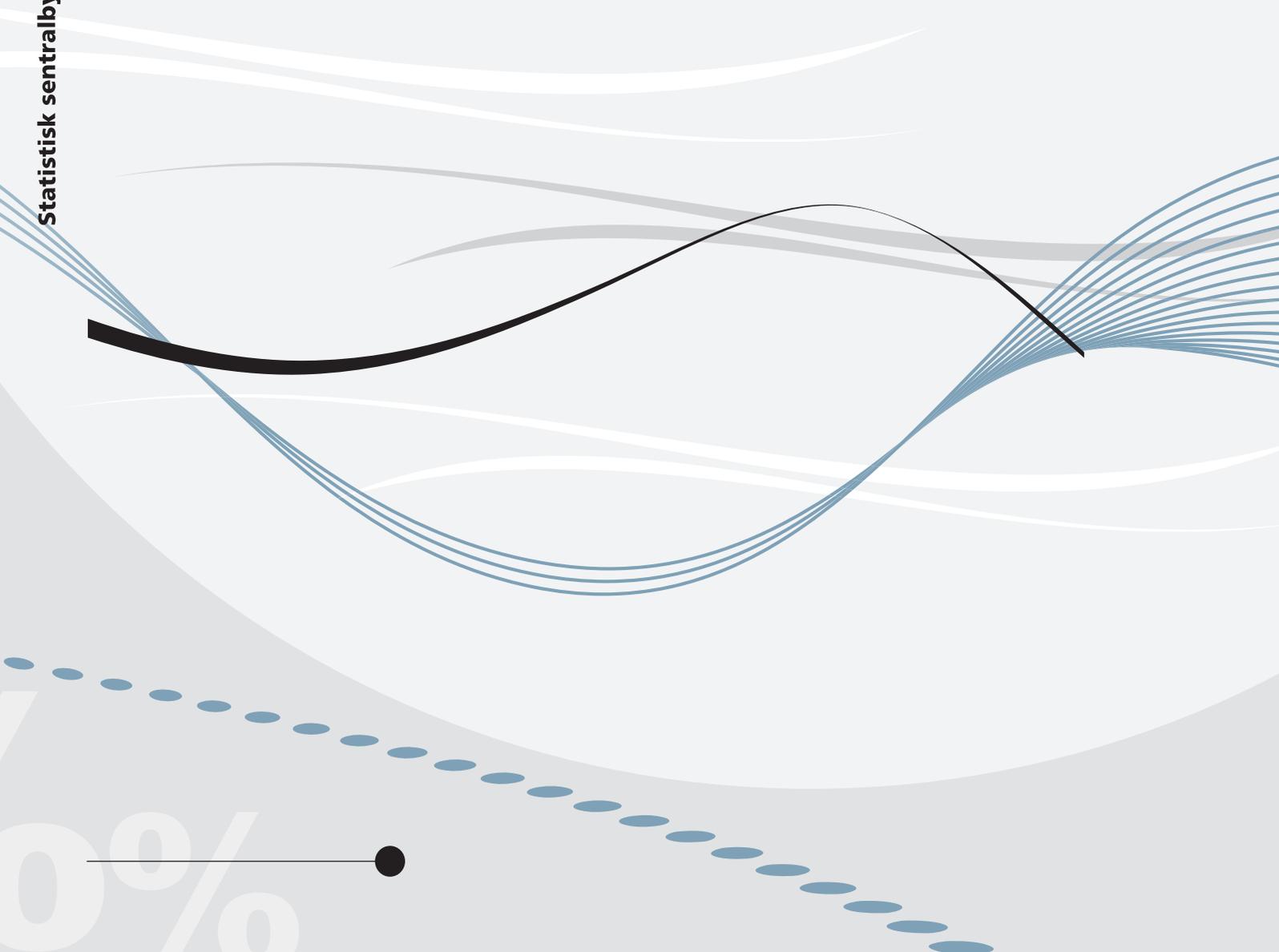


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**The importance of the distribution
sector for exchange rate pass-through
in a small open economy**

A large scale macroeconomic modelling
approach



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Abstract:

The degree of exchange rate pass-through to domestic goods prices has important implications for monetary policy in small open economies with floating exchange rates. Evidence indicates that pass-through is faster to import prices than to consumer prices. Price setting behaviour in the distribution sector is suggested as one important explanation. If distribution costs and trade margins are important price components of imported consumer goods, adjustment of import prices and consumer prices to exchange rate movements may differ. We present evidence on these issues for Norway by estimating a cointegrated VAR model for the pricing behaviour in the distribution sector, paying particular attention to exchange rate channels likely to operate through trade margins. Embedding this model into a large scale macroeconomic model of the Norwegian economy, which inter alia includes the pricing-to-market hypothesis and price-wage and wage-wage spirals between industries, we find exchange rate pass-through to be quite rapid to import prices and fairly slow to consumer prices. We show the importance of the pricing behaviour in the distribution sector in that trade margins act as cushions to exchange rate fluctuations, thereby delaying pass-through significantly to consumer prices. A forecasting exercise demonstrates that exchange rate pass-through to trade margins has not changed in the wake of the financial crises and the switch to inflation targeting. We also find significant inflationary effects of exchange rate changes even in the short run, an insight important for inflation targeting central banks.

Keywords: Exchange rate pass-through, pricing behaviour, the distribution sector, econometric modelling and macroeconomic analysis.

JEL classification: C51, C52, E31, F31.

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Sammendrag

Hvor raskt og sterkt endringer i valutakurser påvirker innenlandske priser har viktige implikasjoner for pengepolitikken i små, åpne økonomier med inflasjonsstyring og flytende valutakurser. Empiri indikerer at valutakursgjennomslaget er raskere til importpriser enn til konsumpriser. En vanlig forklaring på denne forskjellen i valutakursgjennomslag er prisatferden i varehandelen. Dersom distribusjonskostnader og marginer er viktige komponenter i prisene på importerte konsumvarer kan endringer i valutakursen påvirke importpriser og konsumpriser i ulik grad. Vi estimerer ulike valutakurskanaler i en kointegrerende vektor autoregressiv modell for marginene i varehandelen. Beregninger på en stor makromodell for norsk økonomi, som også inkluderer modellen for marginene i varehandelen, viser at valutakursgjennomslaget skjer nokså raskt til importpriser og relativt tregt til konsumpriser. Vi finner forholdsvis store inflasjonsimpulser fra valutakursendringer på kort og mellomlang sikt. På kort sikt blir inflasjonsgjennomslaget svekket av endringer i varehandelsmarginene, som virker som støtpute på impulser fra endringer i valutakursen til konsumprisene.

1. Introduction

Much of the literature on the new open economy macroeconomics is based on models that feature rational expectations, optimizing agents and imperfect competition in markets for goods and possibly also labour. Small new Keynesian open economy models with several or all of these ingredients are popular when analysing analytically exchange rate pass-through and effects of monetary policy, see e.g. Svensson (2000) and Galí and Monacelli (2005) among others. However, it is often necessary to introduce ad hoc based micro-behaviour in order for these models to reproduce essential empirical aspects of real world data, typically by introducing backward-looking behaviour in the new Keynesian Phillips curve. The new open economy literature is based on the assumption of monopolistically competitive pricing behaviour, whereas the standard assumption of the "old" open economy models is price-taking behaviour in international markets, cf. Aukrust (1977) and Lindbeck (1979).¹ The pricing-to-market hypothesis introduced by Krugman (1987) and others, based on the assumptions of imperfect competition, nominal rigidities and market segmentation, is now the standard workhorse of the new open economy literature, see e.g. Atkeson and Burstein (2008) and Bugamelli and Tedeschi (2008).

In open economy models the degree of exchange rate pass-through – the responsiveness of import prices to changes in the nominal exchange rate – plays a vital role. Studies in the new open economy literature typically draw a distinction between producer currency pricing (PCP) and local currency pricing (LCP) when analysing exchange rate pass-through to domestic prices, see e.g. Galí and Monacelli (2005) and Devereux and Engel (2003). According to PCP, prices on internationally traded goods are set in the currency of the producer (exporter). If PCP holds, producers do not change their prices frequently, whereas consumers (and importers) face prices that vary one-for-one with nominal exchange rate changes (due to full pass-through). In this framework, changes in the nominal exchange rate are passed on to the terms of trade and consumers demand for home relative to foreign produced goods. LCP, on the other hand, is a price setting strategy where prices are set in the currency of the consumer, with no (or limited) pass-through of nominal exchange rate changes to import prices, at least in the short run. Thus, there may be only small effects from exchange rate changes to producer costs (to the extent that production is based on imported materials) as well as to consumer prices (to the extent that consumption is based directly on imported goods and services).

¹ See Rogoff (1996) and Goldberg and Knetter (1997) for surveys about the evidence of systematic failure of the law of one price to hold for internationally traded goods. Persistent deviations from long run purchasing power parity are also found by e.g. Engel (2000) and Chen and Rogoff (2003).

Some investigators use evidence of limited exchange rate pass-through to consumer prices as a justification for models with local currency pricing, see for instance Betts and Devereux (1996), Engel (2000) and Engel and Rogers (2001). Goldberg and Knetter (1997) emphasise this evidence as consumer prices often are found to be less affected by changes in exchange rates than export prices. According to Engel and Rogers (2001), possible explanations and failure of the law of one price are tariff and non-tariff barriers to trade, transportation costs and non-traded inputs such as marketing and other distribution services that are part of final goods prices, but not to the same extent part of prices of imported or exported goods. Obstfeld and Rogoff (2000) argue that correlations between changes in terms of trade and exchange rates for a large sample of countries are consistent with models of producer currency pricing. However, they argue that local currency pricing is relevant for retail prices, while prices on imported goods faced by retailers react to fluctuations in exchange rates as these prices are based on producer currency pricing. Burstein *et al.* (2003) consider models in which the pass-through to consumer prices is lower than to import prices as a result of local distribution costs in the wholesale and retail trade sector. Taylor (2000) puts forth the view that the extent to which a firm matches exchange rate movements by changing its own price depends on how persistent the movements are expected to be. For a retail firm that adds services to its imports, a depreciation of the exchange rate raises the costs of the imports evaluated in domestic currency. If the depreciation is viewed as temporary, the retail firm passes through less of the depreciation to its own price. Hence, less persistent exchange rate movements lead to smaller exchange rate pass-through to consumer prices.

In this paper, we present empirical evidence on exchange rate pass-through for the Norwegian economy by estimating a cointegrated VAR model for trade margins in the distribution sector. The degree and speed of exchange rate pass-through to retailers' trade margins are important for inflation dynamics as trade margins make up close to 30 per cent of the official consumer price index. We assume monopolistically competitive pricing behaviour when modelling prices, but do not consider forward-looking behaviour as this hypothesis is found to be clearly at odds with Norwegian data, see e.g. Bjørnstad and Nymoén (2008), Bårdsen *et al.* (2005, p. 145) and Boug *et al.* (2006). The cointegrated VAR model for trade margins is then analysed within an existing large scale macroeconomic model of the Norwegian economy assuming a 10 per cent depreciation of the exchange rate on a permanent basis.² By using the macroeconomic model, which inter alia includes the pricing-to-market hypothesis and price-wage and wage-wage spirals between industries, we are

² A full description of the large scale macroeconomic model is beyond the scope of this paper. Appendix A provides an outline of main parts of the model.

able to examine exchange rate pass-through to import prices, production costs, mark-ups and consumer prices for a large number of commodities and industries. Unlike studies in the new open economy literature, which typically are based on partial analyses of aggregated single-equation models, we thus take account of numerous channels through which the exchange rate is likely to operate in a small, open economy like the Norwegian.

Model simulations show that exchange rate pass-through is quite rapid to import prices and fairly slow to consumer prices in the Norwegian economy. We demonstrate that pass-through to consumer prices is not complete even within a ten-year horizon, a finding which may support the LCP hypothesis. The importance of the distribution sector is clearly apparent as trade margins act as cushions to exchange rate fluctuations in the short run, thus limiting the extent of exchange rate pass-through to consumer prices. If domestic inputs to the distribution sector are quantitatively important, then tradable goods sold to consumers include national value added (retail services) that may explain why there is incomplete pass-through. Likewise, imports as intermediate goods that together with domestic inputs produce final goods sold to consumers may also contribute to limited pass-through of exchange rate movements to consumer prices. We also present evidence that the exchange rate pass-through in the retailers' price setting has not changed significantly following the exchange rate volatility during the financial crisis and the shift in monetary policy to inflation targeting in 2001.

The rest of the paper is organised as follows: Section 2 outlines the main channels of exchange rate pass-through inherent in the macroeconomic model. Section 3 presents the estimated dynamic model of the pricing behaviour in the distribution sector. Section 4 reports empirical findings of exchange rate pass-through in the Norwegian economy based on simulations on the macroeconomic model. Section 5 concludes.

2. Channels of exchange rate pass-through

The theoretical set up of prices is generally based on imperfectly competitive markets characterised by differentiated products. However, the econometric specification of price equations also includes the possibility of price taking behaviour as a special case to accommodate the traditional assumption for small open economies. The Norwegian national accounts system, which is conceptually and statistically our main database, operates with three prices on each product depending on origin and market destination. A domestically produced good is either delivered to the domestic market (home goods) or abroad (exported goods) with potentially different prices. On the domestic market the price of a product produced in Norway may also be different from the import price of the “similar” product.

2.1 Exchange rates and import prices

World market prices in foreign currency times the exchange rate is often considered the main determinants of import prices in domestic currencies, at least in a small open economy. A number of empirical studies have found less than complete pass-through of exchange rate changes to prices of competitive imports, see for instance Goldberg and Knetter (1997), Campa and Goldberg (1999) and Campa and Mínguez (2006). When assuming imperfectly competitive markets symmetry considerations imply that foreign producers may potentially take their market position into account when setting export prices to Norway. The cointegrated VAR modelling of import prices of manufactures is therefore based on the pricing-to-market hypothesis advanced by Krugman (1987). In a simplified form we may write the import price equation of manufactures (m) as

$$(1) \quad PI_m = g(PW_m \cdot E, MC_m),$$

where PW_m is the aggregate foreign export price (in foreign currency) of manufactures, E is the import-weighted nominal exchange rate and MC_m is marginal costs in manufacturing production representing the pricing-to-market hypothesis. The function $g(\cdot)$ is homogenous of degree one in prices and marginal costs enter with an elasticity of 0.35 in the long run, which is close to the corresponding estimate in Naug and Nymoen (1996). The pricing-to-market effects imply that the exchange rate is (partially), but not fully passed on to import prices in domestic currency in the long run due to imperfect competition. In the short run, the effect of the exchange rate is even smaller according to the estimated dynamics of (1). However, as domestic prices and costs also are influenced by changes in the exchange rate the reduced form of the macroeconometric model implies full pass-through in the very long run. For non-competitive imports where no similar domestic production exists, we assume the law of one price or the traditional small open economy assumption to be valid. Benedictow and Boug (2012) discuss the cointegrated VAR modelling of import prices of manufactures in more detail.

2.2 Competing prices, mark-ups and product prices

With imperfect competition producers in each industry j face regular downward sloping demand curves both domestically and abroad. Profit maximisation then leads to the formula stating that the destination specific price l of product i (P_{li}) equals a mark-up (MU_{li}) times marginal costs (MC_j)

$$(2) \quad P_{li} = MU_{li} \cdot MC_j, \quad l = D, A, \quad i = 1, \dots, 44 \quad \text{and} \quad j = 1, \dots, 24,$$

where P_D and P_A are the prices on the domestic market (D) and the export market (A), respectively, MU_{li} are the product specific mark-ups in the domestic and export markets and MC_j is the industry specific marginal costs.⁴ Typically in the new Keynesian literature, see e.g. Galí *et al.* (2001), producers are assumed to face isoelastic demand so the mark-up is a constant. This is the case with CES-utility functions in Dixit and Stiglitz (1977). When commodities within each industry are close substitutes, but poor substitutes for goods in other industries, so-called two-stage budgeting is valid. Moreover, if the number of goods in the industry is large, Dixit and Stiglitz (1977) show that individual producer prices have little impact on the aggregate industry price. Hence, we may assume that the individual producer ignores the effect of his price setting on the aggregate price. In general, the mark-up is not constant, but depends on all factors affecting demand for the particular commodity, see equation (32) in Dixit and Stiglitz (1977). In an open economy framework, the *a priori* assumption of all goods and services being perfect substitutes is clearly unreasonable. We therefore allow the mark-up to depend on relative prices in a way that also accommodates the possibility that producers may be price takers on world markets. Specifically, we let in accordance with Bowitz and Cappelen (2001) and Bjørnstad and Nymoén (2008) the mark-up be determined by

$$(3) \quad MU_{li} = m_{0li} (P_{li} / PI_i)^{m_{1li}}, l = D, A \text{ and } i = 1, \dots, 44,$$

where PI_i denotes the competing import price of product i and $m_{0li} > 0$ and $m_{1li} \leq 0$ reflect conditions on the demand side of the product markets. With $m_{1li} < 0$ an increase in the competing price allows the producer to increase the mark-up over marginal costs. The more negative m_{1li} becomes the more closely pricing decisions resemble price taking behaviour, which can be seen by inserting (3) into (2) and solving for P_{li}

$$(4) \quad P_{li} = m_{0li}^{1/(1-m_{1li})} \cdot PI_i^{-m_{1li}/(1-m_{1li})} \cdot MC_j^{1/(1-m_{1li})}, l = D, A, i = 1, \dots, 44 \text{ and } j = 1, \dots, 24.$$

We see from (4) that P_{li} is homogenous of degree one in PI_i and MC_j and that $P_{li} = PI_i$ if m_{1li} approaches infinity. The estimated price models in most cases imply that mark-ups on domestic markets are independent of the import price while the specification in (3) receives much support by data. The latter result indicates that formation of export prices is closer to the small open economy

⁴ The input-output structure of the macroeconomic model contains more goods than industries so there is joint production in some industries. For instance, the industry Refineries produces petrol, gasoline and a composite good in addition. For these goods the mark up MU_{li} can vary both between goods and destination (home or abroad). However, there is only one observable marginal cost which therefore is indexed by industry not commodity in (2).

assumption than prices on domestic markets. Accordingly, exchange rate pass-through to domestic prices is mainly related to production costs, while exchange rate pass-through to export prices is both related to marginal costs and mark-ups. Export prices of crude oil and natural gas in USD are assumed to be determined on the world markets and the exchange rate pass-through immediate with no domestic cost component, i.e., we assume oil companies are price takers.

2.3 Import prices and domestic production costs

For each industry, we specify a Cobb-Douglas production function with labour and materials as variable factors and capital as quasi fixed. Then, it follows that MC_j and variable unit costs (VUC_j) are proportional. Thus, we replace MC_j with VUC_j , which is defined as

$$(5) \quad VUC_j = (PM_j \cdot M_j + W_j \cdot LW_j) / X_j, \quad j = 1, \dots, 24,$$

where M_j is material inputs or intermediate inputs defined as a simple Leontief-aggregate of the 44 commodities included in the model, PM_j is the dual price index of M_j , W_j is wage costs per hour, LW_j is hours worked and X_j is gross production, see Hungnes (2011) for details on how LW_j and M_j are modelled in the macroeconometric model. The input price index PM_j by industry is determined by summing over all goods

$$(6) \quad PM_j = \sum_i \alpha_{ij} [(1 + VAT_{ij}) \cdot ((1 - IS_i) \cdot P_{Di} + IS_i \cdot PI_i + \psi_{ij} ET_{ij})] + \alpha_{Dj} \cdot TM, \\ i = 1, \dots, 44 \text{ and } j = 1, \dots, 24,$$

where the α_{ij} 's are input-output coefficients, VAT_{ij} are value added taxes, ET_{ij} are excise taxes, IS_i are import shares and TM denotes the national accounts price index for trade margins in the distribution sector. Because inputs of imported materials are important for total material costs (many large values of $\alpha_{ij} IS_i$ in (6)), changes in exchange rates – when passed through to prices in local currency – will affect domestic prices and hence PM_j and VUC_j significantly.

2.4 Import prices and import penetration

The size of import shares determines the degree of import penetration from exchange rate changes both in consumption and production. For each commodity, assuming weak separability in demand between imported goods and home goods of the same variety (i.e., they are linked together using a CES aggregate), the import shares are functions of the relative domestic price to the import price

$$(7) \quad IS_i = l(P_{Di} / PI_i), i = 1, \dots, 44.$$

For each consumption group k we define a consumer price index (CP_k) similar to (6)

$$(8) \quad CP_k = \sum_i \alpha_{ik} [(1 + VAT_{ik}) \cdot ((1 - IS_i) \cdot P_{Di} + IS_i \cdot PI_i + \psi_{ik} ET_{ik})] + \alpha_{Dk} \cdot TM,$$

$$k = 1, \dots, 14 \text{ and } i = 1, \dots, 44.$$

We see that (8) links consumer prices to domestic prices, import prices, import shares, value added taxes, excise taxes and trade margins. The coefficient α_{Dk} represents the share of the trade margins (TM) in total consumer price for each consumption group in the base year. For some categories of consumption, say electricity and transportation, there is no trade margin at all, so $\alpha_{Dk} = 0$. For the CPI as a whole, the share of the trade margins is close to 0.3.⁵ Thus, TM is of great importance for some consumer prices and thereby inflation. The direct (and partial) effect of an import price increase, say due to a depreciation of the exchange rate, on the CPI through the imported goods is estimated in the national accounts to 0.17 in 2006. As long as the trade margins are assumed constant in nominal terms, this pass-through effect takes place in the same quarter as import prices increase.

2.5 Product prices, production costs and wage formation

The modelling of wages in the macroeconometric model is based on the symmetric Nash bargaining model following Nickell and Andrews (1983) and Hoel and Nymoen (1988). In manufacturing, wages are determined by profitability in that sector (which determines the "wage-corridor" in the long run version of the Scandinavian model of inflation, see Aukrust (1977)), while consumer prices as well as income taxes have no long run effects. Thus, the wage-curve relating real wages to unemployment thus includes the producer real wage not the consumer real wage. In private and government services wages are based on the alternative or "outside" wage depending on wages in other sectors and unemployment benefits, see Bowitz and Cappelen (2001) for a more detailed discussion. Consequently wage-wage spirals in non-manufacturing industries lead in the long run to profitability in manufacturing being the main nominal factor determining wages. The wage equation in manufacturing can be simplified as

⁵ The CPI is a weighted sum of all the CP_k . At an aggregate level these weights are determined using national accounts data. The weights are determined by a detailed consumer demand system in the macroeconometric model, see Appendix A.

$$(9) \quad W_m = Z_m \cdot PYF_m \cdot UR^{-\eta},$$

where Z_m is labour productivity in manufacturing defined as value added per hours worked $(X_m - M_m) / LW_m$, PYF_m is the value added deflator at factor prices in manufacturing defined as $(P_{Dm} \cdot (X_m - A_m) + P_{Am} \cdot A_m - PM_m \cdot M_m) / X_m$ and UR is the unemployment rate determined as the difference between supply and demand of labour in the economy as a whole. Hence, exchange rate pass-through to wages mainly works through import prices to the extent that imported materials are important for total material costs and mark-ups and output prices in particular export prices that depend on competing prices in world markets. Further delays in the exchange rate pass-through process result from wage-wage spirals that pass wage impulses from manufacturing to more sheltered sector of the economy. Wages in sheltered sectors affect marginal costs and domestic prices, and thereby reflected in the CPI.

The modelling of wages based on the institutional set-up in Norway is one feature that distinguishes our macroeconometric model from mainstream econometric models in most countries where centralised wage bargaining has become less important. However, disregarding wage formation, the presentation of the main pass through channels in this section is quite general and not very specific to the Norwegian economy. The specific characteristics of the distribution sector in Norway and the importance of the trade margins for the overall pass-through of exchange rate changes to consumer prices are discussed in the next section.

3. The distribution sector

Our modelling of the pricing behaviour in the distribution sector differs somewhat from the general price equation (4). In the Norwegian national accounts, the domestic price in the distribution sector comprises the *trade margins* on distribution services from supplier to user. Thus, the national accounts make a clear distinction between services delivered and products traded, and it is the former that constitutes the production activity in the distribution sector. The consumer price thus consists of two components: the price on the services delivered (i.e., the trade margin) and the purchasing price (or costs) of the good sold (exclusive of the trade margin).

3.1 Theory

In line with (4), we assume trade margins to be proportional to marginal costs in the distribution sector. Here, we may think of two cases depending on the substance of the marginal costs in each

particular wholesale and retail trade firm. First, some firms may set their trade margins as a *constant amount of money per unit traded commodity*, i.e., independent on the purchasing price per unit (exclusive of the trade margin). In this case, the marginal costs are only related to costs of production. We approximate these costs in accordance with (5) letting VUC^d denote variable unit costs in the distribution sector. Second, some firms may set their trade margins as a *fixed percentage mark-up on the purchasing price* (exclusive of the trade margin). In this case, the marginal costs also depend on the purchasing price on goods sold, and not only on costs in production. We approximate these costs by constructing a price index of purchasing prices (PP) in the distribution sector

$$(10) \quad PP = \sum_k \delta_k \left[\sum_i \beta_{ik} (1 - IS_i) \cdot P_{Di} + \beta_{ik} \cdot IS_i \cdot PI_i \right],$$

where δ_k is the volume share of demand category k out of total trade, β_{ik} is the input-output coefficient for total delivery of commodity i to demand category k in the base year and IS_i , P_{Di} and PI_i are as defined in the previous section.⁶ This price index thus weighs together domestic and import prices on all commodities traded by the wholesale and retail trade sector. Both the import shares (through IS_i) and each demand category weight (through δ_k) are time series. For simplicity, we assume constant β_{ik} coefficients and ignore any variations in these coefficients relative to base year values.

The distribution sector in Norway has undergone significant structural changes over the past decades. Shopping centres have replaced a large part of small shops run by self-employed. This has resulted in lower trade margins over time. We capture this underlying structural change by including a ratio of hours-worked by self-employed (H) and total production or services delivered (X^d) in the price equation for the trade margins. We specify aggregate trade margins as

$$(11) \quad TM = PP^\gamma \cdot VUC^{d(1-\gamma)} \cdot (H / X^d)^\phi.$$

The coefficients γ , $(1-\gamma)$ and ϕ measure the degree of pass-through of changes in purchasing prices (through domestic and/or import prices), variable unit costs and the mentioned ratio of the two "trend"-variables, respectively. We interpret (11) as a long run relationship between TM , PP , VUC^d

⁶ The main categories in (10) are Food, Beverages, Tobacco, Fuels for heating purposes, Purchase of and expenses on own transport vehicles, Purchase of other durable goods, Clothes and footwear, Health services and Investments in machines and transport vehicles. The β_{ik} coefficients in (10) are scaled such that for each demand category k they sum up to unity for those commodities included in k . Likewise, by definition, the δ_k coefficients also sum up to unity. Prices included in PP are producer prices (exclusive of trade margins) based on sales to the domestic market only. The national accounts define a similar price index for sales on foreign markets and the export price deflator for the trade sector is equal to this index.

and H/X^d and will serve as the starting point for the cointegration analysis below. In the dynamic modelling, we introduce changes in the nominal exchange rate (E) as an additional explanatory variable and suggest that trade margins act as cushions to exchange rate fluctuations in the short and medium term, thereby mitigating the degree of exchange rate pass-through. We also open up for the nominal interest rates (R) to play a potential role in the short run dynamics of trade margins to account for *financial* costs associated with stock of goods. Details on data definitions and sources can be found in Appendix B.

3.2 Data

The econometric modelling of trade margins is based on quarterly, seasonally unadjusted data that span the period 1970Q1–2010Q3, of which data from the period 1970Q1–1998Q4 and 1999Q1–2010Q3 are used for estimation and *out-of-sample* forecasting, respectively. The reasons for ending the estimation period in 1998Q4 are as follows: Taylor (2000) among others argues that the degree of exchange rate pass-through to domestic prices depends on the monetary policy regime in force. During the 1970s Norway joined the European exchange rate agreement, the so-called "snake". However, the Norwegian currency (the krone) experienced significant revaluations and devaluations during the first decade of our sample period. When Norway left the "snake" at the end of the 1970s and established a currency basket, the krone still showed relatively high variability during the 1980s. Following a 12 percent devaluation of the krone in May 1986, a flexible interest rate policy was introduced with the explicit goal of supporting a policy of fixed exchange rates, and as of October 1990 against the ECU. After the turmoil following the speculative attacks against the krone by the end of 1992, Norway changed to a managed "floating" exchange rate regime whereby the exchange rate was allowed to float within defined upper and lower bands. However, Norway *formally* changed from exchange rate targeting in various forms to freely floating exchange rates following the introduction of inflation targeting in late March 2001. Several Norwegian economists argue that the regime change in fact occurred early in 1999. In any case, the monetary policy change took place after 1998Q4; the last observation used in our estimation. The *major* regime shift in monetary policy could in principle have caused the degree of exchange rate pass-through to alter in accordance with the Lucas critique. We shed light on this hypothesis by conducting an *out-of-sample* forecasting exercise with data covering the period 1999Q1–2010Q3. By ending the forecasting period in 2010Q3, we are also able to test the hypothesis that the distributors pricing behaviour has changed significantly during the financial crises in 2008 and 2009 with highly volatile exchange rates.

Figure 2 displays time series of trade margins (tm_t), purchasing prices (pp_t) and variable unit costs (vuc_t^d) together with the ratio $(h-x^d)_t$, the nominal exchange rate (e_t) and the nominal interest rate (R_t) over the entire sample period 1970Q1–2010Q3.⁷ We observe that trade margins, purchasing prices and variable unit costs exhibit a clear upward trend. The underlying development in the market conditions described above is also evident in the data series as $(h-x^d)_t$ shows a clear downward trend, a trend which presumably has contributed to the observed price dampening since the late 1980s. The exchange rate series and the interest rate series, on the other hand, show some evidence of mean reversion (although slow) property. A clear reduction in trade margins through 1979 coincides with massive governmental price regulations during the second half of the 1970s, cf. Bowitz and Cappelen (2001).

Figure 2. Time series for $tm_t, pp_t, vuc_t^d, (h-x^d)_t, e_t$ and R_t

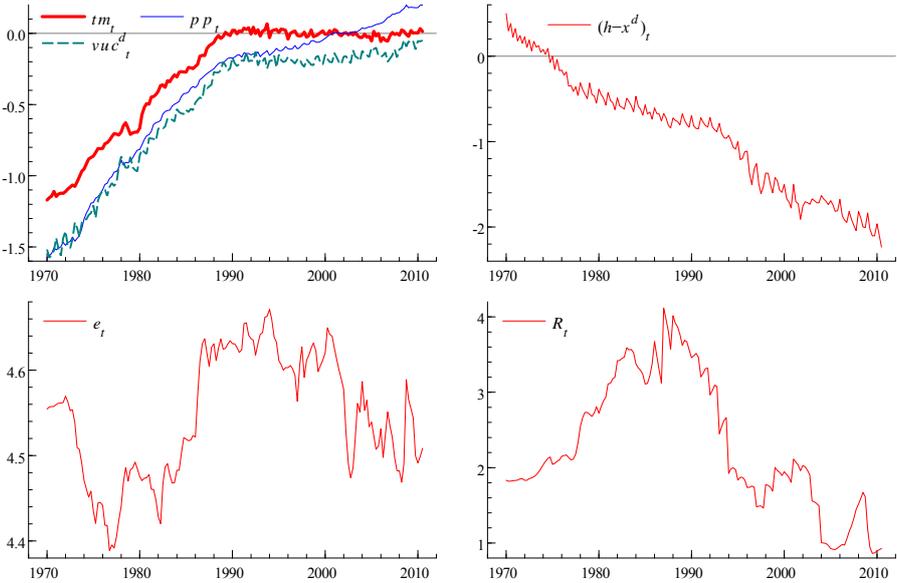


Table 1 reports standard Augmented Dickey-Fuller tests. It is evident that tm_t, pp_t, vuc_t^d and $(h-x^d)_t$ as well as e_t and R_t in our sample period are integrated of order one. Accordingly, all six variables should in principle be modelled as non-stationary $I(1)$ variables in the cointegration analysis below. However, we choose to carry out the cointegration analysis with e_t and R_t being non-modelled stationary variables in order to get a manageable and still statistically well specified underlying vector

⁷ All variables except the interest rates are in logarithms and denoted by lower case letters in what follows.

autoregressive (VAR) model. There is also supporting evidence for this approach in that the corresponding equilibrium correction term in the final dynamic model for trade margins seems to be stationary.

Table 1. Augmented Dickey-Fuller tests

Variable	<i>t</i> -ADF	5% critical value	Lags
tm_t	-1.207	-3.44	1
pp_t	-1.856	-3.44	4
vuc_t^d	-1.384	-3.44	5
$(h-x^d)_t$	-1.997	-3.44	5
e_t	-1.613	-3.44	4
R_t	-1.294	-3.44	4
Δtm_t	-4.541	-2.88	3
Δpp_t	-3.265	-2.88	3
Δvuc_t^d	-4.035	-2.88	4
$\Delta(h-x^d)_t$	-5.390	-2.88	4
Δe_t	-7.100	-2.88	4
ΔR_t	-4.355	-2.88	3

Notes: Sample period: 1971Q3 – 2010Q3 for variables in levels and 1971Q4 – 2010Q3 for variables in first differences.

The regressions include a constant, a trend and seasonals and a constant and seasonals in the cases of ADF-test on variables in levels and variables in first differences, respectively. Initially, the regressions include five lags. Akaike's information criterion is used in order to choose the optimal lag order.

3.3 Cointegration analysis

Because multiple cointegrating vectors among the variables in (11) may exist, we employ the Johansen (1995, p. 155) trace test for cointegration rank determination, both with and without small sample adjustments. In accordance with the Augmented Dickey Fuller tests, we may fit a six-dimensional VAR to the data and then test formally, after having determined the cointegration rank, the exogeneity status or otherwise of the exchange rate series and the interest rate series. However, as pointed out by Johansen (1995, p. 213), the power of the trace test decreases as the dimension of the underlying VAR increases. For this reason, and the fact that the number of parameters to be estimated in a six-dimensional VAR is very large relative to the number of observations in the available data set, it would be useful to impose weak exogeneity on both the exchange rate series and the interest rate series. Hence, we rely on Rahbek and Mosconi (1999) for the cointegration rank inferences with e_t and

R_t being the supposedly non-modelled stationary regressors in our case. We then perform weak exogeneity tests on e_t and R_t by means of standard χ^2 inference after the value of the rank and the estimates of the cointegrating vector (s) are determined. Our starting point of the cointegration analysis and the tests that follow is thus an equilibrium correction representation of a four-dimensional VAR (henceforth CVAR) of order k having the form

$$(12) \quad \Delta x_t = \sum_{i=1}^{k-1} \theta_i \Delta x_{t-i} + \sum_{i=0}^k \phi_i y_{t-i} + \sum_{i=0}^k \varphi_i z_{t-i} + \pi x_{t-1} + \mu + \psi S_t + \eta D_t + \varepsilon_t,$$

where $x_t = (tm_t, pp_t, vuc_t^d, (h-x^d)_t)'$ is a vector of the modelled variables, $y_t = e_t$ and $z_t = R_t$ are the stationary explanatory variables, μ is a vector of constants, S_t is a vector of centered seasonals (labelled S_{1t} , S_{2t} and S_{3t}), D_t contains a price stop dummy (labelled $PSTOP_t$) with a value of unity in price regulation periods and minus unity in catch-up periods during the second half of the 1970s and $\varepsilon_t \sim \text{IN}(0, \Sigma)$. Assuming x_t to be $I(1)$, presence of cointegration implies $0 < r < 4$, where r denotes the rank or the number of cointegrating vectors of π . The null hypothesis of r cointegrating vectors may be formulated as $H_0 : \pi = \alpha\beta'$, where α and β are $4 \times r$ matrices, $\beta' x_t$ comprises r cointegrating $I(0)$ linear combinations and α contains the adjustment coefficients. We let the constants, the seasonals, the price stop dummy and the stationary regressors enter unrestrictedly in (12). However, as pointed out by Rahbek and Mosconi (1999), the asymptotic distribution of the trace test in this model depends on nuisance parameters due to the presence of stationary regressors. Hence, the approach suggested by Rahbek and Mosconi (1999) is to analyse the extended model given by

$$(13) \quad \Delta x_t = \sum_{i=1}^{k-1} \theta_i \Delta x_{t-i} + \sum_{i=0}^k \phi_i y_{t-i} + \sum_{i=0}^k \varphi_i z_{t-i} + \pi^* \begin{pmatrix} x_{t-1} \\ \sum_{i=1}^t y_i \\ \sum_{i=1}^t z_i \\ t \end{pmatrix} + \mu + \psi S_t + \eta D_t + \varepsilon_t,$$

where $\pi^* = \alpha\beta^{*r}$. After the rank is determined using critical values tabulated in Harbo *et al.* (1998), we test the linear restrictions that there are no accumulated level of the exchange rate series and the interest rate series and no linear trend in the cointegrating relations by considering the hypothesis $\beta^* = (\beta, 0)'$ with standard χ^2 inference. The likelihood ratio tests for this hypothesis may be regarded as misspecification tests of the model in (12). Strictly speaking, the cointegration rank needs not be determined from (12) once it has been determined from (13). Nevertheless, we compare the

cointegration rank inference from (13) with the cointegration rank inference from (12) as a robustness check. As guidance for choosing the optimal lag order (k) we rely on both Akaike's information criterion (AIC) and various diagnostic tests. According to AIC we should include five lags ($k = 5$) in both (12) and (13), albeit AIC is a borderline case with respect to $k = 4$ and $k = 5$ in (12). However, although the equation for Δtm_t has well-behaved residuals in both models, this was not the case for the other three equations. To secure valid statistical inference, we include the same set of impulse dummies in (12) and (13) to control for outliers and instabilities in the equations for Δpp_t , Δvuc_t^d and $\Delta(h-x^d)_t$, see Appendix B for details. Diagnostic tests for the preferred VARs (with $k = 5$) including the set of impulse dummies reveal no serious problems with misspecification and recursively estimated one step residuals and sequences of break-point Chow tests indicate that both systems are reasonably stable over the sample. Table 2 reports trace test statistics using (12) and (13).

Table 2. Tests for cointegration rank

Hypothesis	Model (13)		Model (12)	
	λ_{trace}	λ^a_{trace}	λ_{trace}	λ^a_{trace}
$r = 0$	105.39 (80.9)	86.40 (80.9)	60.05 [0.002]	49.23 [0.035]
$r \leq 1$	61.81 (56.3)	50.68 (56.3)	32.34 [0.024]	26.51 [0.117]
$r \leq 2$	32.76 (35.5)	26.85 (35.5)	10.21 [0.270]	8.37 [0.434]
$r \leq 3$	11.16 (17.9)	9.15 (17.9)	0.38 [0.537]	0.31 [0.576]

Notes: Sample period: 1971Q2 – 1998Q4. The underlying VARs are of order 5. r denotes the cointegration rank. The λ_{trace} and λ^a_{trace} are the trace test statistics without and with degrees-of-freedom-adjustments, respectively. The critical values in parenthesis, which correspond to the 5 per cent significance level, are from Table 2 in Harbo *et al.* (1998). The p -values in brackets, which are reported in OxMetrics, are based on the approximations to the asymptotic distributions derived by Doornik (1998). The critical values produced by OxMetrics are only indicative as the inclusion of the two conditioning variables in (12) affects the asymptotic distribution of the trace test, see Rahbek and Mosconi (1999).

Based on (13) and the trace test with a small sample adjustment (λ^a_{trace}), the null hypothesis of no cointegration is rejected at the 5 per cent significance level, whereas the hypothesis of at most one cointegrating vector among the variables involved is not. Testing the hypothesis $\beta^* = (\beta, 0)'$, assuming $r = 1$, gives $\chi^2(1) = 4.324$ (p -value = 0.038), $\chi^2(1) = 0.081$ (p -value = 0.776) and $\chi^2(1) = 4.858$ (p -value = 0.028) for the accumulated level of the exchange rate series, the accumulated level of the interest rate series and the linear trend, respectively. Accordingly, the hypothesis of no accumulated level of the exchange rate series and no linear trend in the cointegrating relationship, although not accepted at the 5 per cent significance level, is not strongly rejected. In this sense, we argue that (12) to a large degree passes the

misspecification tests. Based on (12), we also notice that λ_{trace}^a supports the hypothesis of only one cointegrating vector between tm_t , pp_t , vuc_t^d and $(h-x^d)_t$, the same conclusion about the value of the rank using (13). We therefore apply (12) in the successive cointegration analysis assuming $r=1$. The estimate of the *unrestricted* cointegrating vector (normalised on tm_t) is given by (standard errors in parenthesis)

$$(14) \quad tm_t = \hat{\alpha}_0 + 0.384pp_t + 0.529vuc_t^d + 0.055(h-x^d)_t,$$

(0.175) (0.176) (0.057)

which is interpretable as an equation for trade margins as the estimated coefficients for purchasing prices, marginal costs and the ratio between self-employed hours worked and production are economically reasonable with expected signs. Besides, weak exogeneity tests give $\chi^2(1)=5.504$ (p -value = 0.019), $\chi^2(1)=2.659$ (p -value = 0.103), $\chi^2(1)=4.949$ (p -value = 0.026) and $\chi^2(1)=0.093$ (p -value = 0.761) for tm_t , pp_t , vuc_t^d and $(h-x^d)_t$, respectively, which imply that the cointegrating vector enters the Δtm_t -equation (albeit also the Δvuc_t^d -equation, but not so significantly). The sum of the estimated coefficients of γ and $(1-\gamma)$ in (14) is not far from unity. To complete the cointegration analysis, we thus tested for, and could not reject, homogeneity between tm_t , pp_t and vuc_t^d . Imposing the homogeneity restriction and weak exogeneity of $(h-x^d)$ gives $\chi^2(2)=3.557$ (p -value = 0.169) and the following *restricted* estimate of the cointegrating vector (standard errors in parenthesis):

$$(15) \quad tm_t = \hat{\alpha}_0 + 0.365pp_t + 0.635vuc_t^d + 0.123(h-x^d)_t,$$

(0.186) (0.019)

Recursively estimated parameters of vuc_t^d and $(h-x^d)_t$ are reasonably constant and a sequence of $\chi^2(2)$ test statistics confirms the validity of the homogeneity restriction and the weak exogeneity status of the ratio between self-employed hours worked and production for any sample ending between 1985 and 1998. Also, the restricted cointegrating vector is virtually unchanged from the unrestricted one. Before exploiting results from the cointegration analysis within a dynamic equilibrium correction model of trade margins we shall test formally that the exchange rate series and the interest rate series are weakly exogenous and not just an assumption imposed at the outset. We carry out likelihood ratio tests based on a CVAR system using deviations from (15) as an equilibrium correction mechanism (*EqCM*)

$$(16) \quad \Delta x_t = \sum_{i=1}^4 \theta_i \Delta x_{t-i} + \delta EqCM_{t-1} + \mu + \psi S_t + \eta D_t + \vartheta DUM_t + \varepsilon_t,$$

where x_t now, as opposed to (12), also contains e_t and R_t and DUM_t includes the set of impulse dummies described above. The system in (16) is estimated by FIML. Testing the hypothesis of weak exogeneity of e_t and R_t involves zero restrictions on the associated adjustment coefficients inherent in δ . The likelihood ratio test gives $\chi^2(2)=1.751$ (p -value = 0.417), which means that the hypothesis of weak exogeneity of e_t and R_t with respect to the long run parameters in (12) is not rejected by data.

3.4 Short run dynamics

We now focus on (i) the dynamic adjustment of trade margins to changes in purchasing prices, variable unit costs and the ratio between self-employed hours worked and production and (ii) the role of the exchange rate and the interest rates as separate explanatory variables in the short and medium term. For this purpose, we derive a dynamic equilibrium correction model for trade margins based on a general-to-specific modelling strategy. We recall that the weak exogeneity tests imply that both tm_t and vuc_t^d are error correcting (albeit the latter less significantly), whereas pp_t and $(h-x^d)_t$ are not.

Consistent with the cointegration analysis, we therefore start with a general system

$$\begin{aligned} \Delta tm_t = & \kappa_{tm} + \sum_{i=1}^4 \omega_{1i} \Delta tm_{t-i} + \sum_{i=0}^4 \omega_{2i} \Delta pp_{t-i} + \sum_{i=0}^4 \omega_{3i} \Delta vuc_{t-i}^d + \sum_{i=0}^4 \omega_{4i} \Delta (h-x^d)_{t-i} \\ & + \sum_{i=0}^4 \omega_{5i} \Delta e_{t-i} + \sum_{i=0}^4 \omega_{6i} \Delta R_{t-i} + \lambda_{tm} EqCM_{t-1} + \psi_{tm} S_t + \eta_{tm} D_t + \vartheta_{tm} DUM_t + \varepsilon_{tm,t} \end{aligned} \quad (17)$$

$$\begin{aligned} \Delta vuc_t^d = & \kappa_{vuc^d} + \sum_{i=0}^4 \omega_{1i} \Delta tm_{t-i} + \sum_{i=0}^4 \omega_{2i} \Delta pp_{t-i} + \sum_{i=1}^4 \omega_{3i} \Delta vuc_{t-i}^d + \sum_{i=0}^4 \omega_{4i} \Delta (h-x^d)_{t-i} \\ & + \sum_{i=0}^4 \omega_{5i} \Delta e_{t-i} + \sum_{i=0}^4 \omega_{6i} \Delta R_{t-i} + \lambda_{vuc^d} EqCM_{t-1} + \psi_{vuc^d} S_t + \eta_{vuc^d} D_t + \vartheta_{vuc^d} DUM_t + \varepsilon_{vuc^d,t} \end{aligned}$$

The system in (17) is estimated by FIML. To exactly identify the two equations in the system, the impulse dummy $D74Q1$ and the price stop dummy $PSTOP_t$ are excluded from the equation for trade margins and variable unit costs, respectively. We find a parsimonious model by stepwise elimination of insignificant variables in the system. It turned out that this general-to-specific system analysis produces a dynamic model for trade margins which is close to the economic content and statistical significance of a dynamic model derived from a general-to-specific single equation analysis of (17). For this reason, we focus in the following on the dynamic model for trade margins derived from the single equation analysis. We thereby follow the argument by Boswijk and Urbain (1997), that one may apply single equation analysis with the long run relationship(s) estimated and deduced from a VAR in cases where the conditioning variables are error correcting, but weakly exogenous for the short run

parameters. Also, an equation for variable unit costs, through the definition in (5) in Section 2 and CVARs for wages and labour demand, is already embedded in the macroeconometric model.

The specific dynamic model derived from the single equation analysis is presented in (18). The conditioning on Δpp_t and $\Delta(h-x^d)_t$ may pose caveats because they need not be weakly exogenous for the short run parameters. Adding the predicted counterparts to Δpp_t and $\Delta(h-x^d)_t$ from the VAR, both individually and jointly, yield p -values of 0.307 and 0.545 and $\chi^2(2)=1.386$ (p -value = 0.500), and may be taken as evidence that Δpp_t and $\Delta(h-x^d)_t$ indeed are weakly exogenous for the short run parameters in (18). Consequently, the parameters in (18) are consistently estimated by OLS.^{8,9}

$$\begin{aligned}
 \Delta tm_t = & \text{const.} - 0.188\Delta_2 tm_{t-1} + 0.607\Delta pp_t + 0.258\Delta_2 pp_{t-2} + 0.092\Delta vuc_{t-3}^d \\
 & (0.066) \quad (0.113) \quad (0.071) \quad (0.041) \\
 & + 0.046\Delta(h-x^d)_t - 0.252\Delta e_t + 0.022\Delta R_{t-2} + 0.033\Delta R_{t-4} \\
 & (0.026) \quad (0.107) \quad (0.010) \quad (0.011) \\
 (18) \quad & - 0.245[tm - 0.365pp - 0.635vuc^d - 0.123(h-x^d)]_{t-1} \\
 & (0.054) \\
 & - 0.019S_{1t} - 0.022PSTOP_t \\
 & (0.006) \quad (0.004) \\
 \\
 & OLS, T=111(1971Q2-1998Q4), R^2=0.601, \sigma=1.73\% \\
 & AR_{1-5}: F(5, 94) = 0.935 [0.462] \\
 & ARCH_{1-4}: F(4, 103) = 1.789 [0.137] \\
 & NORM: \chi^2(2) = 1.036 [0.596] \\
 & HET: F(21, 89) = 0.679 [0.843] \\
 & RESET: F(2, 97) = 1.676 [0.193]
 \end{aligned}$$

⁸ Square brackets [...] and parenthesis (..) contain p -values and standard errors, respectively.

⁹ Based on statistical inference we have simplified the dynamics in (18) such that

$$\Delta_2 tm_{t-1} = \Delta tm_{t-1} + \Delta tm_{t-2} = tm_{t-1} - tm_{t-3} \text{ and } \Delta_2 pp_{t-2} = \Delta pp_{t-2} + \Delta pp_{t-3} = pp_{t-2} - pp_{t-4}.$$

Below (18) we report several test statistics.¹⁰ None of the diagnostics are significant at the 1 per cent significance level. The economic variables entering (18) are all significant and the *EqCM* appears in the model with a *t*-value of -4.54 , adding force to the results obtained from the cointegration analysis. We notice that (18) implies rejection of *dynamic* homogeneity and that the mark-up rates decrease with higher inflation, a finding which is in line with previous studies based on European and American data, see e.g. Bénabou (1992), Bowitz and Cappelen (2001) and Banerjee and Russell (2004). Empirical evidence of constancy of (18) is supported by one-step residuals, one-step Chow tests, break-point Chow tests, forecast Chow tests and recursively estimated coefficients, which do not reject constancy between 1979 and 1998. Besides, the impulse dummies used to account for outliers in the Δpp_t , Δvuc_t^d and $\Delta(h-x^d)_t$ equations in the VAR are all *insignificant* when added to (18), both individually and jointly. These findings are evidence against relevance of the Lucas critique in our context, see e.g. Favero and Hendry (1992), and we claim that the degree of exchange rate pass-through to trade margins has remained fairly constant throughout the estimation period.

The estimated impact response of purchasing prices (0.6) is somewhat larger than its long run counterpart. Apparently, the trade margins overshoot with respect to changes in domestic as well as import prices on traded commodities in the short run. The pass-through from variable unit costs to the trade margins is, however, delayed and incomplete in the short run. Turning to the exchange rate itself, the estimated impact elasticity of -0.25 shows that trade margins are significantly affected by exchange rate fluctuations in the short run. These *direct* effects of the exchange rate work in the opposite direction compared to the *indirect* effects of purchasing prices and variable unit costs. If the exchange rate appreciates by 10 percent, say, then trade margins increase immediately by 2.5 percent, but at the same time decrease with changes in purchasing prices (and variable unit costs with some delay) that are caused by decreased import prices of tradable goods and material inputs. With periods of large fluctuations in the exchange rate, firms may find it difficult to perceive whether the changes are transitory or permanent. Hence, it is likely that firms are reluctant to change their prices in response to exchange rate fluctuations for reasons such as menu costs and stock of products with different purchasing price than the current price. Under such circumstances, firms may increase their sales considerably by leaving the trade margins unchanged in periods of exchange rate appreciation.

¹⁰ The reported statistics are as follows: T , R^2 and σ are the number of observations, the squared multiple correlation coefficient (adjusted) and the residual standard errors, respectively. AR_{1-5} is Harvey's (1981) test for up to 5th order residual autocorrelation, $ARCH_{1-4}$ is the Engle (1982) test for up to 4th order autoregressive conditional heteroskedasticity in the residuals, $NORM$ is the normality test described in Doornik and Hansen (1994), HET is a test for residual heteroskedasticity due to White (1980) and $RESET$ tests for functional form misspecification [cf. Ramsey (1969)]. $F(\cdot)$ and $\chi^2(\cdot)$ represent the null distributions of F and χ^2 , with degrees of freedom shown in parenthesis. The null hypothesis underlying the various diagnostic tests is that the residuals are white noise.

Some firms (importers) may also secure themselves against exchange rate fluctuations, either through financial instruments or price agreements, thereby contributing to modest exchange rate pass-through to trade margins and further to consumer prices. The short run dynamics of the trade margins are also in a quantitatively important way influenced by past changes in interest rates. The adjustment towards steady state is rather slow as reflected by the small estimated magnitude of the loading parameter (-0.24).

To explain how the *consumer price* effects are arrived at using (8), (11), (15) and (18), we make use of the consumer price index of new cars as an example. Since Norway has almost no production of cars, we simplify and assume that only the import price of cars enters (8). However, cars are heavily taxed not only through *VAT*, but also through excise taxes (*ET*). A simplified version of (8) for cars reads $CP_{CARS} = 0.54 \cdot PI_{CARS} + 0.32 \cdot ET_{CARS} + 0.14 \cdot TM$,¹¹ where the coefficient 0.14 represents the share of the trade margin in the purchasing price of a car in the base year. We notice that *ET* should be interpreted as the level of the excise tax on cars relative to the base year level. In the base year of the model, calibration to national accounts data implies that *CP*, *PI*, *ET* and *TM* are all one, so that the equation is balanced. Using the estimated coefficients in (15), ignoring the ratio of self-employed to production for simplicity, (11) becomes $TM = c \cdot PP^{0.37} \cdot VUC^{0.63}$. In *PP*, the partial weight of the import price of cars is small. Thus, if the import price on cars goes up by 10 per cent due to an increase in world market prices on cars, the effect on the consumer price of cars is 5.4 percent. Suppose instead that the Norwegian currency depreciates by 10 percent. Then, with full and immediate pass-through to *PI*, the effect is again 5.4 percent, but now there are additional effects through *TM*. Assuming that import prices on all goods traded through the distribution sector make up *half* of the prices that enter *PP*, trade margins increase by 1.9 percent ($0.37 \cdot 0.5 \cdot 10$). However, only 0.14 times this increase adds to the consumer price of cars, which then increases by 5.7 percent ($0.14 \cdot 1.9 + 5.4$). According to (18), the estimated dynamics imply that *TM* acts as a cushion to exchange rate fluctuations the first year due to the short run effects of the exchange rate on *TM*. In later years there is a gradual and smooth increase in the consumer prices on cars due to the fact that variable unit costs also increase gradually, in particular wages according to (9) in Section 2.

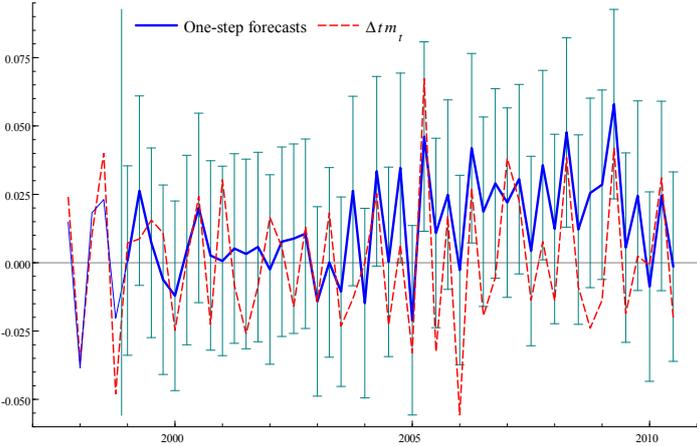
3.5 Out-of-sample forecasting

We now study the *out-of-sample* forecasting performance of (18) to shed light on its robustness with respect to the financial crises and the monetary policy regime shift. If the distributors pricing

¹¹ Noticeably, the *VAT* rate is included in the coefficients of the equation, but assumed constant in this simplified example.

behaviour has changed significantly following the economic events in the last decade, we should expect instabilities in (18) as, for example, indicated by poor *out-of-sample* forecasting ability. To assess the forecasting performance of (18), we employ forty seven quarters (1999Q1–2010Q3) of *out-of-sample* observations, including the periods of both the financial crises and the formal change in monetary policy regime. Figure 3 depicts actual values of Δm_t , together with one-step ahead forecasts, adding bands of 95 per cent confidence intervals to each forecast in the forecasting period.¹² As many as forty two actual values of Δm_t stay clearly within their corresponding confidence intervals over the forecasting period. Interestingly, none of the five forecasting failures coincide with the point in time of the formal change in monetary policy. Thus, the *out-of-sample* forecasting ability of (18) is reasonably good with respect to the major shift in monetary policy from exchange rate targeting to inflation targeting in late March 2001. The regime robustness is further evidence that the Lucas critique lacks force in our case.

Figure 3. Actual values of Δm_t and one-step ahead forecasts with 95 % bands



That said, we observe that the actual values of Δm_t are outside their corresponding confidence intervals in 2008Q4 and 2009Q1, two quarters in which the exchange rate was particularly volatile during the financial crisis, cf. Figure 2. However, the forecasting ability of (18) is thereafter reasonably good in a period with repercussions of the financial crisis still present. Hence, we interpret the two mentioned forecasting failures to be “outliers” rather than evidence of structural breaks in the distributors pricing behaviour caused by the financial crises. Noticeably, (18) is virtually unchanged

¹² The forecast for period s is $\hat{y}_s = x'_s \hat{\beta}_t$, where x_s is the observed value of x for period s , $\hat{\beta}_t$ is estimated from the first t observations of data and $s > t$. In our case s spans the period 1999Q1–2010Q3, while t covers the period 1971Q2–1998Q4.

with respect to both economic content and diagnostics when estimated with a sample period ending in 2010Q3 rather than in 1998Q4. We conclude that the dynamic model of trade margins in the distribution sector shows a high degree of historical constancy and contains some interesting properties with respect to exchange rate pass-through. In the next section, we show the degree of exchange rate pass-through to the overall consumer price index when the model of trade margins is analysed within the macroeconometric model of the Norwegian economy.

4. Simulation results

The purpose of this paper is to study the pass-through of exchange rate changes to consumer prices. We therefore assume an exogenous exchange rate in our simulation study although the exchange rate is clearly not an exogenous variable in an economy where monetary policy is based on inflation targeting. In the simulations, the import-weighted exchange rate is permanently increased (depreciated) by 10 per cent compared to a reference path, which roughly follows the historic development of the Norwegian economy until 2010.¹³ The real after tax interest rate is set equal to the value in the reference path by adjusting the nominal interest rate according to changes in CPI-inflation. The degree of exchange rate pass-through to the Norwegian economy is studied in a full model simulation, thereby taking account of all modelled channels through which the exchange rate affects domestic prices.

We assume fiscal policy to be unchanged in real terms compared to the reference path despite the fact that Norway introduced a fiscal policy rule in 2001. The fiscal policy rule states that over time the government can include 4 per cent (equal to the expected real rate of return) of the value of the Petroleum Fund in the net balance for higher expenditures or lower taxes.¹⁴ In our simulations the exchange rate shock changes the value of the fund by the same rate in domestic currency and one may ask whether fiscal policy should become more expansionary as a consequence. We think not. First, government expenditures also increase in nominal terms since we keep real expenditures fixed. Second, a depreciation of the currency increases GDP in the short run. Fiscal policy should accordingly be slightly less expansionary according to the rule which states clearly that discretionary

¹³ The simulations begin in the first quarter of 2000, but the simulated effects reported below are for practical purposes independent of the actual time period. In line with actual “policy rules” in Norway, all excise taxes in equation (8) adjust in accordance with the consumer price index to avoid any nominal price inertia (due to these taxes) to affect the simulation results.

¹⁴ When the rule was formally introduced actual fiscal policies were already in line with the rule. Hence, the formal introduction of the rule did not bring about a change in policy in that year. The same can be said for monetary policy, which formally changed at the same time from exchange rate targeting to inflation targeting, see the discussion in Section 3. Inflation was close to the target chosen in 2001 and had been so for nearly a decade. The Petroleum Fund was set up in 1991, but revenues transferred to the fund from 1996. The magnitude of the fund was 1.2 times GDP in 2011.

policies should be pursued in addition to relying on automatic stabilisers. Third, the guidelines for the fiscal policy rule state that policies should be smoothed when the fund is affected by nominal shocks. In the longer term prices and costs will be higher. Therefore, the assumption of unchanged fiscal policy in real terms is not unrealistic.

4.1 Effects on prices

Figure 4 shows simulation results for aggregate price indices. The exchange rate pass-through to import prices is quite rapid in the short run, although still incomplete in the medium to longer run (10 years). This finding is in accordance with the pricing-to-market hypothesis. The exchange rate pass-through to export prices is also rather fast, but nevertheless slower than the pass-through to import prices in the short to medium run. One reason is that domestic costs affect export prices and domestic costs are slow to react to exchange rate impulses. The moderate response of export prices affects wage bargaining and slows down the pass-through of prices to wages and further from wages in the tradable goods sector to wages in the service industries. This explains partly why the impact of exchange rate changes on consumer prices is fairly modest both in the short and medium term, an empirical finding in line with what is usually found in the literature, see e.g. Berben (2004) and references therein.

Figure 4. Pass-through to prices of a 10 per cent exchange rate depreciation. Deviations from reference path in per cent

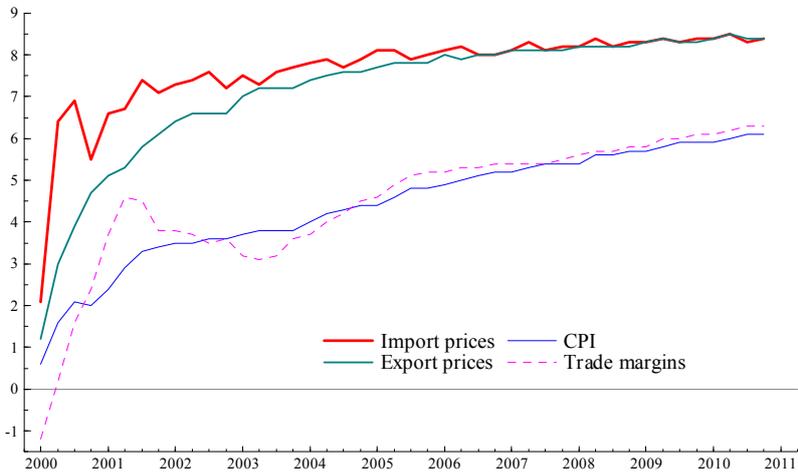


Figure 4 shows export prices of traditional goods, which do not include the major export items crude oil, natural gas and shipping services. Prices of total exports increase much more rapidly than export prices of traditional goods due to the open economy assumption of some important export prices (see Table 4 below). The crude oil price in USD is, as mentioned in Section 2, assumed exogenous for

Norwegian producers. When the exchange rate depreciates the price of oil in domestic currency follows the exchange rate.

The exchange rate pass-through to consumer prices is noticeably delayed by the effects on trade margins in the distribution sector, which act as cushions to exchange rate fluctuations in the short run. With these cushions effects included in the CVAR model for trade margins, CPI inflation increases by 1.6 percentage points compared to the reference path during the first year (see Table 3 below). If the trade margins instead had increased in parallel with other consumer prices following the 10 per cent depreciation of the exchange rate, then the first year effect on CPI would have been 0.3 percentage points higher. Similarly, if trade margins had been constant as a rate on a weighted price average of goods passing through the distribution sector, then the first year effect on CPI would also have been 0.3 percentage points higher.¹⁵ In other words, the value added that fully endogenous trade margins bring to the analysis of overall exchange rate pass-through in the Norwegian economy is estimated to nearly 20 per cent of the CPI-effect during the first year. We thus argue that the simulation results prove the importance of the distribution sector and the CVAR modelling for trade margins when the purpose is to study the overall exchange rate pass-through process in the Norwegian economy. Otherwise, the study of pass-through will ignore some important channels through which the exchange rate is likely to operate according to our estimated CVAR model.

That said, the pricing-to-market effects from import prices, leading to a moderate increase in the import prices (in domestic currency) of only 5.3 per cent during the first year (see Table 4 below), are even more important than the buffer effects from the trade margins in slowing down the exchange rate pass-through to consumer prices. If the 10 per cent depreciation of the exchange rate instead had been immediately and completely passed through to import prices, then CPI inflation would have increased roughly by 3.0 percentage points the first year and not by 1.6 percentage points as with pricing-to-market effects included in the macroeconomic model. According to Figure 4, trade margins overshoot somewhat during the second year, while no significant contribution from trade margins to the CPI is present after the third year. The exchange rate pass-through to consumer prices is far from complete even within a ten-year horizon despite the fact that the wage-price block inherent in the macroeconomic model (cf. Section 2) is homogenous of degree one, which implies complete pass-through of an exchange rate depreciation in the very long run. Table 3 presents simulation results for the various price components of private consumption, trade margins and some price aggregates.

¹⁵ This would correspond to a model of trade margins being $TM = \text{constant} \cdot PP$, cf. equation (11) in Section 3.

Table 3. Consumer price effects of a 10 per cent exchange rate depreciation.**Deviations from reference path in per cent unless otherwise noted**

	1. year	2. year	3. year	4. year	10.year
Food	1.7	3.5	3.9	4.1	6.4
Beverages	1.8	3.5	4.1	4.5	6.6
Tobacco	1.6	3.5	3.9	4.0	6.2
Petrol, etc.	2.5	4.6	5.3	5.7	7.6
Electricity, heating oil etc.	1.8	3.7	4.1	4.6	6.3
Clothing and footwear	3.3	5.3	5.3	5.4	7.1
Cars	3.8	4.9	5.3	5.6	7.2
Furniture, el. appliances	2.7	4.7	5.0	5.2	7.1
Housing	0.0	1.0	1.9	1.8	3.9
Public transport	0.1	0.7	1.3	1.7	3.7
Health care	0.8	1.9	2.7	3.2	5.6
Other goods	2.6	4.8	5.0	5.1	7.1
Other services	0.8	1.9	2.6	3.1	5.5
Trade margins ¹	0.8	4.2	3.7	3.3	6.0
Consumer price index (CPI)	1.6	3.0	3.6	3.8	5.8
CPI-inflation ²	1.6	1.4	0.6	0.2	0.2
Core-inflation ^{2,3}	1.6	1.4	0.6	0.2	0.2

¹ Margins on services in the distribution sector. ² Percentage points³ CPI without energy goods and adjusted for real changes in indirect taxation

Generally speaking, prices on consumer goods react faster to changes in the exchange rate than prices on consumer services. This applies in particular to consumer prices for durable goods due to relatively high import shares or high degree of import penetration. The exchange rate pass-through to consumer prices for *Other services*, which constitute around 20 per cent of total private consumption, is slow both in the short and medium run. The first year effects on these components of CPI are close to half of the average CPI effect. After 10 years the exchange rate pass-through to prices on *Other services* is still lower than the average pass-through to consumer prices. The reason for the slow exchange rate pass-through to *Other services* is mainly modest pass-through to wages, as production is labour intensive in most services. Also, the direct import share for this consumption category is small.

The effect of the exchange rate depreciation on housing rents is also an important factor behind the overall delayed pass-through to consumer prices. We observe that the third year effect on housing

rents is roughly half of the effect on CPI, while the effects after 10 years are two thirds of the CPI effect. Housing rents are determined by user costs of housing capital in the long run, but are mainly indexed to the CPI in the short run as rents typically are based on contracts with an explicit clause linking changes to the CPI. Overall, CPI inflation increases by close to 1.5 percentage points in the first and second year compared to the reference path. There is not much difference between the effects on total CPI and core-inflation. We see that prices on the two energy categories (Petrol, etc. and Electricity, heating oil etc.) increase a bit more than CPI, but their total weight in CPI is only 8 per cent. In addition, excise taxes increase in line with CPI by assumption, such that the effects on core inflation and CPI inflation are similar. Nevertheless, the simulated effects on inflation are clearly important for an inflation targeting central bank.

4.2 Effects on the real economy

Table 4 presents simulation results for some main macroeconomic variables of the real economy.¹⁶ We see that the effects on mainland GDP and unemployment are small following a 10 per cent depreciation of the exchange rate. These findings originate from the moderate nominal exchange rate pass-through, which translates into expansive effects with respect to the level of activity. The effects on non-oil exports and import shares are important in this respect. We notice that the positive effects on exports decline over time as the pass-through to export prices increases. Real wages also decline during the entire simulation period. The fall in real wages is, however, most noticeable in the short and medium run, implying that nominal wages adjust more slowly than prices. The institutional system of wage bargaining in Norway contributes to the slow adjustment in nominal wages. Reduction in labour productivity partly explains the fall in real wages in the longer term. The decline in real wages causes demand from households to decline as well. This counteracts the expansionary effects on exports such that mainland GDP does not change much. Consequently, neither employment nor unemployment change much either.

¹⁶ Norway is a large producer and exporter of crude oil and natural gas. Production of petroleum is exogenous in the macroeconomic model and equal to capacity output based on detailed information from oil companies. With domestic demand endogenous, exports of petroleum are endogenous as a residual. In 2010 crude oil and natural gas alone made up roughly 45 percent of total exports.

Table 4. Macroeconomic effects of a 10 per cent exchange rate depreciation.**Deviations from reference path in per cent unless otherwise noted**

	1. year	2. year	3. year	4. year	10. year
Household consumption	-0.8	-0.9	-1.3	-1.3	-1.2
Real investments, mainland economy	0.1	0.5	-0.2	-0.3	-0.2
Housing	-0.7	-1.5	-1.7	-1.4	-0.9
Business sector	0.6	1.8	0.5	0.1	0.1
Exports, traditional goods	1.4	1.5	1.5	1.4	1.1
Imports	-1.0	-1.1	-1.4	-1.5	-1.3
GDP, mainland economy	0.2	0.3	0.1	0.1	0.0
Manufacturing	1.9	2.5	2.7	2.7	2.2
Employed persons	0.3	0.5	0.4	0.4	0.3
Rate of unemployment ¹	-0.2	-0.3	-0.2	-0.2	0.0
Import prices, total	5.3	7.0	7.4	7.5	8.3
Export prices, total	6.4	7.7	8.2	8.5	8.9
Export prices, traditional goods	3.3	5.6	6.6	7.1	8.3
Consumer price index (CPI)	1.6	3.0	3.6	3.8	5.8
Average wage rate	0.8	1.6	2.3	2.8	5.2
Money market rate ²	3.0	1.7	0.4	0.3	0.3

¹ Percentage points² Percentage points pro anno

Overall, exchange rate changes do not translate into substantial effects on mainland GDP and unemployment in the short and medium term. After ten years the effects are close to zero. The main explanation is that the negative effects on household consumption and housing investments are nearly counteracted by the positive effects on non-oil exports and lower import shares due to improved competitiveness. Comparing changes in the CPI with changes in the export prices, we notice much quicker pass-through to export prices. Thus, using export prices rather than consumer prices when calculating the real exchange rate, the shock in the nominal exchange rate produces only moderate effects on the real exchange rate. Even so, we observe that changes in the industry structure are likely to take place in the face of an exchange rate shock of the magnitude studied here as sizeable increase in manufacturing production is simulated both in the short and medium term.

5. Conclusions

Much of the new open economy literature examines exchange rate pass-through using relatively aggregated price models. We have followed recommendations of empirically based macroeconomics in Colander *et al.* (2008) and studied exchange rate pass-through by means of CVAR models for different prices – trade margins in particular – within a large scale macroeconometric model of the Norwegian economy. Our approach has thus taken into account numerous channels through which the exchange rate is likely to operate in a small open economy. We found that exchange rate pass-through to import prices in domestic currency is quite rapid, but nevertheless incomplete within a ten-year horizon. Even if complete exchange rate pass-through to consumer prices follows from the macroeconometric model in the long run, costs of adjustment and other inertia in the pricing behaviour cause pass-through of exchange rate changes to consumer prices to take considerable time. Econometric analysis and model simulations show the importance of the pricing behaviour in the distribution sector as trade margins do play an important buffer role in delaying pass-through to consumer prices in the short run.

The finding that exchange rate pass-through to consumer prices is not fully completed within a ten-year horizon may be interpreted as supporting the LCP hypothesis. Changes in the exchange rate have substantial effects on CPI inflation even in the short run, an insight important for inflation targeting central banks. Since nominal exchange rate changes and inflation seem to move together (at least partly), we may argue that stability in the one implies stability in the other. However, large first and second year effects and relatively high persistent effects in the medium term can make a strategy of stabilising inflation within a two-year horizon, say, by controlling fluctuations in the nominal exchange rate a difficult task. That exchange rate changes do not seem to produce substantial variability in other targeting variables, like GDP growth and unemployment in the short run, suggests that a floating exchange rate has little effects on the real economy. However, exchange rate fluctuations are likely to produce changes in the industry structure of an open economy like the Norwegian. For an economy like the Norwegian that tries to avoid Dutch Disease problems likely to follow from spending large oil revenues, exchange rate fluctuations that result in de-industrialisation may seem just as undesirable.

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Appendix A. Outline of the macroeconometric model

The current macroeconometric model is a disaggregated input-output based model comprising 24 industries j producing 44 commodities i of which 9 are non-competitive imports. The model is based on definitions and identities in the Norwegian national accounts. The model is also an econometric model as agent's behaviour in the economy is modelled using cointegrated VAR models linking economic theory and time series data. The model has Keynesian features in that production is largely demand driven in the short and medium run, while long run supply effects appear through labour supply and wage formation. Factor demand by industry (including capital stocks and industry investments) is based on a standard, but detailed neoclassical system. Both imports and exports equations by commodity are based on the Armington approach. Aggregate private consumption and investments in housing are determined by household real disposable income, real wealth and real interest rates. Labour supply is fairly inelastic with respect to after tax consumer real wage and includes also a "discouraged worker" effect.

Firms are generally assumed to operate in goods markets with imperfect competition both domestically and abroad. They maximize profits subject to a set of production functions and a set of demand functions specifying conditions on the domestic markets and the export markets. How prices and wages are modelled is discussed in general terms in Section 2. The general structure of the price equations is documented in Bowitz and Cappelen (2001) and in Boug *et al.* (2006). Bowitz and Cappelen (2001) also discuss wage behaviour in the model and analyse income policies which have played an important role in Norwegian economic policies.

The production functions specify seven different types of inputs in the macroeconometric model; labour (LW), electricity (E), fuels (F), a Leontief-aggregate of other commodity inputs (M), capital stock of buildings (KB), machinery (KM) and transportation equipment (KT). In the 17 mainland industries specified in the model we generally assume a homogeneous CES aggregate of the two energy inputs electricity (E) and fuels (F) and a dual price aggregate PU of the electricity price (PE) and the fuel price (PF), where the substitution elasticity (σ) is estimated by (A3)

$$(A1) \quad U_j = CES(E_j, F_j)$$

$$(A2) \quad PU_j = CES(PE_j, PF_j)$$

$$(A3) \quad E_j / F_j = a_j \cdot (PE_j / PF_j)^{-\sigma_j} .$$

At the upper level we assume Cobb-Douglas technology for each industry. In general there is econometric support for assuming constant returns to scale, cf. the framework in Hungnes (2010) and the example in Hungnes (2011). Accordingly, for each industry we have a set of cost minimizing (log linear) input demand functions that are homogeneous of degree zero in factor prices and proportional to gross output (X) and total factor productivity (TFP)

$$(A4) \quad LW_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT)$$

$$(A5) \quad U_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT)$$

$$(A6) \quad M_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT)$$

$$(A7) \quad KB_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT)$$

$$(A8) \quad KM_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT)$$

$$(A9) \quad KT_j / X_j = TFP_j \cdot CD(W_j, PU_j, PM_j, PKB, PKM, PKT) .$$

In (A4) – (A9) W_j is the wage costs per hour worked, PM_j is the price of other materials defined in equation (6) in Section 2 assuming Leontief- technology with parameters based on the most recent input-output matrix from the national accounts. PKB , PKM and PKT are user costs defined in a standard way including the capital income tax rate and depreciation allowances that varies with the type of capital. The user costs do not vary by industry. Capital stocks for each industry evolve according to

$$(A10) \quad K_{njt} = (1 - \delta_{nj}) \cdot K_{njt-1} + J_{njt}, \quad n = KB, KM, KT,$$

where t denotes time and δ_{nj} and J_{njt} denote the rate of capital depreciation and gross investments, respectively. Supply of goods from imports (I) and domestic production (X) equals demand or total use (D) plus exports (A) for each commodity¹⁷

$$(A11) \quad I_i + X_i = \sum_k a_{Cki} \cdot C_k + \sum_j a_{Mji} \cdot M_j + \sum_j \sum_n a_{Jni} \cdot J_{nj} + A_i = D_i + A_i.$$

¹⁷ For simplicity, we drop the terms for electricity and fuels. Electricity enters only the equation for electricity production and distribution, while fuels enter the equations for oil refineries and the distribution sector. To simplify matters, we also drop changes in inventories and housing investments from (A11).

As explained in Section 2, C_k consist of 14 household consumption groups and A_i are exports of commodity i for which (A11) applies. The parameters a_{Cki} , a_{Mji} and a_{Jni} are input-output coefficients taken from the most recent national accounts. The M_j 's and J_{nj} 's are determined from (A6) and (A7) – (A10) for each industry, respectively. For the three government sectors specified in the macroeconometric model the M_j 's are exogenous.

Exports are, as previously noted, modelled using the Armington approach¹⁸

$$(A12) \quad A_i = g(P_{Ai} / PW_i \cdot E, WD),$$

where the export price (P_A) relative to world market prices of similar goods (PW_i) in domestic currency (E is an aggregate of various exchange rates relevant for Norwegian exports) captures price effects. The indicator of world demand (WD), measured by aggregating imports of the main trading partners, captures income effects, cf. Boug and Fagereng (2010).

Imports are assumed to be a variety of the corresponding domestically produced commodity. Each user minimizes the costs of consuming the imported and the domestic variety as in the simplest version of models in Dixit and Stiglitz (1977). The import share (IS) for each user of a composite commodity is thus a CES function of the domestic price (P_D) and the corresponding import price (PI) for each commodity

$$(A13) \quad IS_i = CES(PI_i / P_{Di})$$

$$(A14) \quad I_i = IS_i \cdot D_i .$$

According to (A14) total imports of each commodity equal the import share multiplied with domestic demand. We notice that (A14) is simplified somewhat compared to the actual model as the structure of imports varies between domestic users. Hence, it is a weighted sum of the various components in (A11) that enters into (A14). The weights are again taken from the most recent final national accounts. For non-competitive imports domestic production is zero or negligible and imports are given by demand according to (A14).

¹⁸ For exports of natural resource products such as fish, crude oil and natural gas, domestic gross production is exogenous (given either by “nature” or in case of oil and gas production capacity) and exports are determined by (A11).

Consumer demand is modelled in two stages. There is a conventional macro consumption function at the first stage relating household consumption to disposable real income, real wealth and real after tax interest rate, cf. Jansen (2012). Results from cointegration analysis support a long run homogeneous consumption function in disposable real income and real wealth. At the second stage total household consumption is allocated to the 14 different categories of household consumption using a dynamic AIDS, cf. Skjerpen and Swensen (2000). We use the Stone price index (PC) to simplify and impose symmetry, homogeneity and adding up conditions in the long run such that

$$(A15) \quad CP_k \cdot PC_k / VC = \sum_k \beta_{kk} \cdot \log(PC_k) + \beta_{ck} \cdot \log(VC / PC) + \beta_{0k},$$

where VC is the value of total consumption and β_{kk} , β_{ck} and β_{0k} are estimated parameters. To give an idea of how one arrives at the textbook IS-curve in our macroeconometric model we can proceed as follows: First, we substitute (A7) – (A9) into (A10) and solve for the J_{ij} 's. Gross investments by category will depend on output by industry and relative factor prices including user costs of capital. The J_{ij} 's will be lower the higher the interest rates. The J_{ij} 's can then be inserted into (A11). Exports given by (A12) can also be inserted into the balance equation (A11). To eliminate imports from (A11) we insert the two equations (A13) and (A14). Finally, when the macro consumption function is inserted into the AIDS model for each consumption category in (A15) to eliminate VC from that equation, then each C_k will depend on household real wealth and disposable real income in addition to the after tax real interest rate similar to the user cost term. We then have a model where relative prices, real (after tax) interest rates, various fiscal policy variables, and income abroad that affects non-oil exports from Norway enter the determination of each X_i . By aggregating, we arrive at typical national accounts variables discussed in Section 4. In our simulations, we have assumed that nominal interest rates are adjusted such that real after tax interest rates are constant. Hence, there is not much movement along the IS-curve in the simulations. However, when the exchange rate changes, relative prices will change and the IS-curve shifts as a consequence.

In order to “close” the outline of the macroeconometric model we need to account for how household disposable income and wealth is determined. We here simply refer to standard national accounts definitions of household disposable income as our model incorporates the details of the Norwegian national accounts. Household wealth consists of net financial assets, housing wealth and the value of

other physical capital objects by industry that belongs to the household sector (the capital stock in agriculture is one example as nearly all agriculture in Norway is run by self-employed farmers).

The employment “block” of the macroeconometric model consists of labour demand by industry which can be aggregated using (A4) to total labour demand (L), noting that employment in the three government sectors is exogenous. Total labour supply (LS) is disaggregated by five age groups and gender since participation rates varies a lot between groups and over time. For each group we specify a logit function relating labour supply in terms of the participation rate for each group to the (marginal) real after tax wage as well as the unemployment rate to capture discouraged worker effects. The logit function by age groups and gender generally reads as¹⁹

$$(A16) \quad \log(YP)/[1 - \log(YP)] = g[W \cdot (1 - TMW) / CPI, UR],$$

where YP is the participation rate, W is the relevant hourly wage rate, TMW is the (average) marginal tax rate on wage income, CPI is the consumer price index and UR is the unemployment rate.²⁰ The implied aggregated supply elasticity is in line with microeconomic results in Dagsvik *et al.* (2012). Total labour supply is found by multiplying the various participation rates with the size of the population in the corresponding group. The unemployment rate is defined as $UR = 1 - L/LS$.

In addition to the structure outlined above the macroeconometric model also contains an exchange rate equation linking the Norwegian krone to the euro and a Taylor type interest rate rule, which captures the interest rate setting of the central bank. Neither of these equations is used in our simulations as we focus on the effects of an exogenous exchange rate depreciation assuming a constant after tax real interest rate.

¹⁹ For simplicity, we ignore subscript for age groups and gender in (A16).

²⁰ Some demographic variables also enter (A16) such as the number of children in pre school age in labour supply for women aged 25–39. For older persons the ratio of pension to wage income is included in (A16).

Appendix B. Data definitions and sources

- TM* Trade margins index in the distribution sector (2002=1). The index covers trade margins on all services delivered from the sector. The data on trade margins are taken from the Norwegian national accounts and are based on detailed surveys of trade margins by product every fifth year or so. In between these surveys, average margins by broader product categories are inflated in the national accounts using annual statistics on wholesale and retail trade. Source: Statistics Norway.
- PP* Price index of purchasing prices faced by distributors in the wholesale and retail trade sector (2002=1). The index weights together domestic and import prices on main commodities traded in the sector. Source: Statistics Norway.
- VUC^d* Variable unit costs in the wholesale and retail trade sector, defined as in (5) in the text. Source: Statistics Norway.
- H* Hours worked by self-employed in the wholesale and retail trade sector, expressed in 1000. Source: Statistics Norway.
- X^d* Gross production in the wholesale and retail trade sector (at fixed 2002 prices), expressed in millions. Source: Statistics Norway.
- E* Import-weighted nominal exchange rate index (1995=1). The index covers the main Norwegian trading partners, i.e., the 44 countries with the largest weights in Norway's imports of goods. The weight of each trading partner is the imports from this partner as a share of total imports. Source: Central Bank of Norway.
- R* Average nominal interest rates on bank loans in the private sector. Source: Statistics Norway.
- S_{it}* Centered seasonal dummy for quarter *i*, equals 0.75 in quarter *i*, -0.25 otherwise, *i* = 1,2,3.
- D74Q1*, Dummy variables used to account for outliers and instabilities in the equation for
- D78Q2* Δpp_t in the VARs. *D74Q1* and *D78Q2* equal unity in the first quarter of 1974 and in the second quarter of 1978, respectively, zero otherwise.

D78Q1 Dummy variable used to account for an outlier and instability in the equations for Δpp_t , Δvuc_t^d and $\Delta(h-x^d)_t$ in the VARs. Equals unity in the first quarter of 1978, zero otherwise.

D96Q3, Dummy variables used to account for outliers and instabilities in the equation for

D98Q2 $\Delta(h-x^d)_t$ in the VARs. *D96Q3* and *D98Q2* equal unity in the third quarter of 1996 and in the second quarter of 1998, respectively, zero otherwise.

PSTOP A combined regulation/catch-up dummy variable used to control for governmental price regulations during the second half of the 1970s. Equals unity in years of regulations, minus unity in years of catch-up and zero otherwise, see Bowitz and Cappelen (2001) for details.

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