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ORIGINAL PAPER

The agribusiness cycle and its wavelets

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Abstract Cyclical exposures of farm profit to the economic environment are a fact of life for farmers. By utilising the farmer terms of trade as a net profit margin metric, we show how wavelet analysis can be used to decompose the cycle and trend, analyse causal influences, and detect structural breaks. With the NZ dairy industry as case study, the wavelet decomposition reveals that shorter cycles are almost wholly the result of commodity prices. Longer cycles are produced by the interaction of commodity prices with the exchange rate, but with a strong natural buffering element. The buffer was upset following the Asian crisis of 1997–1998, but may have restored itself since. A favourable long-term trend has appeared from the mid nineties onwards. Implications for risk management are briefly examined.

Keywords Agribusiness cycle · Exchange rates · Farmer terms of trade · Risk management · Wavelets

JEL Classification E32 · C22 · C49 · C53 · Q13 · Q17

1 Introduction

The cyclical behaviour of agricultural prices has long been an object of academic study and research, manifested in dynamics such as the cobweb or hog cycle. However,

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commodity prices are only part of the story, for economic outcomes such as exchange rates, input prices, or interest rates are sometimes of equal impact on farmer incomes. This is especially true in countries that generate a lot of their export income from offshore sales of commodities. For such countries, farmer incomes are heavily exposed to both trends and cycles in all the major components of farm gate returns. Cyclical exposures of the agricultural sector in turn feed through into booms or busts for the economy as whole. Hence to understand how agriculture is impacted by the macroeconomic environment is a first step to understanding the business cycle as a whole. From the practical point of view for the industry itself, it may assist farmers and producer organisations to appreciate the sources of their exposure, their relative importance for the variation of farmer incomes or cash flow, and what can be done to manage the risk.

The purpose of the present paper is to study the agribusiness cycle with particular reference to how it is generated and sustained. We are concerned with how to measure cyclical behaviour, how to examine its origins, how to detect changes in the cycles, and what might cause them. An initial task is to establish an appropriate welfare indicator, one suitably adapted to the statistical metrics and techniques used to measure cyclicity, its components, and to the requirements for the analysis of risk. For this purpose we employ the farmer terms of trade, which is an index of output prices in home currency, divided by an index of farm costs. Taking the logs of this index is a good proxy for the farmer net profit margin, which can be treated as an appropriate welfare object for risk management purposes.

The next set of contributions relates to the methods used to measure and decompose trend and cyclicity. The chosen context, namely the NZ dairy farmer terms of trade, provides an excellent case study. There are obvious cycles; not even the most dyed in the wool proponent of random walks could think otherwise. But they are not of regular periodicity, or of constant amplitude, and nor are there invariant phase differences among components. As a result, one cannot use spectral analysis or ARIMA-type models to capture the cyclicity. Our solution is to draw on the more recent body of work on wavelet analysis, which can encompass cycles that change through time (e.g. Crowley 2005; Raihan et al. 2005; Schleicher 2002; Ramsey 1999). This can be used to filter out historical cycles, and detect break points at which the cycle may have changed, without the straitjacket of maintained specifications as to the form of the change. Unlike standard spectral analysis, wavelet decompositions require no prior decisions as to stationarity or nonstationarity of the subject series; apparent properties of this kind can emerge naturally from the output. In addition, one can use wavelet analysis in conjunction with the log terms of trade to break the historical cycles down into the component macroeconomic contributions; in the present context, commodity prices, the exchange rate, and input prices. In that way it becomes evident which components produce the bulk of the cyclical variation, or examine the role of interactions between components in doing so. The paper contains a striking instance: shorter run variation is produced largely by commodity prices but the intermediate run is characterised by a buffering effect between commodity prices and the exchange rate. At the very long run end, i.e. the highest level decomposition, the ‘father wavelet’ reveals any trend, in a manner that remains consistent with the cyclical elements.

The interest in such decompositions is more than just historical, though even this aspect has its own use as a graphic reminder to policymakers and prospective participants that agriculture is a risky business. A better understanding of just what causes the cycle will help farmers to manage the risk, either in terms of their own personal stabilisation policies, or else knowing just what key exposures to hedge and when. Detection of structural shifts in the cycle and its components are of particular value: farmers who have accommodated to an older regime may find themselves at a loss in coping with a new one. In a wider setting, policymakers may be helped in understanding how monetary or fiscal policies impact on the farmer's environment, and what sort of future for the industry is suggested by the father wavelet.

The application is to the NZ dairy industry, virtually archetypal in its exposure to the external economic environment. The bulk of output is sold offshore on freely traded commodity markets (powder, butter, cheese, casein, other products). Thus it inherits a heavy exposure to both world commodity prices and the NZ dollar, with an additional exposure to costs at home (labour, interest rates, animal health costs, etc.). All this adds up to a substantial risk management problem for NZ farmers, along with an ongoing preoccupation with long term viability trends. Our main findings are as follows:

(a) There is a marked cycle in the farmer terms of trade, though it is quite variable in amplitude and in period. The principal contributors are the commodity price and the exchange rate. But they impact differently. Most of the power in the exchange rate effect comes in the longer-term cycle at around 7–8 years. Commodity prices impact there, but also in the shorter cycle, around 4 years. In that zone they are almost the sole contributor to the variation in the farmer terms of trade.
(b) Historically, there has been a buffering effect between the exchange rate and the commodity price, which has greatly reduced the amplitude of the longer and potentially more powerful swings in the farmer terms of trade. The buffering effect shows up clearly in the longer-term cycle, with the one offsetting the other.
(c) The buffering effect was upset following the Asian crisis of 1997–1998. In the ensuing recovery, the NZ dollar was extremely weak but commodity prices kept up reasonably well; the net effect was for a powerful updraft in the farmer terms of trade. Prognosis is for a resumption of the old buffering, but with greater variation.
(d) The father wavelet indicates a long-term rise in farmer input costs, just as one would expect. But it also indicates a pattern of longer term rising commodity prices for the industry, starting from around 1995. The net effect was to slow quite noticeably the secular decline in the farmer terms of trade. To the extent that rising input prices can be compensated by rising productivity (a notable feature of the industry), the future looks healthier than it has for some time. The only damper is that the last cycle, starting around 2000, was also of greater amplitude, so this could become a high risk—high reward industry.

The scheme of the paper is as follows. Section 2 establishes a well-adapted metric for the subsequent analysis namely the farmer terms of trade, which decomposes environmental influences into commodity prices, the exchange rate, and input (or expense) prices. The log terms of trade has a close correspondence to the classic accounting measure of the net profit margin. Section 3 contains the core wavelet analysis. Both trends and cycles are isolated and their component influences examined, along with the structural break associated with the Asian crisis. Section 4 focuses on the natural longer-term buffer between exchange rates and commodity prices, while Sect. 5 has some concluding comments on what the exposure analysis means for risk management and longer term viability.

2 The farmer terms of trade

Measures such as the farm's accounting profit or net cash flow certainly have their own usefulness, but they are not directly adapted to the study of economic risk, being difficult to normalise across farms, with poor data availability, and badly non stationary as a time series. For such purposes it is more useful to work in terms of one of the standard accounting ratios for profitability or performance, or something closely related. One measure that is suitable for the purpose is the farmer terms of trade, which effectively constructs a home currency price of output or income relative to the price of inputs. Taking logs gives a metric that is approximately equal to the net profit margin for the enterprise.

A schematic decomposition is as follows:

$$\begin{aligned}\text{Profitability index} &= \frac{\text{output price} \times \text{exchange rate} \times \text{output quantity}}{\text{expenses price} \times \text{input quantity}}\\ &= [\frac{\text{output price} \times \text{exchange rate}}{\text{expenses price}}] \times [\frac{\text{output quantity}}{\text{input quantity}}]\\ &\sim \text{terms of trade} \times \text{productivity}.\end{aligned}$$

Productivity is treated as exogenous in what follows, not because it is necessarily so, but because our objective is to understand what would happen in the absence of productivity growth and what sort of economic exposures would exist over the shorter run.

The above profitability index (PI) can be regarded as the ratio of operating revenue to costs. A more standard accounting ratio is the net profit margin (NPM), which is the ratio of revenue net of costs to total revenue. The relationship between the two is $\text{PI} = 1/(1 - \text{NPM})$, so $\log(\text{PI}) \approx \text{NPM}$. We can isolate the log terms of trade (denoted *ftt* = logFTT) as the profit influence that operates independently of productivity, a matter of relative prices alone. A further advantage of using the log terms of trade is that it allows a log linear separation of the variables and this will be fully exploited in the decompositions that follow.

As earlier indicated, the application is to the NZ dairy industry. For this purpose, our focus will be of farmer returns and profitability. It is worth remarking that what is typical as a NZ dairy farm is itself subject to secular change. Operations that milk thousands of cows, as distinct from a hundred or two, were virtually unheard of at the start of our sample period (January 1986) but by the end of the sample period (November 2004) they had become reasonably common. This is another reason to abstract from the productivity factor. But it does not greatly affect the validity of the terms of trade index except possibly via the input expense series, which could reflect economies of scale. The latter should be borne in mind in interpreting the results, though input price variations do turn out to be relatively minor in their impact.

The primary object of analysis will be taken as:

$$ftt = \log\left[\frac{\text{dairy product price index} \times \text{effective exchange rate USD/NZD}}{\text{NZ farmer expense price index}}\right].$$

The NZ farmer expense price is used as an index of the farmer input prices (see the Data Appendix for descriptions and sources). In the absence of an input price series before 1992, we estimate it from the CPI index based on the regression of the farmer expense price index against the CPI index from 1992 to 2004. The output price index series is constructed by using the dairy product price index together with the conversion exchange rate. The latter is taken as the US/NZ dollar exchange rate, as most dairy products over the period were priced and contracted in terms of the US dollar. As to FX quotations, the USD is taken as the commodity currency, e.g. 1USD = 1.4285NZD, so a rising effective farmer-oriented exchange rate means a weakening Kiwi dollar. Note finally that use of the farmer expense price index could alternatively be interpreted in terms of measuring or hedging real farmer incomes.

Figure 1 depicts the history of the farmer terms of trade over the sample period. The most obvious thing is that there is indeed cyclical behaviour. Farming is officially a cyclical business! Of course, this is something every farmer knows, without us telling them. NZ dairy farmers have had to live with and adapt to cycles of boom and bust, which at times have been severe enough to constitute a survival hazard. It would be useful to deconstruct the cycles into their component elements. But it is not obvious that the cycle is regular. A spectral analysis does show a very slight peak at 3.5 years, but too minor to accept as statistically significant. Moreover, there are indications of some sort of change occurring around 2000. Wavelet analysis can help to solve such problems.

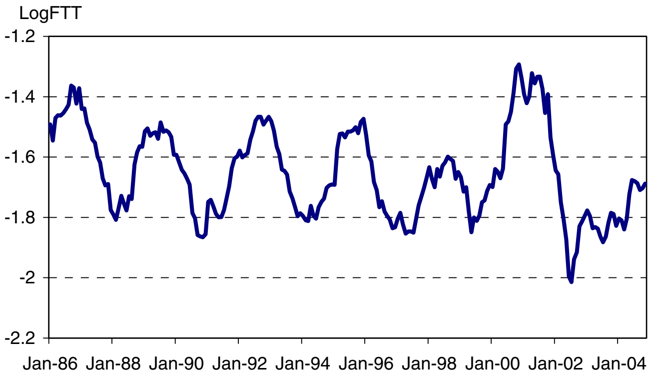


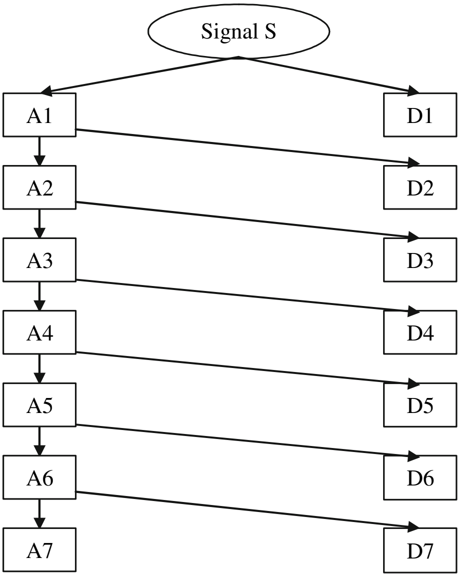
Fig. 1 Farmer log terms of trade

3 Wavelet decompositions

Wavelets can be exposited in at least two different ways, both with their own insights. Multi resolution analysis (MRA) looks at things much as a person approaching a painting: from a distance one sees that it is a portrait, closer up, that it is female, and closer still, that it is Mona Lisa. Applied to a time series, MRA can be viewed as a sophisticated way of progressive smoothing. It does this by fitting functions of the same family but at different scales, and with some orthogonality properties useful for economic analysis. Collectively, these are the wavelets. The wavelets for any given family are divided into two types. Those representing the cycles are called the 'mother wavelets' and such functions have the property that they integrate to zero. Longer run wavelets are referred to as the 'father wavelets', and they integrate to unity. An analogy would be the function $y = t$ versus $y = \sin(t)$. Appendix 2 contains a further discussion and depicts the two alternative wavelet families used in the present study, namely the Coif 5 and Sym10 wavelets. These were chosen as being individually more symmetric in nature than others, in view of the somewhat symmetric nature of the cycles exhibiting in Fig. 1. Collectively across different scales, however, the wavelets of either family are flexible enough to allow for asymmetric local cycles of rather arbitrary form, so this is no longer a story requiring regular sinusoidal patterns. For useful reviews of the use of wavelet analysis in economics, see Ramsey (1999); Schleicher (2002), or Crowley (2005).

The results of fitting mother (cyclical) wavelets of different scales are called the 'details' (D) and they are additive in their effect. Their progressive sums, by adding more details, are called the 'approximations' (A). The overall effect is rather like adjusting more and more exactly the focus of a microscope. Figure 2 is a schematic decomposition. Level 1 is the smallest scale or highest quasi frequency, so D_1

Fig. 2 Schematic decomposition into successive details and approximations



represents the cycle at this level of detail. The given series is then split into $D_1 + A_1$, where A_1 is the series once the very shortest fluctuations have been removed. Levels 2, 3,.... contain successively less small-scale complexity. Extracting these leads to broader time frame approximations designed to reveal longer run cycles and ultimately the trend. An 'average period' construct for a given level of detail D can be derived by finding the sinusoid whose period most closely matches that of the wavelet fitted at any point in time, suitably adjusted for its scale. Then one simply averages out these local equivalent periods over time. This enables us to think of the successive details as corresponding to progressively longer cycles, just as in spectral analysis (see below). Figure 2 shows the general idea. Note finally that some authors use the reverse convention, namely that higher numbered details refer to progressively finer complexity, while lower numbered details refer to longer term elements.

The overall effect can be viewed as an operational generalisation of the schematic time series decomposition familiar from economic statistics textbooks:

$$\text{Series} = \text{irregular} + \text{seasonal} + \text{cycle} + \text{trend}.$$

The successive details in the above would be irregular $= D_1$, seasonal $= D_2$, cycle $= D_3$, while the trend would correspond to the father wavelet. However, the decomposition can be made a lot finer than this; there are more levels of cyclical detail and the father wavelet can itself take the form of a sum. In the present application, details can be constructed only up to level 7. This leaves the approximation A7, which we are content to call the trend, as it shows no residual cyclical character.

A second way of approaching wavelet analysis views it as a generalisation of standard spectral analysis (mathematically it is itself a spectral decomposition). Readers familiar with spectral analysis will recall that this decomposes a given series into the sum of sinusoids of different frequencies (a process called 'complex demodulation'). It also attaches amplitudes or power to these sinusoids, so that if one frequency is more powerful than others, it means that much of the variance in the given series can be explained in terms of a well defined cycle at this frequency, or equivalently period. However the elementary sinusoids themselves do not change over time, either in their frequency or their amplitude. This is one of the limitations of spectral analysis, although from time to time suggestions were made as to how to develop time varying spectra (e.g. Priestley 1965). But even here the change had to be very slow over an extended period of time.

Limitations of such kinds were effectively removed by the development of wavelet theory and practice, notably by authors such as Mallat (1989); Daubechies (1988, 1990, 1992); Coifman et al. (1990); Cohen et al. (1992). A wavelet is rather like a sinusoid localised at a particular point in time, so that its power drops off rapidly on either side of that time point (see Appendix 2). Moving along through time, one fits a succession of such wavelets. Each time point contains contributions from wavelets of the same 'scale' (quasi frequency) but centred at neighbouring points. In addition, it will also contain contributions from wavelets of different scales, corresponding to cycles of different frequencies. By a similar mathematical argument to complex demodulation, one can express the series at any point in time as a sum of the wavelets of different scales. The shorter scales represent the higher frequency fluctuations, while the large scale wavelets capture the long run movements.

MRA for the farmer terms of trade

Figure 3 is a wavelet decomposition of the *ftt* series, i.e. the farmer log terms of trade. As earlier indicated, the approximation at level 7 is treated as the trend. As successively more detail is added vertically upwards (the right hand graphs), the approximations (left hand graphs) approach closer and closer to the original *ftt* series. In practice, the fitting moves vertically downwards ('deconstruction', as it were), removing more and more of the detail (see Appendix 2); a vertical upwards movement is referred to as 'reconstruction'.

The respective powers or energy of the details can effectively be gauged from the scales on the vertical axis. A more formal energy measure can be derived that is

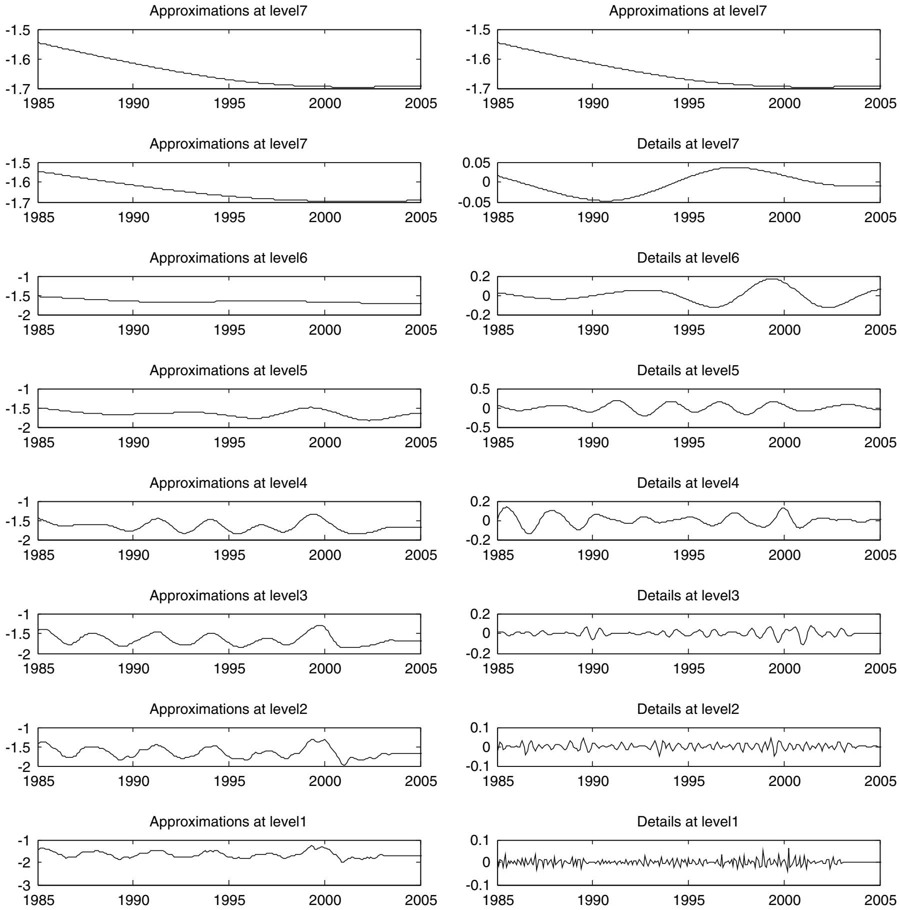


Fig. 3 Actual decomposition of *ftt* up to level 7

Table 1 Power decomposition

Approx. and details	A7	D7	D6	D5	D4	D3	D2	D1
Average period (Years)	15.47	15.47	7.73	3.87	1.93	0.97	0.48	0.24
Energy %	52.28	1.7	13.42	21.81	7.64	2.01	0.53	0.51

analogous to the variance of each detail level, expressed a percentage of the overall energy (see Appendix 2). As Table 1 shows, apart from the longer term trend component, most cyclical power in *ftt* is allocated to the level 5 detail, which corresponds to an 'average period' of 3.87 years, but neighbouring levels 4 and 6 also attract some weight. Note finally that the longer cycle (level 6 detail) does show some evidence of growing amplitude over time. The causes of this are explored in what follows.

The wavelet properties or 'signatures' depicted in Fig. 3 and Table 1 are not consistent with a stationary data generating process. Stationary processes admit a Fourier (spectral) decomposition in which frequency bands with any power have regular sinusoidal time functions for the details. This is not the case at the powerful D5 level in Fig. 3. Likewise, the irregularity of detail cycles is inconsistent with linear vector autoregressive representations. Note also that wavelet methods do not need to make any specific assumptions about the order of any nonstationarity (e.g. I(1) or I(d) for fractionally integrated processes). Details correspond to generalised difference processes, so do not exhibit any drift; the latter would appear in the approximation series and be manifested in higher power. In the present application there does not appear to be any substantial time series drift in the farmer terms of trade. The point is examined further in what follows.

Long term behaviour

Figure 4 depicts the trend component (the level 7 approximation) for the farmer terms of trade and also for its components, namely the commodity price, the exchange rate,

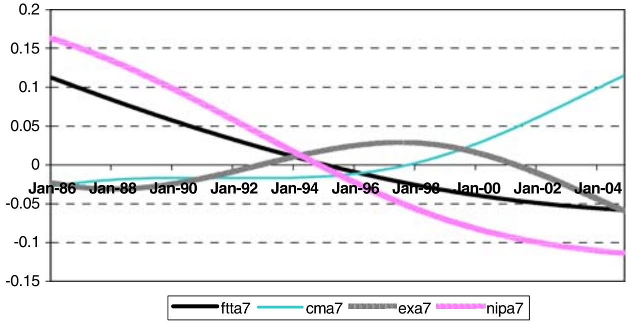


Fig. 4 Trends in the farmer log terms of trade and components. Key: 'ftt' = farmer terms of trade; 'cm' = commodity price index; 'ex' = exchange rate index; 'nip'= (negative) input price index. The last two letters indicate approximations or detail levels, e.g. 'a7' refers to approximations at level 7, 'd6' standing for level 6 detail. The conventions apply to Figs. 4, 5, and 8

and the input price or expense index. These are logs in each case. Note that the input price component has been illustrated with a *negative* sign; thus to get the *ftt* series simply add the component graphs vertically.

It can be observed that the marked negative trend in the farmer terms of trade in earlier years derives from steadily increasing expenses in the form of the input price series. Until the mid 1990s, Prebisch (1960) and Singer (1950) were evidently right (as to the Prebisch–Singer thesis): the terms of trade for these particular primary producers were indeed declining. Only secular growth of about 2.4% per annum in dairy farm productivity (Dexcel 2004) kept the industry competitive. But in more recent years, stronger commodity prices have helped to swing the long-term balance in terms of growing farm profitability.

Cyclical behaviour and its components

Once the trend has been removed, levels 4 to 6 provide most of the cyclic power. The respective levels can be added to give a composite level:

$$D_{4-6} = D_4 + D_5 + D_6.$$

The underlying orthogonality of the wavelet decomposition means that the composite levels 4 to 6 can be treated as a detail in its own right. A construction of this kind is effectively a band pass filter, isolating longer term ‘cycles’, even if the latter are not regular. It corresponds to complex demodulation in conventional Fourier analysis, where a stationary time series, or one that can transformed to stationarity via a linear differencing operation, is decomposed into longer or shorter term contributions. Thus Christiano and Fitzgerald (2003) use linear filters to isolate longer and shorter term covariances between inflation and unemployment. The present procedure amount to a generalisation of such techniques, which covers both stationary and non stationary processes, necessary in the present context.

Figure 5 depicts the composite levels 4 to 6 in detail for the farmer terms of trade series and also for its constituent components, namely the commodity price, the exchange rate and the input price.

Several things are evident from Fig. 5. The first is that at a cyclical level, input prices are relatively unimportant: just about all the action comes from commodity prices and the exchange rate. The second is that the two major peaks, 1995 and 2001, have quite different causes. The 1995 peak is due to commodity prices, which are dragged down by a high NZD. The 2001 peak is a major one because the two components no longer conflict: a very weak NZ dollar is reinforced by high commodity prices. A smaller peak in 1992 derives from the same effect.

Robustness of the above findings was checked by using another widely employed generator wave form, the sym10. The results were very similar, except that commodity prices were allocated a greater role in the 2001 peak, though remaining subsidiary to the exchange rate.

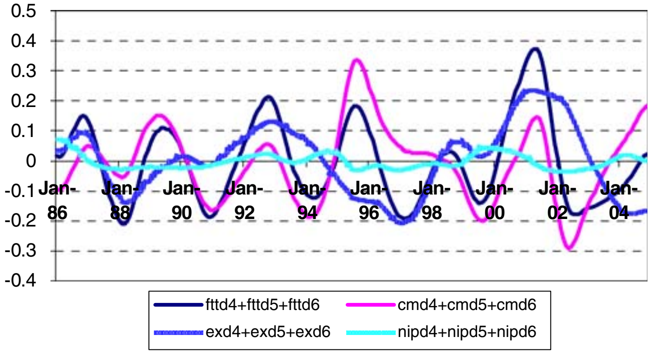


Fig. 5 Detail 4–6 for *ftt* and its components

Has there been a structural break?

Details at levels 1 and 2 can be used to examine the issue of structural breaks in the cycle. One manifestation of a break is that high resolution levels show a local more violent fluctuation around any break point. Intuitively, when the major cycle suddenly changes character, this places too much burden on the higher level (lower resolution) wavelets centred around this point and the poorness of local fit is transferred through to appear as more violent short run fluctuation in the lower level details. In Fig. 6a and 6b, both details D_1 and D_2 do show increased volatility around 2001–2002, suggesting a break.

One hypothesis is that prior to 2000, it was commodity prices that generated the fluctuation in the farmer terms of trade. This could happen either directly or indirectly via the lagged dependence of the NZD exchange rate on commodity prices, of which dairy prices are the largest by value. After that date, commodity price are partially usurped by an independent influence from the exchange rate.

To test this idea, we projected the exchange rate and input prices on the commodity price, and isolated the respective residuals, as the bits of each that could not be attributed to any causal influence from commodity prices. In order to concentrate on longer run cycles, this was done using the composite detail levels 4 to 6 using overlapping semi-annual time intervals for each lag. The projection was done by least squares in the form of a one-sided distributed lag, in which the exchange rate or input price is potentially affected by current and prior commodity prices. Thus if L is the backward lag operator (e.g. $Ly_t = y_{t-1}$), one fits a polynomial lag structure of the form

$$D_{4-6}^{\text{exch}} = \alpha(L)D_{4-6}^{\text{comm}} + e^{\text{exch}}$$
$$D_{4-6}^{\text{input}} = \gamma(L)D_{4-6}^{\text{comm}} + e^{\text{input}},$$

where the lag structure is extended back for eight semi-annual periods. The residuals e^{exch} and e^{input} represent the effects independent of the commodity price. Finally we formed the constructed series

$$\tilde{f}tt_{4-6}^{C} = (1 + \alpha(L) - \gamma(L))D_{4-6}^{\text{comm}}.$$

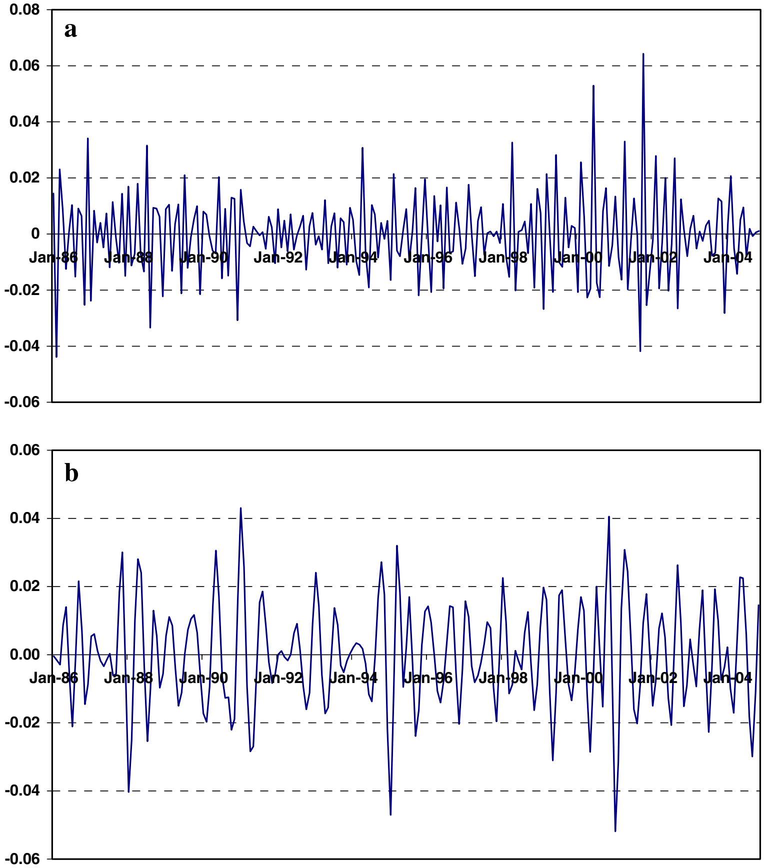


Fig. 6 **a** Details at level 1, **b** Details at level 2

The projection $\tilde{f}tt^{C}_{4-6}$ can be taken to represent the sum total of commodity price causality, and the object is to see how well it succeeds in tracking the farmer terms of trade *ftt*. Figure 7, which plots *ftt* against ftt^{C} is instructive. Up to 1997 the tracking is reasonably good. But after that date it becomes poor, suggesting a stronger independent influence for the exchange rate. Chow-type tests of coefficient stability for the above distributed lags also indicate that the period pre 1997 was not the same as after. As a second check, the regime model of Bai and Perron (2003) was utilised, which searches for the optimal break date. The results indicated a clear boundary break at August 1997 for the exchange rate equation. Prior to this date the fit is good, but after that data, there is very little distributed lag connection between the exchange rate and commodity price index. The maximising break date for the input price distributed lag was January 2002, but the break itself is not nearly as marked as for the commodity price-exchange rate connection. Such tests are no more than suggestive, as the underling dependent variables D^{exch}_{4-6} and D^{input}_{4-6} themselves represent constructed data.

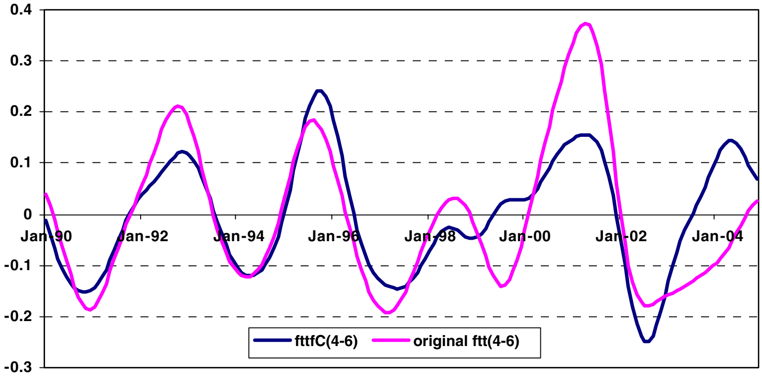


Fig. 7 Role of commodity prices – ftt^C versus *ftt*

The above findings as to the greater independence of the exchange rate can be attributed to structural changes in the economy as a whole, which in turn reflect increasing globalisation of world capital markets. The year 1997 marked the Asian crisis, which resulted in a sudden correction to an overvalued NZ exchange rate. From mid 1997, the NZ dollar lost a third of its value against the USD, with a minor recovery in 1999, but thereafter resuming a downward slide until late 2001. The economy as whole fell into a mild recession, but commenced a recovery in 2000, buoyed up by rising commodity prices and a Kiwi dollar at historically low levels and still continuing to fall. This is why the farmer terms of trade rose so dramatically up to 2001.

However, the recovery spread into the asset markets, most notably the housing market, and it came to be financed by large scale borrowing by banks through the eurobond and uridashi markets, either directly so, or indirectly via the swap market. After 2001 the trend accelerated, it became a virtual offshore hoovering of money to support home mortgages and consumer lending (Bowden 2004). At the same time, the Reserve Bank of New Zealand, concerned at inflationary pressures, started a cycle of monetary tightening which also attracted short term ‘hot money’ from offshore. The result was a soaring NZ dollar at a time when the US dollar itself was coming under attack. The farmer terms of trade succumbed to the exchange rate pressure.

4 The natural buffer and its prognosis

Wavelet analysis can be used to break down the component effects into contributions from different periodicities. When we do so, it becomes apparent that the commodity price effect has incidence in two different bands, while the exchange rate has its primary impact in only one. Figure 8a displays the component details for level 5, with an average period of 3.87 years, while figure 8b shows what happens for level 6 detail, with an average period of 7.7 years.

Although a little out of phase in the early years, commodity prices predominate in explaining the shorter level 5 band. The power of the exchange rate effect is minor.

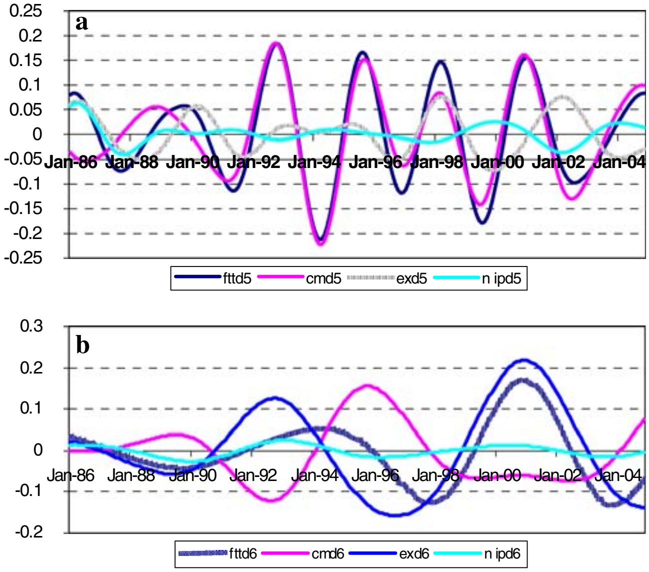


Fig. 8 **a** Details at level 5-components, **b** Details at level 6-components

This means that a fair amount of shorter run fluctuation is apparent throughout the whole period and it is predominantly associated with commodity prices.

Exchange rates come into their own at the longer cycles corresponding to level 6 detail. Commodity prices are also powerful in this band, but up until 1998, the two had a clear tendency to neutralise each other. This amounted to a buffering effect: whenever commodity prices became strong, the NZD exchange rate also became strong. Because they were slightly out of phase, there was a resultant effect on the farmer terms of trade but a relatively minor one. Things changed between 2000 and 2002. In the latter case, the NZ dollar was exceptionally weak coming out of the Asian crisis. Commodity prices were not strong, but on the other hand not weak enough to neutralise the beneficial effects of the weak NZ dollar. The level 6 buffering effect failed. Because the bulk of the exchange rate effect accrues in this band, the farmer terms of trade appeared to dislocate as a whole.

The post 2002 period in Fig. 8a,b gives an early clue that things might well restore themselves to normal patterns. The level 5 detail is much as before. At level 6 however, where the exchange rate is important, commodity prices and the exchange rate look to be once again on opposing tacks, just as they were prior to the Asian crisis. If this indeed turns out to be the case, something like the normal cycle might be restored.

On the other hand, there seems to be potential for a more inter-run volatile NZ dollar. For in addition to the short end volatility associated with monetary policy, there are exposures arising from the growing use of offshore funding to raise debt for mortgages, consumer spending and other purposes. It is unclear whether the more or less natural buffer of early years will continue to apply, or with the same force. As a result, the farmer terms of trade may be in for an even bumpier ride in the years to come.

5 Implications for risk management

Perceptions of a need to shield dairy farmers against foreign exchange and commodity prices exposures have on occasion caused more harm than good. In late 1997, the NZD was at historically high rate of 71c US, while milk solids and other dairy prices had taken a turn for the worse. The NZ Dairy Board thought that farmers were at risk of serious financial harm should the Kiwi strengthen further, and instituted a hedging strategy that effectively locked the NZ dollar at a range of rates down to 64c US, mostly around the 69c mark. Shortly afterwards, the NZ dollar plummeted to USD42c, and subsequently to 39c, in the aftermath of the Asian crisis, resulting in the Board taking a charge of almost NZD 500 m representing the opportunity costs relative to the unhedged position (Bowden 2005, Chap. 12); possibly the largest FX hedging write-down in history.

The implicit buffer, as it appears in Fig. 8, makes it fairly clear (with the advantage of hindsight) that there was little need at the time to protect against FX and commodity price exposures at the same time. Over a term long enough to threaten survival for the typical dairy farmer, the one exposure tended to balance out the other—the natural buffer. The wavelet analysis suggests that if formal hedge instruments were to be employed, they should have been confined to commodity price exposures and the instrument maturities should be fairly short. Essentially, one would be aiming to hedge the level 5 cycle at about 3–4 years. But because dairy commodities do not possess well developed forward markets, this in turn suggests that market based hedges such as forwards or options should better not be employed at all. Instead farmers should realise that commodity prices come and go in cycles of about 3–4 years and institute their own income buffering strategies based on nothing more complicated than saving in good times to fund continuing farm maintenance in bad. However, an emerging possibility is that the natural buffering referred to above may have broken down in more recent times. If so, this would create more of a need for formal hedges, to protect against episodes where the NZ dollar stays high while commodity prices remain low.

In the particular case of the NZ dollar, there are good reasons (based on expected values not risk) for a bias towards using forwards, arising from the chronic forward discount on the Kiwi dollar associated with high NZ interest rates, but as the above episode shows, it can go wrong on occasions (see also Bowden and Zhu 2006). Nor does the existence of a forward bias preclude the more adventurous dairy company treasury from seeking to take advantage of what might be seen as unduly high or low foreign exchange rates, or of attempting to second guess market efficiency (Bowden et al. 2006). But it is in effect opportunistic behaviour, and will sometimes go wrong as well as right. To have a chance of being successful, it needs a good understanding of the economics of medium-term foreign exchange, and the role of capital flows in driving the exchange rate. Zhu (2006) contains an extended treatment of the welfare gains from active medium term hedging of the exchange rate risk.

Adventures of this kind are only for the finance industry professionals, and the theory of efficient capital markets would argue caution at that. But it may nevertheless assist the average farmer or farm management adviser to know how to formalise the ups and downs of profitability and to recognise when the cycle is at historic highs or lows. Information of this kind is an important input into the estimation of likely recovery periods for prospective farm development programmes or decisions about herd replacement.

A longer-term strategy for the industry as a whole is to seek growth and diversification into developing markets, especially those based on engines of economic growth such as the Chinese economy. There is some evidence that it is this that has been responsible for the trend effects noted in Sect. 3. Likewise, diversification into resurgent economies such as Japan can yield business cycle diversification. Of course, things would look even better if the agricultural rounds at the WTO ever looked like succeeding. But even without multilateral trade deals, things don't look too bad for the industry on a purely bilateral basis. The long run wavelet suggests that between them, improving commodity prices and productivity growth will more than compensate for farm expenses, while shorter run prospects for a correction to the high Kiwi dollar will do no harm either.

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Appendices

Appendix 1: Data definitions and sources

The data are monthly, spanning the period Jan 1986 to Nov 2004, giving 227 observations. Details are given in Table 2.

Table 2 Data definitions and sources

Variable	Details	Sources
Exchange rate	Taken with the US dollar as commodity currency and NZ dollar as terms currency (so 1USD=SNZD)	MSCI mid rate; from Thomson Financial Datastream
Farmer input price index or expenses price index (INP)	An expenditure-based weighted price index, which includes all the farmer inputs and excludes the depreciation, and Goods and Services Tax. The interest cost is the largest component, with a weight of 17%. Other main factors are livestock purchase, repair and maintenance, wages and salaries. The base time period is December 1992. We reconstructed the index prior to 1992 by using the correlation between farmer input price and CPI after that date. The index is calculated at the mid-point of each quarter. To obtain the monthly data, the quarterly observations are linearly interpolated	Statistics New Zealand (official government statistics agency)
Commodity price index for NZ dairy farmers (CMP)	Includes whole milk powder, skim milk powder, butter, cheese and casein, all prices expressed in US$. Weights are based on contribution to merchandise exports	Australia and New Zealand Banking Group Ltd Economics Dept
Farmer term of trade (FTT) or log terms of trade (*ftt*)	Constructed by multiplying the commodity and exchange rate, to give a local currency index value, then dividing by the expenses price index	

Appendix 2: Wavelet analysis

Wavelet decompositions

The following treatment based on Crowley (2005) and other sources, though much of the terminology is common in the wavelet literature. Wavelets for a given family are generator functions, indexed by two parameters called the scale (j) and the translation or location (k). For instance the symmlet family has two sets, the father and mother wavelets, respectively of the form:

$$\phi_{j.k}(t) = 2^{-j/2}\phi\left(\frac{t-2^{j}k}{2^{j}}\right); \quad \psi_{j.k}(t) = 2^{-j/2}\psi\left(\frac{t-2^{j}k}{2^{j}}\right).$$

The mother wavelets (ψ's) integrate to zero, as they are meant to span the cyclical influences. The father wavelets (ϕ) are normalised to integrate to 1. The scale parameter determines the span of the wavelet, meaning its non-zero support, as each wavelet damps down to zero on either side of its centre. For a given time t, there are contributions from neighbouring wavelets translated to either side of t. Figure 9a,b depicts the two wavelet generators used in the present study.

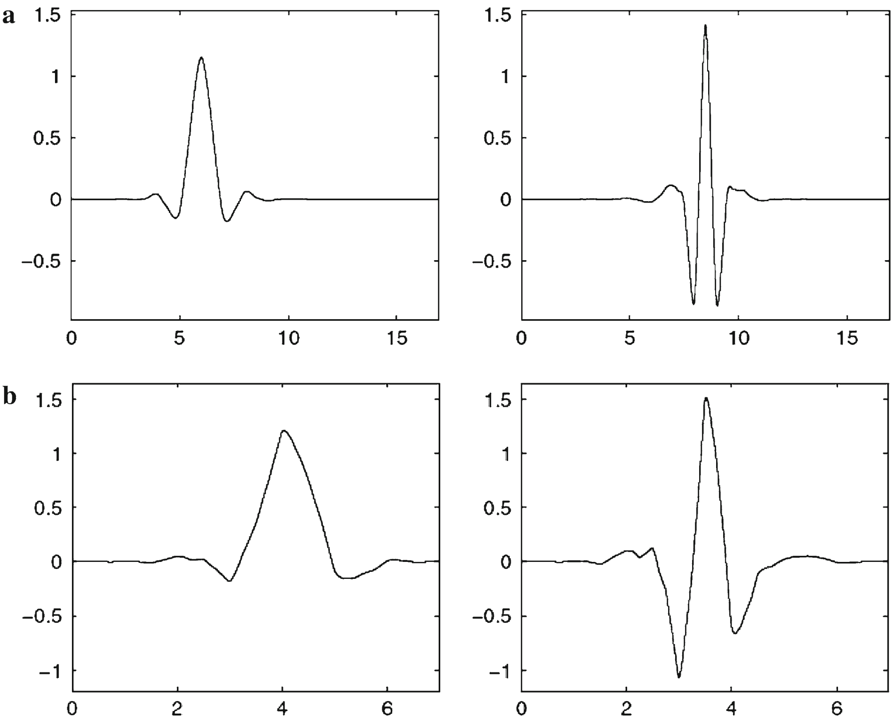

Fig. 9 **a** Coiflet father wavelet (*left*) and mother wavelet (*right*), **b** Symmlet father wavelet (*left*) and mother wavelet (*right*)

The family of functions defined as above are mutually orthogonal. Something analogous to Fourier analysis will therefore hold. We form coefficients as

$$s_{J,k} = \int x(t)\phi_{J,k}(t)dt; \quad d_{j,k} = \int x(t)\psi_{j,k}(t)dt,$$

for $j = 1, 2, \ldots, J$, where J is limited by the number of observations on x available. As with the inverse transform in Fourier analysis, we can recover $x(t)$ in terms the wavelet functions as:

$$x(t)=\sum_k s_{J,k}\phi_{J,k}(t)+\sum_k d_{J,k}\psi_{J,k}(t)+\sum_k d_{J-1,k}\psi_{J-1,k}(t)+\cdots+\sum_k d_{1,k}\psi_{1,k}(t).$$

We write $D_j(t) = \sum_k d_{j,k}\psi_{j,k}(t)$. Note that just the one father wavelet has been used in the above with maximal scale.

Computational procedure

The quasi Fourier approach illustrated above would be slow computationally. In the present paper, computations were done in Matlab (Misiti et al. 2005) using Mallat's algorithm, which is considerably more efficient. The algorithm follows through the basic sequence as illustrated in Fig. 2 of the text. The original signal $x(t)$ is fed through a high pass and low pass filter, one the quadrature of the other, which ensures orthogonality of the two outputs. The low pass filter is adapted to the longer run father wavelets and the higher to the mother wavelets. Output from the high pass filter is downloaded as the level 1 detail D_1, and the output from the low pass filter becomes the level 1 Approximation. Starting afresh with A_1, the process is successively repeated.

Power

The powers of the wavelets at each scale are basically set by the coefficients $s_{j,k}$ and $d_{j,k}$. Having obtained the details $D_{j,t}$ at each time point t, one can express the average power or energy at each level of detail, relative to the whole:

$$E_j^D = \frac{1}{E}\sum_t D_{j,t}^2, \quad E_j^A = \frac{1}{E}\sum_t A_{j,t}^2$$
$$E = \sum_t A_{j,t}^2 + \sum_j \sum_t D_{j,t}^2$$

Table 1 of the text shows the energies E_j^D for the log farmer terms of trade *ftt* in the form of percentage contributions relative to E. It will be observed that these are consistent with the vertical scales in Fig. 3.

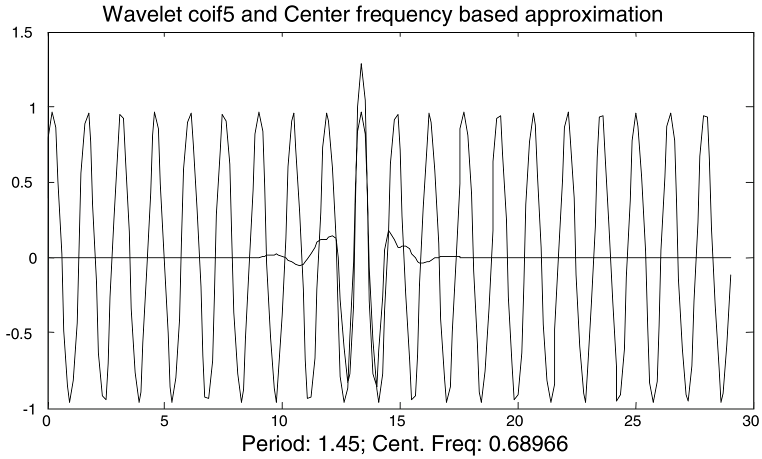

Fig. 10 Scale in terms of equivalent sinusoidal frequency

Scale and frequency

To connect the scale to frequency, a pseudo frequency is calculated. The algorithm works by associating with the wavelet function a purely periodic signal of frequency F_c that maximizes the Fourier transform of the wavelet modulus. When the wavelet is dilated by the scaling factor 2^j, the pseudo frequency corresponding to the scale is expressed as:

$$F_s = \frac{F_c}{2^j \times \Delta}, \quad \text{where } \Delta \text{ is the sampling period.}$$

Taking the wavelet 'coif5' as an example, the centre frequency as seen from Fig. 10 is 0.68966 and thus the pseudo frequency corresponding to the scale 2^5 is 0.02155. As the sampling period is one month, the period corresponding to the pseudo frequency is 3.87 years.

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