	0.8575	0.7247	0.8545	0.9872	0.7146	0.7417
1988	0.7799	0.8867	0.8105	0.8774	0.9321	0.7979	0.8094
1989	0.8270	0.8944	0.8732	0.9278	0.9308	0.8509	0.8514
1990	0.8807	0.9192	0.8859	1.0083	0.9812	0.8969	0.8904
1991	0.9243	0.8956	0.9295	0.9803	1.0081	0.9130	0.9203
1992	0.9356	0.9360	0.9507	0.9702	1.0287	0.9209	0.9366
1993	0.9494	0.9487	0.9780	1.0362	1.0897	0.9406	0.9533
1994	0.9570	0.9770	0.9771	1.0259	1.0512	0.9574	0.9637
1995	0.9721	0.9830	0.9827	1.0161	1.0244	0.9740	0.9760
1996	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000
1997	1.0158	0.9930	1.0230	0.9692	0.9598	1.0145	1.0118
1998	1.0288	0.9888	1.0300	0.9713	0.9743	1.0193	1.0200
1999	1.0444	0.9749	1.0613	1.0085	1.0190	1.0297	1.0329
2000	1.0477	0.9705	1.0755	1.0303	1.0474	1.0296	1.0354
2001	1.0754	0.9946	1.1075	1.1952	1.1873	1.0672	1.0627

Table 4:

Real Growth Rates, alternative measures (percentages)

	$Q^L_{t,t-1}$	$\tilde{Y}_{t,t-1}$	$Y^L_{t,t-1}$
1987	3.29	4.84	5.07
1988	0.79	2.99	3.13
1989	1.80	3.16	3.20
1990	0.23	0.89	1.04
1991	0.00	-1.48	-1.52
1992	-1.15	-2.27	-2.03
1993	1.01	1.41	1.36
1994	6.26	7.04	6.99
1995	5.14	5.70	5.61
1996	3.69	3.96	3.91
1997	3.07	3.34	3.35
1998	2.78	2.45	2.43
1999	-0.26	-0.42	-0.50
2000	4.82	4.44	4.57
2001	2.11	3.09	3.12