Inflation Targeting and Economic Reforms in New Zealand*

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We study the consequences of economic reforms in New Zealand since the beginning of the 1990s. Inflation targeting became the monetary policymaking framework of the RBNZ in 1990. In the years that followed, New Zealand implemented labor market reform and became increasingly integrated in world trade. We use a New Keynesian model with rich trade microfoundations and labor market dynamics to study the performance of inflation targeting versus alternative monetary policy rules for New Zealand in relation to these market characteristics and reforms. We show that nominal income targeting would have been a better choice than inflation targeting or price-level targeting prior to market reforms by delivering more stable unemployment dynamics in a distorted economic environment. Nominal income targeting would also have been better than inflation targeting with respect to the transition costs

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of labor market reforms, though inflation targeting allowed for better management of the transition after trade integration. With New Zealand in its new long-run environment of integrated trade and flexible labor markets, the welfare gap between nominal income targeting and price/inflation targeting declines, as market reforms lower unemployment volatility.

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1. Introduction

After a decade or more of disappointing economic performance, beginning in 1984, with the election of the Labour Party, the New Zealand government embarked upon a major restructuring of the nation's economy. The reforms that were undertaken touched almost all facets of the economy, both public and private, and have on occasion been characterized as being revolutionary; see, e.g., Grafton, Hazledine, and Buchardt (1997).[1]

A crucial element of the reforms was the Reserve Bank of New Zealand (RBNZ) Act passed in late 1989 and taking effect in early 1990. The cornerstone of the Act was that the primary function of the RBNZ was to conduct monetary policy so as to maintain price stability across a broad spectrum of prices. The first Policy Targets Agreement (PTA) published in early 1990 stated that the target for the RBNZ was to maintain CPI inflation within a (0–2 percent) band. This has subsequently been modified in minor ways in a revision to the PTA published in September 2012; see Kendall and Ng (2013).

The objective of this paper is to evaluate the effectiveness of the inflation-targeting policy as it has been implemented in conjunction with other reforms implemented by New Zealand. The model we employ is one developed by Cacciatore and Ghironi (2012), used to analyze the consequences of trade integration for monetary policy in open economies. This model is a New Keynesian extension of Ghironi and Melitz (2005) that incorporates sticky prices and wages, together with search-and-matching frictions in labor markets. By incorporating endogenous costly entry of producers into domestic

[1]For an extensive discussion of the reforms, see Evans et al. (1996) and Silverstone, Bollard, and Lattimore (1996).

and export markets, the model makes it possible to analyze how trade integration impacts micro-level and aggregate dynamics, and how this matters for monetary policy. By incorporating labor market frictions, the model is suited for analyzing labor market reform and its consequences for macro policy.[2]

The small open-economy version of the Cacciatore-Ghironi model that we employ here is particularly well adapted to addressing issues pertaining to the New Zealand experience of liberalization. In this regard, while the reforms in New Zealand have been extremely broad, we focus our attention on two aspects that are particularly relevant and which, as noted, the model is well suited to address. These include (i) trade liberalization, and (ii) labor market liberalization.[3] In assessing the inflation-targeting policy, we also compare it with two natural alternatives that have received attention in recent and ongoing policy discussions in New Zealand and other inflation-targeting countries, namely nominal income targeting and price-level targeting. The main conclusions we obtain include the following:[4]

- Strict nominal income targeting dominates inflation and price-level targeting in the pre-deregulation scenario, as it stabilizes unemployment fluctuations in the presence of distorted product and labor markets. In this environment, inflation targeting performs better than price-level targeting.
- Along the transitional dynamic path triggered by the implementation of reforms, strict inflation targeting performs better than does strict nominal income targeting following trade

[2] Cacciatore, Fiori, and Ghironi (2015) use the model to study the consequences of market reforms in Europe, including product market deregulation, for U.S.-Europe interdependence and monetary coordination.

[3] Labor market liberalization was implemented through the Employment Contracts Act (ECA) enacted in 1991, which substantially changed the way that employers and employees contract with one another. One of its most profound effects was to reduce union membership by almost 50 percent.

[4] A key feature of our analysis is that we focus on the interaction of the inflation-targeting rule with two aspects of the market reforms. An earlier paper by Buckle, Kim, and McLellan (2003) employs a structural VAR model to examine the effects of inflation targeting on the variability of inflation and business cycles, but abstracting from any of the concurrent reforms that were taking place in the New Zealand economy.

liberalization. But strict nominal income targeting is more beneficial in response to labor market deregulation.

- In the new, deregulated, environment, the welfare gap between strict nominal income targeting and price/inflation targeting declines, as market reforms eliminate some key distortions that were responsible for inefficiently high volatility of job creation. Interestingly, post-deregulation, price targeting dominates inflation targeting when the labor market is flexible.

By incorporating producer dynamics and endogenous selection into trade, our paper contributes to a vast literature on monetary policy in New Keynesian small open-economy models where these market characteristics are not incorporated, and only a reduced-form approach to the consequences of trade integration for monetary policy incentives is considered (usually by varying home bias in preferences). This is the approach in many studies that build, for instance, on Galí and Monacelli's (2005) influential small open-economy model. Our approach fully separates policy—a trade policy action—from structural parameters in analyzing the effect of trade on monetary policy incentives, and results. It relies on a model that, as discussed by Cacciatore and Ghironi (2012), more successfully reproduces international business-cycle statistics—especially with respect to the effect of trade on the business cycle—than does the standard New Keynesian framework without producer dynamics and labor market frictions.

We also contribute to the literature on the consequences of market reforms for fluctuations and macroeconomic policy, by focusing on the case of New Zealand for a set of policy regimes not considered in other studies. A recent strand of the literature introduces product and labor market frictions into otherwise-standard real business-cycle models to study the dynamic effects of market deregulation, including transition dynamics and business-cycle implications of reforms (see, for instance, Cacciatore and Fiori 2010 and Veracierto 2008).[5] Another line of research investigates the consequences of labor (and product) market reforms for monetary policy in New Keynesian models where market reforms are modeled as exogenous cuts in wage (and price) markups (see, for instance, Eggertsson, Ferrero,

[5] A more complete list of references is available in Cacciatore and Fiori (2010).

and Raffo 2014, and Fernández-Villaverde, Guerrón-Quintana, and Rubio-Ramírez 2011). Market reforms necessarily have deflationary consequences and exacerbate zero lower bound issues in these exercises. Exogenous markup cuts also improve the external balance by immediately depreciating the terms of trade. The more structural approach to market reforms that we adopt does not necessarily have these implications.[6]

Finally, we contribute to a recent and growing literature that studies macroeconomic dynamics following trade integration. In this vein, our paper is closest to Cacciatore (2014) and Itskhoki and Helpman (2014), who investigate how labor market frictions affect short-run dynamics following trade integration.[7] We contribute to this literature by investigating how monetary policy affects transitional dynamics and the business-cycle implications of stronger trade linkages.

The remainder of the paper is structured as follows. Section 2 describes the model, while section 3 sets out the alternative specifications of monetary policy. Our analysis treats New Zealand (NZ) as a small open economy, which is impacted by certain key variables in the rest of the world but has no impact on the rest of the world. The relevant aspects of foreign aggregates are briefly summarized in section 4. Section 5 calibrates the model, where we base the calibration parameters of the rest of the world on data pertaining to the United States. Section 6 reports the numerical simulations in the pre-deregulation phase, while section 7 discusses the macroeconomic effects of the reform, both during the transition and in the post-deregulation phase. Section 8 summarizes the sensitivity analysis we have conducted, while section 9 concludes. Relevant technical details of the model are summarized in an appendix.

[6]See Cacciatore, Fiori, and Ghironi (2013) for an analysis of these issues and optimal monetary policy in the context of a monetary union. Andrés, Arce, and Thomas (2014) and Krebs and Scheffel (2014) contribute to this literature by studying the consequences of debt overhang for the effects of exogenous markup cuts, and by addressing the role of market incompleteness.

[7]Burstein and Melitz (2011), Costantini and Melitz (2011), and Kambourov (2009) also study the transition dynamics following trade liberalization, abstracting from the role of frictions in the labor market. Albertini, Kamber, and Kirker (2012) estimate a model for New Zealand that incorporates search and frictional unemployment, focusing on the resulting labor market dynamics.

2. The Model

The model we employ is an application of the framework developed by Cacciatore and Ghironi (2012). The difference is that NZ is the prototype small open economy. As is now standard practice in the literature, we model the small open economy as a limiting case of a two-country dynamic general equilibrium model in which one country (the small open economy, also referred to as Home) is of measure zero relative to the rest of the world (Foreign henceforth). As a consequence, the policy decisions and macroeconomic dynamics of the small open economy have no impact on Foreign. Next we describe in detail the problem facing households and firms located in the small open economy.

2.1 Household Preferences

The small open economy is populated by a unit mass of atomistic households, where each household is viewed as an extended family with a continuum of members along the unit interval. In equilibrium, some family members are employed, while others are unemployed. As is common in the literature, we assume that family members insure each other perfectly against variations in labor income due to changes in employment status, so that there is no ex post heterogeneity across individuals in the household (see Andolfatto 1996 and Merz 1995).

The representative household in the Home economy maximizes the expected intertemporal utility function $E_0 \sum_{t=0}^{\infty} \beta^t \left[u(C_t) - l_t v(h_t)\right]$, where $\beta \in (0, 1)$ is the discount factor, C_t is a consumption basket that aggregates domestic and imported goods as described below, l_t is the number of employed workers, and h_t denotes hours worked by each employed worker. Period utility from consumption, $u(.)$, and disutility of effort, $v(.)$, satisfy the standard assumptions.

The consumption basket C_t aggregates Home and Foreign sectoral consumption outputs, $C_t(n)$, in Dixit-Stiglitz (1977) form:

$$C_t = \left[\int_0^1 C_t(n)^{\frac{\phi-1}{\phi}} dn\right]^{\frac{\phi}{\phi-1}}, \tag{1}$$

where $\phi > 1$ is the symmetric elasticity of substitution across goods. The corresponding consumption-based price index is given by

$$P_t = \left[\int_0^1 P_t(n)^{1-\phi} dn \right]^{\frac{1}{1-\phi}}, \tag{2}$$

where $P_t(n)$ is the price index for sector n, expressed in Home currency.

2.2 Production

There are two vertically integrated production sectors. In the upstream sector, perfectly competitive firms use labor to produce a non-tradable intermediate input. In the downstream sector, each consumption-producing sector n is populated by a representative monopolistically competitive multi-product firm that purchases the intermediate input and produces differentiated varieties of its sectoral output. In equilibrium, some of these varieties are exported while the others are sold only domestically.[8]

2.2.1 Intermediate Goods Production

There is a unit mass of intermediate producers. Each of them employs a continuum of workers. Labor markets are characterized by search-and-matching frictions as in the Diamond-Mortensen-Pissarides (DMP) framework.[9] To hire new workers, firms need to post vacancies, incurring a cost of κ units of consumption per vacancy posted. The probability of finding a worker depends on a constant-returns-to-scale matching technology, which converts aggregate unemployed workers, U_t, and aggregate vacancies, V_t, into aggregate matches, $M_t = \chi U_t^{1-\varepsilon} V_t^{\varepsilon}$, where $\chi > 0$ and $0 < \varepsilon < 1$. Each firm meets unemployed workers at a rate $q_t \equiv M_t/V_t$. As in Krause and Lubik (2007) and other studies, we assume that newly created matches become productive only in the next period. For

[8] This production structure greatly simplifies the introduction of labor market frictions and sticky prices in the model.

[9] See Diamond (1982a, 1982b) and Mortensen and Pissarides (1994).

an individual firm, the inflow of new hires in period $t+1$ is therefore $q_t\upsilon_t$, where υ_t is the number of vacancies posted by the firm in period t.[10]

Firms and workers can separate exogenously with probability $\lambda \in (0,1)$. Separation occurs only between firms and workers who were active in production in the previous period. As a result, the law of motion of employment, l_t (those who are working at time t), in a given firm is given by $l_t = (1-\lambda)l_{t-1} + q_{t-1}\upsilon_{t-1}$.

The representative intermediate firm produces output $y_t^I = Z_t l_t h_t$, where Z_t is exogenous aggregate productivity.[11] We normalize steady-state productivity, Z, to 1 and assume that Z_t follows an $AR(1)$ process in logarithms, $\log Z_t = \phi_Z \log Z_{t-1} + \boldsymbol{\epsilon}_t$, where $\boldsymbol{\epsilon}_t$ represents i.i.d. draws from a normal distribution with zero mean and standard deviation σ_ϵ.

As in Arseneau and Chugh (2008), firms face a quadratic cost of adjusting the hourly nominal wage rate, w_t. For each worker, the real cost of changing the nominal wage between period $t-1$ and t is $\vartheta\pi_{w,t}^2/2$, where $\vartheta \geq 0$ is in units of consumption and $\pi_{w,t} \equiv (w_t/w_{t-1}) - 1$ is the net wage inflation rate. If $\vartheta = 0$, there is no cost of wage adjustment.

Intermediate goods producers sell their output to final producers at a real price φ_t, expressed in units of consumption. Intermediate producers choose the number of vacancies, υ_t, and employment, l_t, to maximize the expected present discounted value of their profit stream:

$$E_0 \sum_{t=0}^{\infty} \beta^t \frac{u_{C,t}}{u_{C,0}} \left(\varphi_t Z_t l_t h_t - \frac{w_t}{P_t} l_t h_t - \frac{\vartheta}{2}\pi_{w,t}^2 l_t - \kappa\upsilon \right),$$

subject to the dynamics of employment, where $u_{C,t}$ denotes the marginal utility of consumption in period t. Profit in any period consists of output sales less labor costs inclusive of wage adjustment costs plus vacancy costs. Future profits are discounted at the stochastic discount factor of domestic households, who are assumed to own Home firms.

[10]In equilibrium, $\upsilon_t = V_t$.

[11]Note that the assumption of a unit mass of intermediate producers ensures that y_t^I is also the total output of the intermediate sector.

Combining the first-order conditions for vacancies and employment yields the following job-creation equation:

$$\frac{\kappa}{q_t} = E_t \left\{ \beta_{t,t+1} \left[(1-\lambda)\frac{\kappa}{q_{t+1}} + \varphi_{t+1} Z_{t+1} h_{t+1} \right.\right.$$
$$\left.\left. - \frac{w_{t+1}}{P_{t+1}} h_{t+1} - \frac{\vartheta}{2}\pi^2_{w,t+1} \right] \right\}, \tag{3}$$

where $\beta_{t,t+1} \equiv \beta u_{C,t+1}/u_{C,t}$ is the one-period-ahead stochastic discount factor. The job-creation condition states that, at the optimum, the vacancy-creation cost incurred by the firm per current match is equal to the expected discounted value of the vacancy-creation cost per future match, further discounted by the probability of current match survival $1-\lambda$, plus the profits from the time-t match. Profits from the match take into account the future marginal revenue product from the match and its wage cost, including future nominal wage adjustment costs.

Wage and Hours. The nominal wage is the solution to an individual Nash bargaining process, and the wage payment divides the match surplus between workers and firms. Due to the presence of nominal rigidities, we depart from the standard Nash bargaining convention by assuming that bargaining occurs over the nominal wage payment rather than the real wage payment.[12] With zero costs of nominal wage adjustment ($\vartheta = 0$), the real wage that emerges would be identical to the one obtained from bargaining directly over the real wage. This is no longer the case in the presence of adjustment costs.

The details of wage determination are set out in the appendix. There we show that the equilibrium sharing rule can be written as $\eta_{w,t} H_t = (1-\eta_{w,t}) J_t$, where $\eta_{w,t}$ is the bargaining share of firms, H_t is worker surplus, and J_t is firm surplus (see the appendix for the expressions). As in Gertler and Trigari (2009), the equilibrium bargaining share is time varying due to the presence of wage adjustment costs. Without these costs, we would have a time-invariant bargaining share $\eta_{w,t} = \eta$, where η is the weight of firm surplus in the Nash bargaining problem. (The steady-state value of $\eta_{w,t}$, η_w,

[12]The same assumption is made by Arseneau and Chugh (2008), Gertler, Sala, and Trigari (2008), and Thomas (2008).

differs from η if wages are sticky and there is non-zero steady-state wage inflation.)

The bargained wage satisfies

$$\begin{aligned}\frac{w_t}{P_t}h_t = \eta_{w,t}\left(\frac{v(h_t)}{u_{C,t}}+b\right) + (1-\eta_{w,t})\left(\varphi_t Z_t h_t - \frac{\vartheta}{2}\pi_{w,t}^2\right)\\ + E_t\left\{\beta_{t,t+1}J_{t+1}\left[(1-\lambda)(1-\eta_{w,t})\right.\right.\\ \left.\left.-(1-\lambda-\iota_t)(1-\eta_{w,t+1})\frac{\eta_{w,t}}{\eta_{w,t+1}}\right]\right\},\end{aligned} \quad (4)$$

where $v(h_t)/u_{C,t}+b$ is the worker's outside option (the utility value of leisure plus an unemployment benefit b), and ι_t is the probability of becoming employed at time t, defined by $\iota_t \equiv M_t/U_t$. With flexible wages, the third term on the right-hand side of this equation reduces to $(1-\eta)\iota_t E_t(\beta_{t,t+1}J_{t+1})$, or, in equilibrium, $\kappa(1-\eta)\iota_t/q_t$. In this case, the real wage bill per worker is a linear combination—determined by the constant bargaining parameter η—of the worker's outside option and the marginal revenue product generated by the worker (net of wage adjustment costs) plus the expected discounted continuation value of the match to the firm (adjusted for the probability of worker's employment). The stronger the bargaining power of firms (the higher η), the smaller the portion of the net marginal revenue product and continuation value to the firm appropriated by workers as wage payments, while the outside option becomes more relevant. When wages are sticky, bargaining shares are endogenous, and so is the distribution of surplus between workers and firms. Moreover, the current wage bill reflects also expected changes in bargaining shares.

As is common practice in the literature, we assume that hours per worker are determined by firms and workers in a privately efficient way, i.e., so as to maximize the joint surplus of their employment relation.[13] The joint surplus is the sum of the firm's surplus and the worker's surplus, i.e., $J_t + H_t$, as defined in (24) and (27). The maximization yields a standard intratemporal optimality condition for hours worked that equates the marginal revenue product of hours

[13]See, among others, Thomas (2008) and Trigari (2009).

per worker to the marginal rate of substitution between consumption and leisure: $v_{h,t}/u_{C,t} = \varphi_t Z_t$, where $v_{h,t}$ is the marginal disutility of effort.

2.2.2 Final Goods Production

A contribution of Cacciatore and Ghironi (2012) is to show how price stickiness can be introduced in a tractable way in the Ghironi-Melitz (2005) model of trade and macroeconomic dynamics, while preserving the aggregation properties of Melitz's (2003) heterogeneous firms model. This is done by introducing price stickiness at the level of sectoral product bundles for domestic sale and export that aggregate individual product varieties produced by plants with heterogeneous productivity. In this subsection we describe final goods creation and production, the export decision, and price setting.

In each consumption sector, n, the representative, monopolistically competitive firm n produces the sectoral output bundle, $Y_t(n)$, sold to consumers in Home and Foreign. Producer n is a multi-product firm that produces a set of differentiated product varieties, indexed by ω and defined over a continuum Ω:

$$Y_t(n) = \left(\int_{\omega \in \Omega}^{\infty} y_t(\omega, n)^{\frac{\theta - 1}{\theta}} d\omega \right)^{\frac{\theta}{\theta - 1}}, \tag{5}$$

where $\theta > 1$ is the symmetric elasticity of substitution across product varieties.[14]

Each product variety $y(\omega, n)$ is created and developed by the representative final producer n. Since consumption-producing sectors are symmetric in the economy, we omit the index n to simplify notation. The cost of the product bundle Y_t, denoted by P_t^y, is

$$P_t^y = \left(\int_{\omega \in \Omega}^{\infty} p_t^y(\omega)^{1-\theta} d\omega \right)^{\frac{1}{1-\theta}}, \tag{6}$$

where $p_t^y(\omega)$ is the nominal marginal cost of producing variety ω.

[14] Sectors (and sector-representative firms) are of measure zero relative to the aggregate size of the economy. Notice that $Y_t(n)$ can also be interpreted as a bundle of product features characterizing product n.

The number of products created and commercialized by each final producer is endogenously determined. At each point in time, only a subset of varieties $\Omega_t \subset \Omega$ is actually available to consumers. To create a new product, the final producer needs to undertake a sunk investment, $f_{e,t}$, in units of intermediate input. Product creation requires each final producer to create a new plant that will produce the new variety.[15] Plants employ different technologies indexed by relative productivity z. To save notation, we identify a variety with the corresponding plant productivity z, omitting ω. Upon product creation, the productivity level of the new plant z is drawn from a common distribution $G(z)$ defined over $[z_{\min}, \infty)$. This relative productivity level remains fixed thereafter. Each plant uses intermediate input to produce its differentiated product variety, with real marginal cost:

$$\varphi_{z,t} \equiv \frac{p_t^y(z)}{P_t} = \frac{\varphi_t}{z}. \tag{7}$$

At time t, each final Home producer commercializes $N_{d,t}$ varieties and creates $N_{e,t}$ new products that will be available for sale at time $t+1$. New and incumbent plants can be hit by a "death" shock with probability $\delta \in (0,1)$ at the end of each period. The law of motion for the stock of producing plants is

$$N_{d,t+1} = (1-\delta)(N_{d,t} + N_{e,t}).$$

When serving the Foreign market, each final producer faces per-unit iceberg trade costs, $\tau_t > 1$, and fixed export costs, $f_{x,t}$.[16] Fixed export costs are denominated in units of the intermediate input and are paid for each exported product. Thus, the total fixed cost is

[15] Alternatively, we could model product creation by assuming that monopolistically competitive firms produce product varieties (or features) that are sold to final producers, in this case interpreted as retailers. The two models are equivalent. Details are available upon request.

[16] Empirical micro-level studies have documented the relevance of plant-level fixed export costs—see, for instance, Bernard and Jensen (2004). Although a substantial portion of fixed export costs are probably sunk upon market entry, we follow Ghironi and Melitz (2005) and do not model the sunk nature of these costs explicitly. We conjecture that introducing these costs would further enhance the persistence properties of the model. See Alessandria and Choi (2007) for a model with heterogeneous firms, sunk export costs, and Walrasian labor markets.

$F_{x,t} = N_{x,t} f_{x,t}$, where $N_{x,t}$ denotes the number of product varieties (or features) exported to Foreign. Without fixed export costs, each producer would find it optimal to sell all its product varieties in Home and Foreign. Fixed export costs imply that only varieties produced by plants with sufficiently high productivity (above a cut-off level $z_{x,t}$, determined below) are exported.[17]

To proceed further, we define two special average productivity levels (weighted by relative output shares): (i) an average $\tilde{z}_d$ for all producing plants, and (ii) an average $\tilde{z}_{x,t}$ for all plants that export:

$$\tilde{z}_d = \left[\int_{z_{\min}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{\theta-1}},$$

$$\tilde{z}_{x,t} = \left[\frac{1}{1-G(z_{x,t})}\right]\left[\int_{z_{x,t}}^{\infty} z^{\theta-1} dG(z)\right]^{\frac{1}{\theta-1}}.$$

We assume that $G(\cdot)$ is a Pareto distribution with shape parameter, $k_p > \theta - 1$. As a result, $\tilde{z}_d = \alpha^{\frac{1}{\theta-1}} z_{\min}$ and $\tilde{z}_{x,t} = \alpha^{\frac{1}{\theta-1}} z_{x,t}$, where $a \equiv k_p/[k_p - (\theta-1)]$. Thus, the share of exporting plants is given by

$$N_{x,t} \equiv [1 - G(z_{x,t})] N_{d,t} = \left(\frac{z_{\min}}{\tilde{z}_{x,t}}\right)^{-k_p} \alpha^{\frac{k_p}{\theta-1}} N_{d,t}. \tag{8}$$

The output bundles for domestic and export sale, and associated unit costs, are defined as follows:

$$Y_{d,t} = \left[\int_{z_{\min}}^{\infty} y_{d,t}(z)^{\frac{\theta-1}{\theta}} dG(z)\right]^{\frac{\theta}{\theta-1}},$$

$$Y_{x,t} = \left[\int_{z_{x,t}}^{\infty} y_{x,t}(z)^{\frac{\theta-1}{\theta}} dG(z)\right]^{\frac{\theta}{\theta-1}}, \tag{9}$$

[17] Notice that $z_{x,t}$ is the lowest level of plant productivity such that the profit from exporting is positive.

$$P^y_{d,t} = \left[\int_{z_{\min}}^{\infty} p^y_t(z)^{1-\theta} dG(z) \right]^{\frac{1}{1-\theta}},$$

$$P^y_{x,t} = \left[\int_{z_{x,t}}^{\infty} p^y_t(z)^{\frac{\theta-1}{\theta}} dG(z) \right]^{\frac{1}{1-\theta}}. \tag{10}$$

Using equations (7) and (10), the real costs of producing the bundles $Y_{d,t}$ and $Y_{x,t}$ can then be expressed as

$$\frac{P^y_{d,t}}{P_t} = N_{d,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_d}, \quad \frac{P^y_{x,t}}{P_t} = N_{x,t}^{\frac{1}{1-\theta}} \frac{\varphi_t}{\tilde{z}_{x,t}}. \tag{11}$$

The present discounted cost facing the final producer in the determination of product creation and the export bundle is thus

$$E_t \left\{ \sum_{s=t}^{\infty} \beta_{t,s} \left[\frac{P^y_{d,s}}{P_s} Y_{d,s} + \tau_s \frac{P^y_{x,s}}{P_s} Y_{x,s} \right. \right.$$
$$\left. \left. + \left(\frac{N_{s+1}}{1-\delta} - N_s \right) f_{e,s}\varphi_s + N_{x,s} f_{x,s} \varphi_s \right] \right\}.$$

The producer chooses $N_{d,t+1}$ and the productivity cutoff $z_{x,t}$ to minimize this expression subject to (8), (11), and $\tilde{z}_{x,t} = \alpha^{\frac{1}{\theta-1}} z_{x,t}$.[18]

The first-order condition with respect to $z_{x,t}$ yields

$$\frac{P^y_{x,t}}{P_t} Y_{x,t} \tau_t = \frac{(\theta-1)k_p}{[k_p - (\theta-1)]} f_{x,t} N_{x,t} \varphi_t. \tag{12}$$

The above condition states that, at the optimum, marginal revenue from adding a variety with productivity $z_{x,t}$ to the export bundle has to be equal to the fixed cost. Thus, varieties produced by plants with productivity below $z_{x,t}$ are distributed only in the domestic market. The composition of the traded bundle is endogenous, and the set of exported products fluctuates over time with changes in the profitability of export.

The first-order condition with respect to $N_{d,t+1}$ determines product creation:

[18]Equation (8) implies that by choosing $z_{x,t}$ the producer also determines $N_{x,t}$.

$$\varphi_t f_{e,t} = (1-\delta)E_t\left\{\beta_{t,t+1}\left[\varphi_{t+1}\left(f_{e,t+1} - \frac{N_{x,t+1}}{N_{d,t+1}} f_{x,t+1}\right)\right.\right.$$
$$\left.\left. + \frac{1}{\theta-1}\left(\frac{P^y_{d,t+1} Y_{d,t+1}}{P_{t+1} N_{d,t+1}} + \frac{P^y_{x,t+1} Y_{x,t+1}}{P_{t+1} N_{x,t+1}} \frac{N_{x,t+1}}{N_{d,t+1}} \tau_{t+1}\right)\right]\right\}.$$

In equilibrium, the cost of producing an additional variety, $\varphi_t f_{e,t}$, must equal its expected benefit (expected savings on future sunk investment costs augmented by the marginal revenue from commercializing the variety, net of fixed export costs, if it is exported).

We are now left with the determination of domestic and export prices. We denote by $P_{d,t}$ the price (in Home currency) of the product bundle $Y_{d,t}$ and let $P_{x,t}$ be the price (in Foreign currency) of the exported bundle $Y_{x,t}$. Each final producer faces the following domestic and foreign demand for its product bundles:

$$Y_{d,t} = \left(\frac{P_{d,t}}{P_t}\right)^{-\phi} Y^C_t, \qquad Y_{x,t} = \left(\frac{P_{x,t}}{P^*_t}\right)^{-\phi} Y^{C^*}_t,$$

where Y^C_t and $Y^{C^*}_t$ are aggregate demands of the consumption basket in Home and Foreign. Aggregate demand in each country includes sources other than household consumption, but it takes the same form as the consumption basket, with the same elasticity of substitution $\phi > 1$ across sectoral bundles. This ensures that the consumption price index for the consumption aggregator is also the price index for the aggregate demand of the basket.

Prices in the final sector are sticky. We follow Rotemberg (1982) and assume that final producers must pay quadratic price adjustment costs when changing domestic and export bundle prices, which we assume are set in accordance with producer currency pricing (PCP): Each final producer sets $P_{d,t}$ and the domestic currency price of the export bundle, $P^d_{x,t}$, letting the price in the foreign market be $P_{x,t} = \tau_t P^d_{x,t}/S_t$, where S_t is the nominal exchange rate (units of Home currency per unit of Foreign). The nominal costs of adjusting domestic and export price are, respectively, $\Gamma_{d,t} \equiv v\pi^2_{d,t} P_{d,t} Y_{d,t}/2$ and $\Gamma^d_{x,t} \equiv v\pi^{d^2}_{x,t} P^d_{x,t} Y_{x,t}/2$, where $v \geq 0$ determines the size of the adjustment costs (domestic and export prices are flexible if $v = 0$), $\pi_{d,t} \equiv (P_{d,t}/P_{d,t-1}) - 1$, and $\pi^d_{x,t} \equiv (P^d_{x,t}/P^d_{x,t-1}) - 1$.

In the absence of fixed export costs, the producer would set a single price $P_{d,t}$ and the law of one price (adjusted for the presence of trade costs) would determine the export price as $P_{x,t} = \tau_t P_{x,t} = P_{d,t}/S_t$. With fixed export costs, however, the composition of domestic and export bundles is different, and the marginal costs of producing these bundles are not equal. Therefore, final producers choose two different prices for the Home and Foreign markets even under PCP.

We relegate the details of optimal price setting to the appendix. We show there that the (real) price of Home output for domestic sales is given by

$$\frac{P_{d,t}}{P_t} = \frac{\phi}{(\phi-1)\Xi_{d,t}}\left(\frac{P^y_{d,t}}{P_t}\right), \tag{13}$$

where

$$\Xi_{d,t} \equiv 1 - \frac{\nu}{2}\pi^2_{d,t} + \frac{\nu}{(\phi-1)}\left\{\pi_{d,t}(1+\pi_{d,t}) - E_t\left[\beta_{t,t+1}\pi_{d,t+1}\frac{(1+\pi_{d,t+1})^2}{1+\pi^C_{t+1}}\frac{Y_{d,t+1}}{Y_{d,t}}\right]\right\}, \tag{14}$$

and $\pi_{C,t} \equiv (P_t/P_{t-1}) - 1$. As expected, price stickiness introduces endogenous markup variations: The cost of adjusting prices gives firms an incentive to change their markups over time in order to smooth price changes across periods. When prices are flexible ($v = 0$), the markup is constant and equal to $\phi/(\phi-1)$.

The (real) price of Home output for export sales is equal to

$$\frac{P_{x,t}}{P^*_t} = \frac{\phi}{(\phi-1)\Xi^d_{x,t}}\left(\frac{\tau_t P^y_{x,t}}{Q_t P_t}\right), \tag{15}$$

where $Q_t \equiv S_t P^*_t/P_t$ is the consumption-based real exchange rate (units of Home consumption per units of Foreign), and

$$\Xi^d_{x,t} \equiv 1 - \frac{\nu}{2}\pi^{d^2}_{x,t} + \frac{\nu}{(\phi-1)}\left\{(1+\pi^d_{x,t})\pi^d_{x,t} - E_t\left[\beta_{t,t+1}\pi^d_{x,t+1}\frac{(1+\pi^d_{x,t+1})^2}{1+\pi^C_{t+1}}\frac{Y_{x,t+1}}{Y_{x,t}}\right]\right\}. \tag{16}$$

Absent fixed export costs, $z_{x,t} = z_{\min}$ and $\Xi^d_{x,t} \equiv \Xi_{d,t}$. Plant heterogeneity and fixed export costs, instead, imply that the law of one price does not hold for the exported bundles.

For future purposes, define the average real price of a domestic variety, $\tilde{\rho}_{d,t} \equiv N_{d,t}^{\frac{1}{\theta-1}}(P_{d,t}/P_t)$, and the average real price of an exported variety, $\tilde{\rho}_{x,t} \equiv N_{x,t}^{\frac{1}{\theta-1}}(P_{x,t}/P^*_t)$. Combining equations (11), (13), and (15), we have

$$\tilde{\rho}_{d,t} = \mu_{d,t}\frac{\varphi_t}{\tilde{z}_d}, \qquad \tilde{\rho}_{x,t} = \mu_{x,t}\frac{\tau_t}{Q_t}\frac{\varphi_t}{\tilde{z}_{x,t}}, \tag{17}$$

where $\mu_{d,t} \equiv \phi/[(\phi-1)\Xi_{d,t}]$ and $\mu_{x,t} \equiv \phi/[(\phi-1)\Xi^d_{x,t}]$. Finally, letting $\tilde{y}_{d,t}$ and $\tilde{y}_{x,t}$ denote the average output of, respectively, a domestic and exported variety, we have

$$\tilde{y}_{d,t} \equiv \tilde{\rho}_{d,t}^{-\phi} N_{d,t}^{\frac{\theta-\phi}{1-\theta}} Y_t^C, \qquad \tilde{y}_{x,t} \equiv \tilde{\rho}_{x,t}^{-\phi} N_{x,t}^{\frac{\theta-\phi}{1-\theta}} Y_t^{C^*}. \tag{18}$$

2.3 Household Budget Constraint and Intertemporal Decisions

International assets markets are incomplete, as the representative household can invest only in nominal riskless bonds denominated in Home and Foreign currency. Home-currency-denominated bonds are traded only domestically. Let A_{t+1} and $A_{*,t+1}$ denote, respectively, nominal holdings of Home and Foreign bonds at Home.[19] To ensure a determinate steady-state equilibrium and stationary responses to temporary shocks in the model, we follow Turnovsky (1985) and, more recently, Benigno (2009) and assume a quadratic cost of adjusting Foreign bond holding, $\psi(A_{*,t+1}/P^*_t)^2/2$.[20] These costs are paid to financial intermediaries whose only function is to collect these transaction fees and to rebate the revenue to households in lump-sum fashion in equilibrium.

[19] Foreign nominal holdings of Foreign bonds are denoted by $A^*_{*,t}$.

[20] Given that idiosyncratic risk is pooled among domestic households, and foreign households only trade foreign-currency-denominated bonds, domestic-currency-denominated bonds are in zero net supply. That is, in reality only foreign-currency-denominated bonds are traded in equilibrium. As a result, defining the intermediation costs over the foreign currency bond only is sufficient to pin down the overall steady-state net foreign asset position.

The Home household's period budget constraint is

$$A_{t+1} + S_t A_{*,t+1} + \frac{\psi}{2} S_t P_t^* \left(\frac{A_{*,t+1}}{P_t^*}\right)^2 + P_t C_t$$
$$= (1+i_t)A_t + (1+i_t^*)A_{*,t}S_t + w_t L_t + P_t b(1-l_t) + T_t^G$$
$$+ T_t^A + T_t^I + T_t^F,$$

where i_t and i_t^* are, respectively, the nominal interest rates on Home and Foreign bond holdings between $t-1$ and t, known with certainty as of $t-1$. Moreover, T_t^G is a lump-sum transfer (or tax) from the government, T_t^A is a lump-sum rebate of the cost of adjusting bond holdings from the intermediaries to which it is paid, and T_t^I and T_t^F are lump-sum rebates of profits from intermediate and final goods producers.[21]

Let $a_{t+1} \equiv A_{t+1}/P_t$ denote real holdings of Home bonds (in units of Home consumption) and let $a_{*,t+1} \equiv A_{*,t+1}/P_t^*$ denote real holdings of Foreign bonds (in units of Foreign consumption). The Euler equations for bond holdings are

$$1 = (1+i_{t+1})E_t\left\{\frac{\beta_{t,t+1)}}{1+\pi_{C,t+1}}\right\}, \tag{19}$$

$$1 + \psi a_{*t+1} = (1+i_{t+1}^*)E_t\left[\beta_{t,t+1}\frac{Q_{t+1)}}{Q_t(1+\pi_{C,t+1}^*)}\right], \tag{20}$$

where $\pi_{C,t}^* \equiv (P_t^*/P_{t-1}^*) - 1$.

We present below the law of motion for net foreign assets that follows from imposing equilibrium conditions in the household's budget constraint. Other details on the equilibrium can be found in the appendix.

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[21] In equilibrium,

$$T_t^G = -P_t b(1-l_t), \quad T_t^A = S_t P_t(\psi/2)(A_{*,t+1}/P_t^*)^2,$$
$$T_t^I = P_t(\varphi_t Z_t l_t - (w_t/P_t)l_t - (\vartheta/2)\pi_{w,t}^2 l_t - \lambda V_t),$$
$$T_t^F = \left(\frac{\mu_{d,t}-1}{\mu_{d,t}} - \frac{\nu}{2}(\pi_{d,t})^2\right)\tilde{\rho}_{d,t}N_{d,t}\tilde{y}_{d,t} + Q_t\left(\frac{\mu_{x,t}-1}{\mu_{x,t}} - \frac{\nu}{2}(\pi_{x,t})^2\right)\tilde{\rho}_{x,t}N_{x,t}\tilde{y}_{x,t}$$
$$- \varphi_t(N_{x,t}f_{x,t} + N_{e,t}f_{e,t}).$$

2.4 Net Foreign Assets and the Trade Balance

Bonds are in zero net supply, which implies that the equilibrium for the domestic bonds, being non-traded, is $a_t = 0$ in all periods. Home net foreign assets are determined by

$$Q_t a_{*,t+1} = Q_t \frac{1 + i_t^*}{1 + \pi_{C,t}^*} a_{*,t} + Q_t N_{x,t} \tilde{\rho}_{x,t} \tilde{y}_{x,t} - N_{x,t}^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^*.$$

Defining $1 + r_t^* \equiv (1 + i_t^*)/(1 + \pi_{C,t}^*)$, the change in net foreign assets between t and $t + 1$ is determined by the current account:

$$Q_t(a_{*,t+1} - a_{*,t}) = CA_t \equiv Q_t r_t^* a_{*,t} + TB_t,$$

where TB_t is the trade balance:

$$TB_t \equiv Q_t N_{x,t} \tilde{\rho}_{x,t} \tilde{y}_{x,t} - N_{x,t}^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^*.$$

3. Monetary Policy and Data-Consistent Variables

Before describing the interest rate setting rule, we must address an issue that concerns the data that are actually available to the central bank, i.e., we need to determine the empirically relevant variables that should enter the theoretical representation of historical policy. As pointed out by Ghironi and Melitz (2005), in the presence of endogenous product creation and "love for variety" in the production of final consumption varieties, variables measured in units of consumption do not have a direct counterpart in the data, i.e., they are not data consistent. As the economy experiences entry of Home and Foreign firms, the welfare-consistent aggregate price index P_t can fluctuate even if product prices remain constant. In the data, however, aggregate price indexes do not take these variety effects into account.[22] To resolve this issue, we follow Ghironi and Melitz (2005), and we construct an average price index $\tilde{P}_t \equiv (N_{d,t} + N_{x,t}^*)^{1/(\theta-1)} P_t$. The average price index $\tilde{P}_t$ is closer to the actual CPI data constructed by statistical agencies than is the welfare-based index P_t, and, therefore, it is the data-consistent CPI implied by the model.

[22] There is much empirical evidence that gains from variety are mostly unmeasured in CPI data, as documented most recently by Broda and Weinstein (2010).

In turn, given any variable X_t in units of consumption, its data-consistent counterpart is $X_{R,t} \equiv X_t P_t / \tilde{P}_t$. The data-consistent CPI inflation rate is $\tilde{\pi}_t^C \equiv (\tilde{P}_t / \tilde{P}_{t-1}) - 1$.

We now specify the monetary policy adopted by the small open economy. As Huang, Margaritis, and Mayes (2001) have shown, a standard Taylor (1993) rule describes New Zealand monetary policy quite well. In order to capture the basic policy of inflation targeting, we begin by assuming that the central bank of the small open economy sets the contemporaneous policy interest rate, according to

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left\{ (1 + i) \left[E_t \left(\frac{\hat{P}_{t+k}}{\hat{P}_{t+k-1}} \right) \right]^{\varrho_\pi} \left(\hat{Y}_{R,t}^g \right)^{\varrho_{Y^g}} \right\}^{1-\varrho_i},$$

where $\hat{Y}_{R,t}^g \equiv Y_{R,t} / Y_{R,t}^{flex}$ denotes the output gap—deviations of real output, $Y_{R,t}$, from real output under flexible prices and wages, $Y_{R,t}^{flex}$—and $\hat{P}_t$ denotes deviations of the data-consistent CPI from trend. (Here and for nominal income below, deviations from trend are defined as ratios to trend levels.)

One of our objectives is to compare this with alternative monetary policies and, in this regard, we specify the price-level targeting and nominal income targeting policies as follows:

Price-level targeting:

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left[(1 + i) \left(E_t \hat{P}_{t+k} \right)^{\varrho_P} \left(\hat{Y}_{R,t}^g \right)^{\varrho_{Y^g}} \right]^{1-\varrho_i};$$

Nominal income targeting:

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left[(1 + i) \left(E_t \hat{Y}_{t+k}^N \right)^{\varrho_{Y^N}} \left(\hat{Y}_{R,t}^g \right)^{\varrho_{Y^g}} \right]^{1-\varrho_i},$$

where $\hat{Y}_t^N$ denotes deviations of nominal income from trend.

The three policy rules above can be written more compactly as

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left\{ (1 + i) \left[E_t \left(\frac{\hat{P}_{t+k}}{\hat{P}_{t+k-1}^{I_P}} \right)^{1 - I_{Y^N}} \left(E_t \hat{Y}_{t+k}^N \right)^{I_{Y^N}} \right]^{\varrho} \right.$$
$$\left. \times \left(\hat{Y}_{R,t}^g \right)^{\varrho_{Y^g}} \right\}^{1-\varrho_i}, \qquad (21)$$

where I_P and I_{Y^N} take value zero or one. Inflation targeting implies $I_P = 1$ and $I_{Y^N} = 0$; price-level targeting implies $I_P = I_{Y^N} = 0$; nominal income targeting implies $I_{Y^N} = 1$. Two points regarding the specification of (21) merit comment insofar as the Reserve Bank of New Zealand is concerned. First, it allows for a lagged adjustment, reflecting a policy of interest rate smoothing and cautious adjustment in response to multiplicative uncertainty (Tarkka and Mayes 1999). Second, it allows for a forward-looking policy according to which the interest rate is adjusted to k-period forecasts of inflation, prices, and output; see Huang, Margaritis, and Mayes (2001). In our benchmark specification we set $k = 0$.

Table 1 summarizes the key equilibrium conditions of the model. The table contains thirteen equations that determine thirteen endogenous variables of interest: $C_t, \tilde{\rho}_{d,t}, l_t, h_t, V_t, N_{d,t}, w_t/P_t, \tilde{z}_{x,t}, \pi_{w,t}, \pi_{C,t}, i_{t+1}, a_{*,t+1}$, and Q_t. (Other variables that appear in the table are determined as described above.)

4. Foreign Aggregates

As summarized in table 1, six Foreign variables directly affect the macroeconomic dynamics in the small open economy: $Y_t^{C^*}, i_t^*, \pi_{C,t}^*, N_{x,t}^*, \tilde{y}_{x,t}^*, \tilde{\rho}_{x,t}^*$. Aggregate demand, $Y_t^{C^*}$, the nominal interest rate, i_t^*, and inflation, $\pi_{C,t}^*$, are determined by treating the rest of the world (Foreign) as a closed economy that features the same production structure, technology, and frictions that characterize the small open economy.[23] Here we focus on the determination of the number of Foreign exporters, $N_{x,t}^*$, the average output of Foreign exported varieties, $\tilde{y}_{x,t}^*$, and their average relative price, $\tilde{\rho}_{x,t}^*$. Since the small open economy is infinitesimally small relative to the rest of the world, these variables affect macroeconomic dynamics in the small open economy without having any effect on Y_t^{C*}, i_t^*, and $\pi_{C,t}^*$.

We assume that Foreign producers solve a profit-maximization problem that is equivalent to that faced by Home producers, including the assumption that export prices are denominated in producer currency. The number of Foreign exporters is a time-varying fraction

[23] We do not report the details of the foreign economy. They are discussed in depth by Cacciatore and Ghironi (2012).

Table 1. Model Summary

Equilibrium Price Index: $1 = \tilde{\rho}_{d,t}^{1-\theta} N_{d,t}^{\frac{1-\phi}{1-\theta}} + \tilde{\rho}_{x,t}^{*\,1-\theta} N_{x,t}^{*\,\frac{1-\phi}{1-\theta}}$

Equilibrium Exports: $\tilde{\rho}_{x,t}^{-\theta} N_{x,t}^{\frac{\theta-\phi}{1-\theta}} Y_t^{C*} = \frac{(\theta-1)}{k_p-(\theta-1)} \frac{\tilde{z}_{x,t}}{\tau_t} f_{x,t}$

Labor Market Clearing: $l_t h_t = N_{d,t} \frac{\widetilde{y}_{d,t}}{Z_t \tilde{z}_d} + N_{x,t} \frac{\widetilde{y}_{x,t}}{Z_t \tilde{z}_{x,t}} \tau_t + N_{e,t} \frac{f_{e,t}}{Z_t} + N_{x,t}$

Employment Dynamics: $l_t = (1-\lambda) l_{t-1} + q_{t-1} V_{t-1}$

Product Creation: $1 = E_t \left\{ \beta_{t,t+1} \frac{\tilde{\rho}_{d,t+1}}{\tilde{\rho}_{d,t}} \left[\begin{array}{c} \frac{\mu_{d,t}}{\mu_{d,t+1}} \left(\frac{f_{e,t+1}}{f_{e,t}} - \frac{N_{x,t+1}}{N_{d,t+1}} \frac{f_{x,t+1}}{f_{e,t}} \right) + \\ \frac{1}{(\theta-1) f_{e,t}} \left(\frac{\mu_{d,t}}{\mu_{d,t+1}} \widetilde{y}_{d,t+1} + \frac{N_{x,t+1}}{N_{d,t+1}} \frac{Q_{t+1} \tilde{\rho}_{x,t+1} \tilde{z}_{x,t+1}}{\tilde{\rho}_{d,t+1} \tilde{z}_d} \frac{\mu_{d,t+1}}{\mu_{x,t+1}} \widetilde{y}_{x,t+1} \right) \end{array} \right] \right\}$

Job Creation: $1 = E_t \left\{ \beta_{t,t+1} \left[(1-\lambda) \frac{q_t}{q_{t+1}} + \frac{q_t}{\kappa} \left(\varphi_{t+1} Z_{t+1} h_{t+1} - \frac{w_{t+1}}{P_{t+1}} h_{t+1} - \frac{\vartheta}{2} \pi_{w,t+1}^2 \right) \right] \right\}$

Determination of Hours: $v_{h,t} / u_{C,t} = \varphi_t Z_t$

Wage Inflation: $1 + \pi_{w,t} = \frac{w_t / P_t}{w_{t-1} / P_{t-1}} (1 + \pi_{C,t})$

Equilibrium Wage Bargain:
$$\frac{w_t}{P_t} h_t = \eta_{w,t} \left(\frac{v(h_t)}{u_{C,t}} + b \right) + (1 - \eta_{w,t}) \left(\varphi_t Z_t h_t - \frac{\vartheta}{2} \pi_{w,t}^2 \right)$$
$$+ E_t \left\{ \beta_{t,t+1} J_{t+1} \left[(1-\lambda)(1-\eta_{w,t}) - (1-\lambda-\iota_t)(1-\eta_{w,t+1}) \frac{\eta_{w,t}}{\eta_{w,t+1}} \right] \right\}$$

Monetary Policy Rule: $1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left\{ (1+i) \left[E_t \left(\frac{\hat{P}_{t+k}}{\hat{P}_{t+k-1}^{I_P}} \right)^{1-I_{\tilde{Y}}} \left(E_t \hat{Y}_{t+k}^N \right)^{I_{\tilde{Y}}} \right]^{\varrho} \left[\left(\hat{Y}_{R,t}^g \right)^{\varrho_{Y^g}} \right] \right\}^{1-\varrho_i}$

Euler Equation for Domestic Bonds: $1 = (1 + i_{t+1}) E_t \beta_{t,t+1} \left(\frac{1}{1+\pi_{C,t+1}} \right)$

Euler Equation for Foreign Bonds: $1 + \psi a_{*t+1} = \left(1 + i_{t+1}^*\right) E_t \left\{ \beta_{t,t+1} \frac{Q_{t+1}}{Q_t \left(1+\pi_{C,t+1}^*\right)} \right\}$

Foreign Asset Accumulation: $Q_t (a_{*,t+1} - a_{*,t}) = Q_t \frac{(1+i_t^*)}{\left(1+\pi_{C,t}^*\right)} a_{*,t} + Q_t N_{x,t} \tilde{\rho}_{x,t} \tilde{y}_{x,t} - N_{x,t}^* \tilde{\rho}_{x,t}^* \tilde{y}_{x,t}^*$

of the number of Foreign producers that serve their domestic market:

$$N_{x,t}^* \equiv \left[1 - G\left(z_{x,t}^*\right)\right] N_{d,t}^* = \left(\frac{z_{\min}}{\tilde{z}_{x,t}^*}\right)^{-k_p} \alpha^{\frac{k_p}{\theta-1}} N_{d,t}^*,$$

where $\tilde{z}_{x,t}^*$ is determined by imposing a zero export-profit condition that is the Foreign counterpart to equation (12):

$$\tilde{\rho}_{x,t}^{*-\theta} N_{x,t}^{*\frac{\theta-\phi}{1-\theta}} Y_t^C = \frac{(\theta-1)}{k_p - (\theta-1)} \frac{\tilde{z}_{x,t}^*}{\tau_t^*} f_{x,t}^*.$$

In the above expression, τ_t^* and $f_{x,t}^*$ denote, respectively, iceberg trade costs and fixed export costs for Foreign firms (both costs are exogenous). The average output of a variety exported by Foreign to Home is

$$\tilde{y}_{x,t}^* = \left(\tilde{\rho}_{x,t}^*\right)^{-\phi} \left(N_{x,t}^*\right)^{\frac{\theta-\phi}{1-\theta}} Y_t^C,$$

where the average relative price $\tilde{\rho}_{x,t}^*$ is given by

$$\tilde{\rho}_{x,t}^* = Q_t \mu_{x,t}^* \tau_t^* \frac{\varphi_t^*}{\tilde{z}_{x,t}^*}.$$

In the above expression, φ_t^* denotes the marginal costs of production of an individual variety in the rest of the world; the term $\mu_{x,t}^*$ denotes the export markup:

$$\mu_{x,t}^* \equiv \xi_t \frac{\phi}{(\phi-1)\Xi_{x,t}^{*d}},$$

where

$$\begin{aligned}\Xi_{x,t}^{*d} \equiv {} & 1 - \frac{\nu}{2}\pi_{x,t}^{*d^2} + \nu(1+\pi_{x,t}^{*d})\pi_{x,t}^{*d} \\ & - \frac{\nu}{(\phi-1)} E_t\left[\beta_{t,t+1}^*(1+\pi_{x,t+1}^{*d})\pi_{x,t+1}^{*d}\frac{Y_{x,t+1}^*}{Y_{x,t}^*}\right],\end{aligned}$$

$Y_{x,t}^* = (N_{x,t}^*)^{\frac{\theta}{\theta-1}} \tilde{y}_{x,t}^*, 1 + \pi_{x,t}^{*d} \equiv (1+\pi_{C,t}^*)(Q_{t-1}/Q_t)(\tilde{\rho}_{x,t}^*/\tilde{\rho}_{x,t-1}^*)$ denotes Foreign export price inflation, and ξ_t is a Foreign export markup shock that we will use to introduce shocks to the terms of trade in our sensitivity analysis below.

5. Calibration and Model Properties

5.1 Calibration

We interpret periods as quarters and calibrate the rest-of-the-world parameters to match standard post-war U.S. macroeconomic data. With the exception of the workers' bargaining power, the monetary policy coefficients appearing in the interest rate rule, and the process of exogenous shocks, we assume that the parameters that characterize the small open economy are symmetric to the rest of the world. Given that NZ is an advanced economy, we view this as being a plausible assumption. Table 2 summarizes the calibration. (Variables without time indexes denote steady-state levels; parameters denoted with an asterisk are specific to the rest of the world, i.e., the calibration of those parameters is not symmetric across countries.)

5.1.1 Rest of the World

We set the discount factor β to 0.99, implying an annual real interest rate of 4 percent. The period utility function is given by $u_t = C_t^{1-\gamma_C}/(1-\gamma_C) - l_t h_t^{1+\gamma_h}/(1+\gamma_h)$. The risk aversion coefficient γ_C is equal to 2, while the Frisch elasticity of labor supply $1/\gamma_h$ is set to 0.4, a midpoint between empirical micro and macro estimates.[24] The elasticity of substitution across product varieties, θ, is set to 3.8 following Bernard et al. (2003), who find that this value fits U.S. plant and macro trade data. Following Ghironi and Melitz (2005), we set the elasticity of substitution across Home and Foreign goods, ϕ, equal to θ. Also as in Ghironi and Melitz (2005), we set $k_p = 3.4$ and normalize $z_{\min}$ to 1.

To ensure steady-state determinacy and stationarity of net foreign assets, we set the bond adjustment cost parameter ψ to 0.0025 as in Ghironi and Melitz (2005). The scale parameter for the cost of

[24] The value of this elasticity has been a source of controversy in the literature. Students of the business cycle tend to work with elasticities that are higher than microeconomic estimates, typically unity and above. Most microeconomic studies, however, estimate this elasticity to be much smaller, between 0.1 and 0.6. For a survey of the literature, see Card (1994). Keane and Rogerson (2012) offer a reconciliation that credibly supports the range of estimates typically adopted in macroeconomic simulations. Our results are not affected significantly if we hold hours constant at the optimally determined steady-state level.

Table 2. Calibration

	Parameter
Risk Aversion	$\gamma_C = 2$
Frisch Elasticity	$1/\gamma_h = 0.28$
Discount Factor	$\beta = 0.99$
Elasticity Matching Function	$\varepsilon = 0.4$
Firm Bargaining Power	$\eta = 0.6$
Unemployment Replacement Rate	$b/w = 0.54$
Exogenous Separation	$\lambda = 0.1$
Vacancy Cost	$\kappa = 0.08$
Matching Efficiency	$\chi = 0.73$
Elasticity of Substitution	$\theta = 3.8$
Plant Exit	$\delta = 0.035$
Pareto Shape	$k_p = 3.4$
Pareto Support	$z_{\min} = 1$
Sunk Entry Cost	$f_e = 0.51$
Fixed Export Costs	$f_x = 0.003$
Iceberg Trade Costs	$\tau = 1.52$
Rotemberg Wage Adjustment Cost	$\vartheta = 260$
Rotember Price Adjustment Cost	$\upsilon = 80$
Policy Rule—Interest Rate Smoothing	$\varrho_i = 0$
Policy Rule—Inflation Parameter	$\varrho_\pi = 1.44$
Policy Rule—Output-Gap Parameter	$\varrho_{Y^g} = 0.18$
Bond Adjustment Cost	$\psi = 0.0025$

adjusting prices, υ, is equal to 80, as in Bilbiie, Ghironi, and Melitz (2008). We choose ϑ, the scale parameter of nominal wage adjustment costs, so that the model reproduces the volatility of unemployment relative to GDP observed in the data. This implies $\vartheta = 260$. To calibrate the entry costs, we follow Ebell and Haefke (2009) and set f_e so that regulation costs imply a loss of 5.2 months of per capita output.

Unemployment benefits, b, are equal to 54 percent of the steady-state wage, the average value for the United States reported by OECD (2004). The steady-state bargaining share of workers, $1-\eta^*$, is equal to 0.4, as estimated by Flinn (2006) for the United States. The unemployment elasticity of the matching function, $1-\varepsilon$, is also equal to 0.6, within the range of estimates reported by Petrongolo and Pissarides (2006) and such that the Hosios condition holds in steady state. The exogenous separation rate between firms and workers, λ, is 10 percent, as reported by Shimer (2005). To pin down exogenous plant exit, δ, we target the portion of worker separation due to plant exit equal to 40 percent reported by Haltiwanger, Scarpetta, and Schweiger (2008).

Two labor market parameters are left for calibration: the scale parameter for the cost of vacancy posting, κ, and the matching efficiency parameter, χ. We set these parameters to match the steady-state probability of finding a job and the probability of filling a vacancy. The former is 60 percent, while the latter is 70 percent, in line with Shimer (2005).

For the productivity process, we follow King and Rebelo (1999) and set persistence equal to 0.979 and standard deviation of innovations to 0.0072. In our benchmark scenario, we assume that there are no shocks to the Foreign export markup, i.e., we set $\xi_t = 1$ in all periods. Finally, the parameter values in the policy rule for the Federal Reserve's interest rate setting are those estimated by Clarida, Galí, and Gertler (2000). The inflation and GDP gap weights are 1.65 and 0.34, respectively, while the smoothing parameter is 0.71.

5.1.2 Small Open Economy

As discussed above, parameters are assumed to be symmetric across countries, with the exception of the firm's bargaining power, η, the coefficients appearing in the interest rate rule (21), and the standard deviation of productivity innovations. Moreover, three exogenous variables are specific to the small open economy: the fixed export cost, $f_{x,t}$; iceberg trade costs related to imports, τ_t^*; and iceberg trade costs related to exports, τ_t. We assume that these costs are constant, except for one-time, permanent changes in iceberg costs associated with trade integration. Thus, we drop the time index for simplicity. Moreover, we assume that iceberg trade costs related to imports (exports) are the sum of tariffs, τ^{T^*} (τ^T), and non-tariff barriers, τ^{NT^*} (τ^{NT}), i.e., $\tau^* = 1 + \tau^{T^*} + \tau^{NT^*}$ $(\tau = 1 + \tau^T + \tau^{NT})$. Moreover, we let $\tau = \tau^*$, so that in the benchmark scenario trade costs associated with exports and imports are assumed to be symmetric.

For the parameters that we use to capture market reforms (flexible-wage, worker bargaining power, and tariffs: η, τ^{T^*}, and τ^T), we consider two alternative parameterizations. The first one captures the level of market regulation prior to the introduction of reforms in NZ. In this case, we set $1 - \eta = 0.8$, since trade-union density in NZ was approximately twice as large as in the United States, and $\tau^{T^*} = \tau^T = 0.27$.[25] The second parameterization reflects the adoption of market reforms. Consistent with the observed 30 percent reduction in union density, we set $1 - \eta = 0.65$, and consistent with the observed tariff reductions, we set $\tau^{T^*} = 0.07$. For Foreign tariffs, we consider two alternative scenarios: In one, we leave $\tau^T = 0.27$; in the other, we consider a symmetric reduction also in τ^T to 0.07. We treat these parameter changes as permanent shocks to NZ and study the response of the economy to these shocks under alternative policy regimes.

We consider different cases for the policy rule (21), depending on the specific monetary policy regime at study—inflation targeting (IT), price-level targeting (PLT), and nominal income targeting (NIT). The benchmark rule is historical NZ's monetary policy post-1990, which corresponds to the inflation-targeting regime. As described above, this implies setting the indicator parameters $I_P = 1$ and $I_{Y_N} = 0$ in the policy rule (21). Consistent with the estimates in Huang, Margaritis, and Mayes (2001), we set $k = 0$, $\varrho_i = 0$, $\varrho = 1.44$, and $\varrho_{Y^g} = 0.18$.[26] When we consider the alternative scenarios of price-level or nominal income targeting, we keep k and the response coefficients ϱ_i, ϱ, and ϱ_{Y^g} at these values, but we change the targets in the policy rule by resetting the indicator parameters in (21) appropriately: $I_P = I_{Y^N} = 0$ for price-level targeting and $I_{Y^N} = 1$ for nominal income targeting. Under all policy scenarios, the data-consistent CPI in the initial steady state is normalized to 1. Under IT, the target inflation rate is 1.5 percent annually as dictated by the RBNZ mandate. Under PLT, the target price-level path is the path implied by 1.5 percent annual inflation starting from the

[25]Data are available at http://www.oecd.org/employment/emp/onlineoecdemploymentdatabase.htm#epl.

[26]The figures refer to table 3, column 3 on page 189 of their article. Notice that the authors show that a Taylor rule with the standard parameters used in the United States also describes NZ monetary policy quite well. However, their estimates point out that the RBNZ has focused more strongly on price stability, as required by its Policy Targets Agreements.

initial data-consistent CPI level of 1. Under NIT, the target nominal income path is the path implied by the steady-state level of data-consistent real GDP times the price level implied by 1.5 percent annual inflation starting from the initial data-consistent CPI level of 1. For illustrative purposes, for all three policy regimes, we also consider scenarios of strict targeting, in which the relevant target variable is fully stabilized at the trend target in all periods.

Finally, we choose f_x so that the share of exporting plants is equal to 30 percent and set non-tariff barriers equal to 0.45, an average of the estimates provided by Winchester (2009) for NZ. We set the persistence of productivity and the volatility of innovations to match the autocorrelation and volatility of NZ's labor productivity over the period 1990–2014. This requires setting $\phi_Z = 0.95$ and $\sigma_\epsilon = 0.095$.

5.2 Model Properties

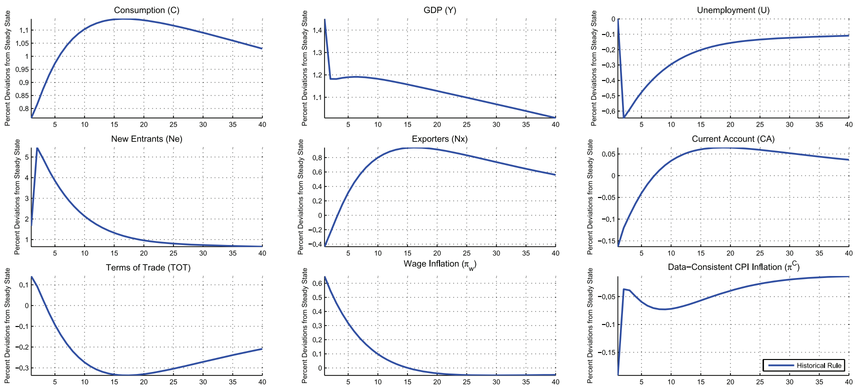
We now discuss the propagation of aggregate shocks in the model and compare business-cycle dynamics under historical monetary policy (inflation targeting) relative to the data.

Figure 1 shows the impulse responses to a 1 percent innovation in Home (NZ) productivity under the historical rule for interest rate setting. Unemployment (U_t) declines in the periods immediately following the shock. On impact, the higher expected return of a match induces domestic intermediate input producers to post more vacancies, which results in higher employment the following period. Firms and workers renegotiate nominal wages because of the higher surpluses generated by existing matches, and wage inflation ($\pi_{w,t}$) increases. Wage adjustment costs make the effective firm's bargaining power procyclical, i.e., $\eta_{w,t}$ rises.[27] Other things equal, the increase in $\eta_{w,t}$ dampens the response of the renegotiated equilibrium wage, amplifying the response of job creation to the shock.

Higher productivity increases producer entry in NZ and reduces the export cutoff, $z_{x,t}$. Accordingly, a larger share of NZ goods are available to domestic and foreign consumers. On impact, Foreign

[27] Intuitively, $\eta_{w,t}$ increases to ensure optimal sharing of the cost of adjusting wages between firms and workers.

Figure 1. Home Productivity Shock, High Market Regulation, Historical Monetary Policy



households shift resources to finance product creation in the more productive economy. As a consequence, NZ runs a current account deficit in response to the productivity increase (CA_t falls). NZ terms of trade (defined as $TOT_t \equiv Q_t\tilde{\rho}_{x,t}/\tilde{\rho}^*_{x,t}$) depreciate, so that NZ goods become relatively cheaper. However, the terms-of-trade depreciation is mild compared with standard international business-cycle models. Producer entry and the countercyclical response of $z_{x,t}$ counteract the effects of higher productivity on marginal costs, and domestic export prices fall by less, as compared with a model that abstracts from plant entry and heterogeneity.

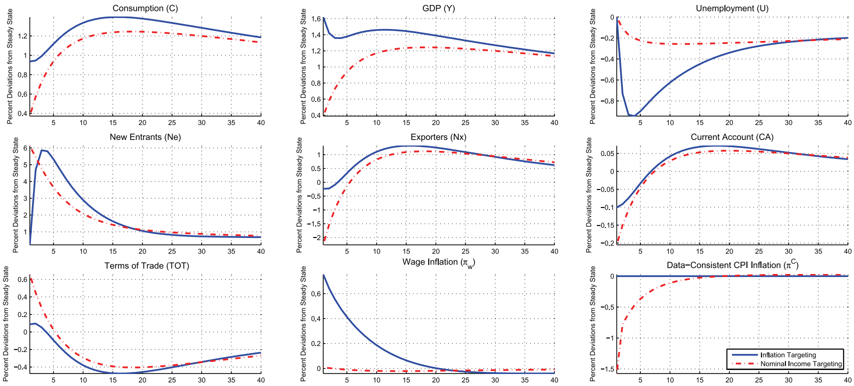
Table 3 presents the implied second moments for key aggregates of the model NZ under historical policy. In the table, model I refers to the benchmark model, where the only stochastic shocks are due to aggregate productivity shocks occurring in the intermediate goods sector. In that case, our parameterization matches the moments for real GDP, investment, employment, and real wages fairly well, but understates the volatility of real consumption, exports, and imports. (Investment in our model is given by investment in new product creation: $I_t \equiv \varphi_t f_{e,t} N_{e,t}$ and $I_{R,t} \equiv P_t I_t/\tilde{P}_t$.) The model is also rather successful in reproducing, at least qualitatively, the observed autocorrelations and the contemporaneous correlation of macroeconomic variables with GDP. Model II augments the productivity shocks with an exogenous stochastic component in terms-of-trade

Table 3. Historical Policy, Business-Cycle Statistics

Variable	σ_X			σ_X/σ_{Y_R}			$corr(X_t, Y_{R,t})$		
	Data	**Model I**	**Model II**	**Data**	**Model I**	**Model II**	**Data**	**Model I**	**Model II**
Y_R	1.50	1.50	1.77	1	1	1	1	1	1
C_R	1.60	0.82	1.48	1.06	0.55	0.83	0.75	0.89	0.85
I_R	8.88	7.60	8.60	5.86	5.06	4.83	0.66	0.63	0.68
L	1.24	1.07	1.10	0.82	0.72	0.62	0.64	0.57	0.48
w_R	0.91	0.59	1.011	0.60	0.40	0.56	−0.02	0.30	0.51
X_R	5.55	1.77	3.76	3.70	1.18	2.11	0.13	0.45	0.34
IM_R	7.10	1.43	8.77	4.72	0.95	4.93	0.35	0.79	0.61
TOT	3.60	0.44	4.23	2.39	0.29	2.39	−0.04	−0.40	0.20
$corr(Y_{R,t}, Y^*_{R,t})$	0.23	0.18	0.18						

Notes: $\sigma_X \equiv$ standard deviation of variable X; $\sigma_{Y_R} \equiv$ standard deviation of data-consistent, real GDP. Model I $\equiv$ TFP shocks; Model II $\equiv$ TFP and terms-of-trade shocks.

Figure 2. Home Productivity Shock, High Market Regulation, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)



dynamics (discussed in more detail in section 8 below), a result of which is that the model matches trade-related moments much more closely.

6. Business Cycles and Alternative Policy Regimes in Pre-Reform New Zealand

To begin our analysis of different monetary policy regimes, we study how alternative monetary policy arrangements—inflation targeting, price-level targeting, and nominal income targeting—affect NZ's business-cycle fluctuations and welfare in the highly regulated economy with high trade protection. That is, we study the performance of alternative monetary policy regimes, assuming that the NZ economy did not adopt market reforms.

Figure 2 compares the impulse responses with a 1 percent innovation in Home productivity under strict nominal income targeting and strict inflation targeting.[28] The figure shows that strict NIT is more

[28] Notice that strict inflation targeting implies $\hat{P}_t = 0$ (assuming a constant inflation target). In turn, zero deviations of the CPI index from trend imply strict price-level targeting.

effective in stabilizing unemployment fluctuations than is strict IT (or PLT). At issue are efficiency trade-offs that exist over the business cycle. These include, first, the tension between the beneficial effects of manipulating inflation and its costs. In addition, there is the trade-off between stabilizing price inflation (which contributes to stabilizing markups) and wage inflation (which stabilizes unemployment). Third, there is the impossibility to stabilize domestic and export markups jointly, due to the presence of firm heterogeneity, as discussed earlier.

These policy trade-offs explain why a policy of price stability can be sub-optimal. Under this policy, wage inflation is too volatile, and markup stabilization correspondingly too strong. Following fluctuations in aggregate productivity, sticky wages (and positive unemployment benefits) generate real wage rigidities, i.e., a positive (negative) productivity shock is not fully absorbed by the rise (fall) of the real wage, affecting job creation over the cycle. Higher NZ productivity pushes the real wage above its steady-state level, as the real value of existing job matches has increased. Under a policy of price stability, the effect of wage stickiness is magnified, since the real wage becomes even more rigid. Firms post too many vacancies and, in equilibrium, nominal wage adjustment costs are too large. In turn, lower unemployment volatility leads to smaller aggregate volatility. Both consumption and investment respond less under NIT.

Table 4 summarizes the welfare effects associated with the reforms we consider, and comprises two panels. Panel A reports the overall benefits resulting from the reforms, including those incurred along the transitional path that we will discuss in section 7 in conjunction with the dynamic adjustments. Panel B presents the welfare costs of business cycles associated with the alternative monetary policy regimes. To determine this we compute the percentage Δ^{BC} of steady-state consumption that would make the households indifferent between living in a world with uncertainty under monetary policy $m (m = IT, PLT, NIT)$ and living in a deterministic world:

$$E_0 \sum_{t=0}^{\infty} \beta^t u\left(C_t^m, l_t^m, h_t^m\right) = \frac{1}{1-\beta} u\left[\left(1+\frac{\Delta^{BC}}{100}\right) C, l, h\right]. \qquad (22)$$

First-order approximation methods are inappropriate to compute the welfare associated with each monetary policy arrangement. This

Table 4. Welfare Effects of Reform

	Inflation Targeting ($\tilde{P}_t/\tilde{P}_{t-1}$)			Price-Level Targeting ($\tilde{P}_t$)			Nominal Income Targeting ($\tilde{P}_t Y_{R,t}$)		
	Strict	**Hist.**	**Smoothing**	**Strict**	**Hist.**	**Smoothing**	**Strict**	**Hist.**	**Smoothing**
A. Δ Welfare									
Market Reform									
Bargaining Power (η)	3.95	3.96	3.96	3.95	3.95	3.95	3.98	3.98	3.98
Tariffs (τ^*)	1.61	1.58	1.57	1.61	1.59	1.59	1.58	1.58	1.58
Tariffs (τ^* and τ)	3.16	3.10	3.11	3.16	3.15	3.15	3.10	3.10	3.10
B. Δ^{BC} Welfare									
High Regulation	0.77	0.87	0.63	0.77	0.75	0.72	0.07	0.08	0.08
Market Reform									
Bargaining Power (η)	0.43	0.49	0.40	0.43	0.42	0.41	0.04	0.04	0.04
Tariffs (τ^*)	0.73	0.81	0.60	0.73	0.71	0.69	0.07	0.07	0.07
Tariffs (τ^* and τ)	0.70	0.76	0.57	0.70	0.67	0.66	0.06	0.07	0.06

Notes: $\tilde{P}_t \equiv$ data-consistent CPI; $Y_{R,t} \equiv$ data-consistent GDP; Strict $\equiv$ strict targeting: $\varrho_i = 0$; $\varrho = 1,000$; $\varrho_{Yg} = 0$. Hist $\equiv$ historical rule: $\varrho_i = 0$; $\varrho = 1.44$; $\varrho_{Yg} = 0.18$. Smoothing $\equiv$ historical rule with smoothing: $\varrho_i = 0.71$; $\varrho = 1.44$; $\varrho_{Yg} = 0.18$. Δ Welfare $\equiv$ steady-state welfare change (% of pre-reform steady-state consumption), including transition dynamics. Δ^{BC} Welfare $\equiv$ change in welfare costs of business cycles (% of pre-reform steady-state consumption).

is because the solution of the model implies that the expected value of each variable coincides with its non-stochastic steady state. However, in an economy with a distorted steady state, volatility affects both the first and second moments of the variables that determine welfare. Hence we compute welfare by taking a second-order approximation to the policy functions. Thus, a lower value of Δ^{BC} implies that the welfare costs of business cycles so computed are reduced.

The first line in panel B of table 4 compares the three monetary policies in the pre-deregulation period. There it is seen that strict NIT significantly reduces the welfare costs of business cycles relative to strict IT, reducing the welfare costs from 0.77 percent to 0.07 percent. As discussed above, this is so since NIT stabilizes job creation and thus unemployment fluctuations, whereas IT does not achieve this. That is, NIT better addresses the unemployment-inflation trade-off faced by the RBNZ.

Next, we compare the historical monetary policy of flexible IT with the alternatives of flexible PLT and flexible NIT. As described above, we do so by keeping the estimated coefficients in the interest rate rule fixed and replacing the inflation target with price or nominal income targets. NIT still clearly dominates, reducing welfare costs to 0.08 percent from 0.87 percent. Furthermore, by reducing welfare costs to 0.75 percent, PLT is also superior to IT. This is because PLT results in more volatile inflation, which ultimately dampens unemployment volatility more effectively relative to IT. When we allow for interest rate smoothing ($\varrho_i = 0.71$), the picture remains generally unchanged, although now IT is superior to PLT.

A natural question is whether NIT remains the more desirable regime when monetary policy is chosen optimally. To address this issue, we solve a constrained Ramsey problem in which the monetary authority maximizes the welfare of agents subject to the constraints represented by the competitive economy relations and a given monetary policy rule. We consider the following interest rate reaction function:

$$1 + i_{t+1} = (1 + i_t)^{\varrho_i} \left\{ (1 + i) \left[E_t \left(\frac{\hat{P}_{t+k}}{\hat{P}_{t+k-1}} \right) \right]^{\varrho_\pi} \right.$$
$$\left. \times \left(E_t \hat{P}_{t+k} \right)^{\varrho_P} \left(E_t \hat{Y}^N_{t+k} \right)^{\varrho_{Y^N}} \left(\hat{Y}^g_{R,t} \right)^{\varrho_{Y^g}} \right\}^{1-\varrho_i}$$

and search across the grid of parameters $\{\varrho_i, \varrho_\pi, \varrho_P, \varrho_{Y^N}, \varrho_{Y^g}\}$ for the rule that minimizes the welfare cost of business cycles in (22). We maintain the assumption that $k = 0$ and perform the search over the range [0, 10] for each parameter, with fineness equal to 0.01. We consider only those combinations of policy parameters that deliver a unique rational expectations equilibrium. The maximized rule yields $\varrho_{Y^N} = 10$ and $\varrho_i = \varrho_\pi = \varrho_P = \varrho_{Y^g} = 0$, which virtually mimics the policy of strict NIT described above—the welfare cost of business cycles is 0.07, identical to that obtained above.

7. The Macroeconomic Effects of Market Reforms in New Zealand

We now study the macroeconomic consequences of NZ labor market reform and trade integration under the alternative monetary policy regimes. Starting from an initial steady state featuring a highly regulated labor market and high barriers to trade, we consider the transitional dynamics generated by the reductions in worker bargaining power and tariffs described above. We treat these parameter changes as shocks to the NZ economy—the results of labor market and trade policy changes—and we assume that these changes are permanent and implemented under perfect foresight.[29] We begin by studying the dynamic adjustment to these reforms.

7.1 Transition Dynamics

Given the large size of the reform shocks, transitional dynamics from the initial equilibrium to the final equilibrium are found by solving the model as a non-linear forward-looking deterministic system using a Newton-Raphson method, as described in Laffargue (1990). This method solves simultaneously all equations for each period, without relying on local approximations.

Figure 3 illustrates the dynamic adjustment to labor market deregulation, while figures 4 and 5 refer to asymmetric and symmetric trade liberalization, respectively (i.e., tariff reductions only in NZ or in both NZ and Foreign). In each figure we compare the adjustment under strict IT (solid lines) and strict NIT (dotted lines).

[29] In our analysis, reforms are implemented in just one period.

Figure 3. Labor Market Deregulation, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)

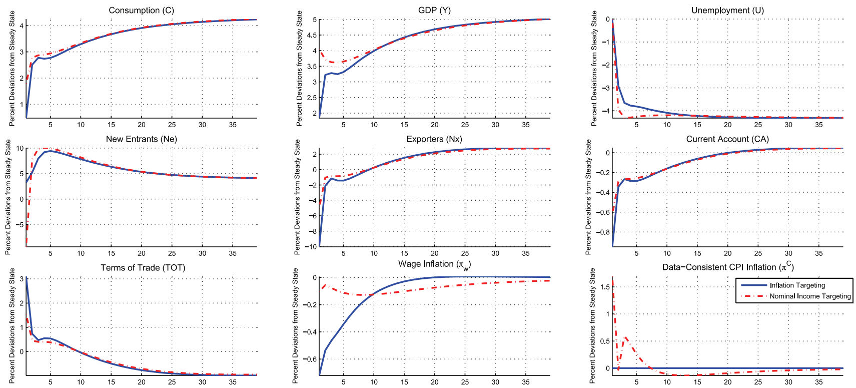
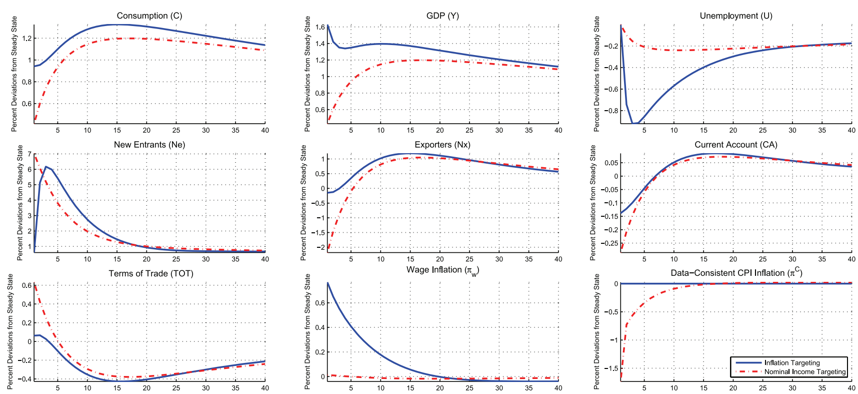
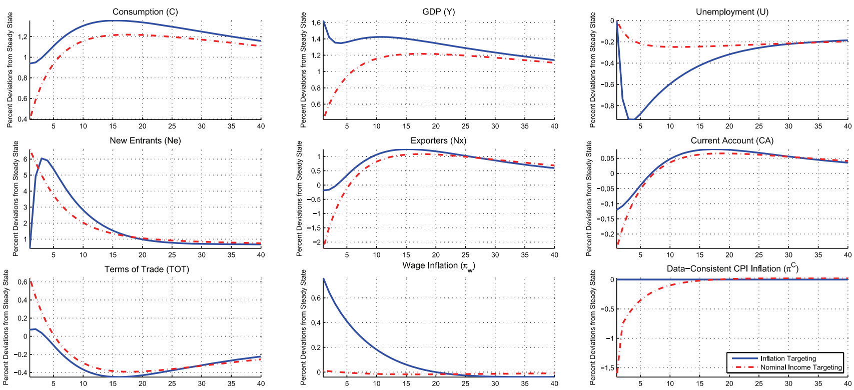


Figure 4. Asymmetric Trade Liberalization, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)



In the long run, market reforms boost aggregate output and reduce unemployment, a result consistent with the observed steady reduction in NZ's unemployment that took place from the early 1990s, when in ten years, the unemployment rate dropped from a peak of 11.4 percent to 5 percent. In the absence of aggregate shocks, monetary policy affects welfare by reducing (or increasing)

Figure 5. Symmetric Trade Liberalization, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)



transition costs. As discussed by Cacciatore and Ghironi (2012), pre-deregulation the economy features a steady state with inefficiently low job creation due to the presence of firm monopoly power, distortionary regulation, and misallocation of resources to change prices and wages (in the presence of positive trend inflation). Since the positive effects of reforms take time to materialize, expansionary monetary policy is beneficial, as it reduces markups and boosts job creation during the transition.

However, which monetary rule is more expansionary depends on the reform considered. In the case of labor market deregulation, strict NIT is superior to strict IT; see table 4. As shown in figure 3, strict NIT results in a larger monetary expansion in the aftermath of the reform, boosting consumption and reducing unemployment, more so than under strict IT. The reason is that reducing worker bargaining power has a milder effect on producer prices on impact: on the one hand, lower η lowers wages (by reducing the workers' outside option at the bargaining stage); on the other hand, as job creation increases, it becomes more costly to recruit new workers, which pushes up equilibrium wages. By contrast, NIT results in a stronger monetary expansion; in the aftermath of the reform the central bank induces inflationary pressure to boost consumption and reduce investment in product creation. As a result, the beneficial effects of deregulation materialize sooner.

In the case of trade liberalization, strict IT induces higher welfare. The key difference is that trade liberalization induces sizable price dynamics, as cheaper foreign imports induce deflation in the aftermath of the reform. The monetary response under strict IT is therefore expansionary. When we allow for endogenous monetary responses to the output gap or interest rate smoothing, the picture is a bit more nuanced, although the general results discussed above continue to hold. It is also interesting to observe the contrast in the current account dynamics implied by the two reforms (regardless of the form of monetary policy in effect).

As noted, panel A of table 4 quantifies the overall benefits of the reforms by computing the changes in steady-state welfare including transition dynamics. Specifically, we compute the percentage increase Δ in steady-state consumption relative to the status quo (no reform) that leaves households indifferent between whether or not the reform is implemented. Thus Δ is obtained by solving

$$\sum_{t=0}^{\infty} \beta^t u\left(C_t^m, l_t^m, h_t^m\right) = \frac{1}{1-\beta} u\left[\left(1+\frac{\Delta}{100}\right) C^{SQ}, l^{SQ}, h^{SQ}\right], \quad (23)$$

where “SQ” denotes the status quo, and m denotes the monetary regime (m = *IT, PLT, NIT*). A higher value of Δ implies that welfare increases following the reform.

As shown in table 4, during the transition, strict IT performs slightly better than does strict NIT in response to trade liberalization, raising welfare by 1.61 percent versus 1.58 percent in the case of domestic tariff reduction and 3.16 percent versus 3.10 percent in the case of symmetric trade liberalization. However, in the case of labor market reforms, the relative merits are reversed (3.96 percent vs. 3.98 percent).

7.2 Business Cycles in Post-Deregulation New Zealand

The dynamic effects of reforms are not limited to transition dynamics, since the economy may face a different adjustment to aggregate shocks once reforms are completed, with consequences for the welfare cost of business cycles. We now turn to this issue.

Figure 6. Home Productivity Shock, Low Labor Market Regulation, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)

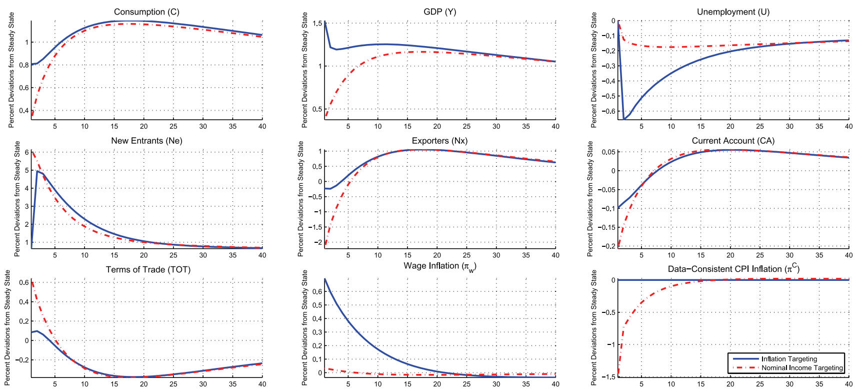


Figure 6 compares the impulse responses with the domestic productivity shock under strict IT and strict NIT following labor market deregulation and yields the following observations. NZ labor market reform affects the propagation of aggregate shocks through the cyclical behavior of the workers' outside option. Increased labor market flexibility makes job creation less responsive to shocks. Reduced worker bargaining power implies that adjustment takes place increasingly through the real wage, reducing job flows over the cycle. Strict NIT remains most effective in stabilizing unemployment. However, differences in unemployment dynamics across the two monetary regimes are reduced. This occurs because the need to stabilize wage inflation is mitigated.

Figures 7 and 8 trace out the impulse responses to the NZ productivity shock following a reduction in domestic tariffs and symmetric trade reforms, respectively. Similar to the labor market reform, there is less need to stabilize wage inflation over the cycle. As a result, the volatility gap between strict NIT and IT is reduced. To understand this result, notice that the reduction of NZ tariffs increases domestic competition, reallocating resources toward relatively more productive firms. In this process, expenditure switching toward cheaper Foreign goods reduces the

Figure 7. Home Productivity Shock, Low Import Tariffs, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)

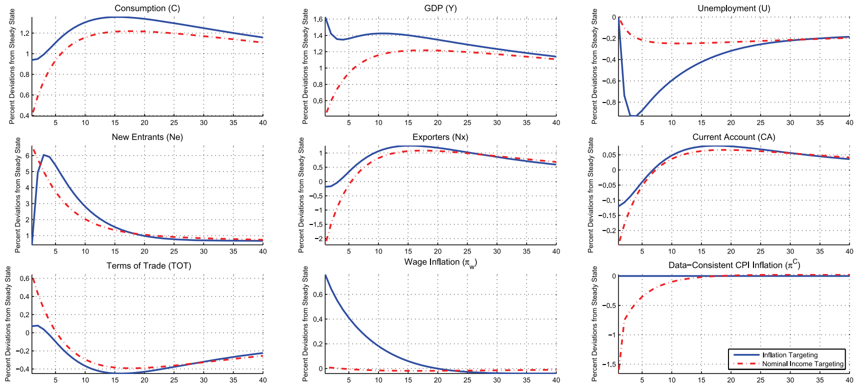
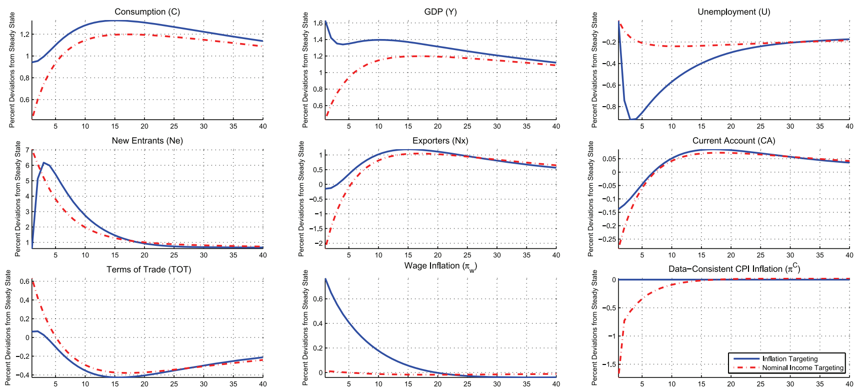


Figure 8. Home Productivity Shock, Low Import and Export Tariffs, Strict Inflation Targeting (solid line) vs. Strict Nominal Income Targeting (dashed line)



market value of NZ firms, which leads to a higher cut-off productivity for export in the new equilibrium. Furthermore, cheaper Foreign goods induce a positive income effect for Home households which, other things equal, increases the demand for NZ goods. In equilibrium, demand for intermediate inputs increases, resulting in higher profits per job match. Accordingly, in the new steady state, vacancy postings increase and unemployment falls. Therefore, unemployment varies by less (as a percentage of steady state) in response to aggregate disturbances, reducing the need to stabilize wage inflation.

This effect is stronger when trade integration is symmetric; see figure 8. In this case exporting becomes less costly for NZ producers and resource allocation toward more productive firms is stronger. Higher average productivity further increases the demand for intermediate inputs and reduces unemployment.

Comparing the measures of Δ^{BC} following the market reforms with the pre-deregulation measures reported in table 4, we see that both labor market and trade reforms reduce the welfare costs of business cycles for any given monetary policy regime. As explained above, reduced worker bargaining power makes real wages more procyclical, dampening the volatility of job creation. Trade liberalization reallocates market shares towards more productive firms, reducing the sensitivity of firm profits to aggregate shocks, which ultimately results in a moderation of aggregate employment volatility.

Thus, reform reduces the need for inflation volatility to stabilize cyclical unemployment. Accordingly, IT and PLT become less costly relative to NIT, which, however, continues to remain the best rule. This is particularly pronounced with labor market reforms. In that case, the welfare costs of business cycles are reduced by 35 percent under IT.

Table 5 reports post-reform business-cycle statistics for several key variables. Comparing these with the corresponding statistics in table 3, it is evident that reform results in less volatility in almost all cases, independent of the form of monetary policy. The one exception appears to be investment, the volatility of which has marginally increased.[30]

To conclude, we investigate whether market reforms change the nature of optimal monetary policy. Toward this end, we repeat the maximization described in the latter part of section 6. The maximized rule continues to prescribe strict NIT.

[30] These moments are generally consistent with the post-deregulation NZ business-cycle statistics reported by Hall, Thompson, and McKelvie (2014) and McKelvie and Hall (2012), although there are inevitable differences.

Table 5. Regulation and Business-Cycle Statistics

	σ_X							
	High Regulation		**Bargaining Power (η)**		**Tariffs (τ*)**		**Tariffs (τ* and τ)**	
Variable	**SIT**	**SNIT**	**SIT**	**SNIT**	**SIT**	**SNIT**	**SIT**	**SNIT**
Y_R	1.41	0.73	1.27	0.67	1.39	0.72	1.32	0.72
C_R	0.91	0.73	0.75	0.68	0.88	0.71	0.87	0.70
I_R	8.69	8.03	7.18	7.74	8.92	8.50	9.09	8.92
L	1.43	0.52	0.90	0.35	1.41	0.52	1.38	0.51
w_R	0.67	0.84	0.60	0.81	0.67	0.84	0.67	0.84
X_R	2.12	2.75	1.77	2.65	2.02	2.72	1.93	2.69
IM_R	1.69	1.68	1.51	1.61	1.64	1.60	1.60	1.56
$corr(Y_{R,t}, Y^*_{R,t})$	0.058	0.040	0.056	0.050	0.068	0.050	0.069	0.059

Notes: $\sigma_X \equiv$ standard deviation of variable X (percentage points). $SIT \equiv$ strict inflation targeting; $SNIT \equiv$ strict nominal income targeting.

8. Sensitivity Analysis

In the benchmark version of our model, the Home economy's terms of trade fluctuate only endogenously in response to Home and Foreign productivity shocks due to the presence of firm monopoly power in both countries. However, as previously discussed, the benchmark model understates the volatility of TOT_t relative to output, suggesting that unmolded forces affect NZ's terms-of-trade fluctuations. Indeed, existing evidence suggests that terms-of-trade shocks are an important driver of NZ's business cycles (Karagedikli and Price 2012). To address this issue, we introduce exogenous terms-of-trade shocks, in the form of exogenous shocks ξ_t to the Foreign export markup, $\mu^*_{x,t}$.[31] Normalizing the steady-state value of ξ_t to 1, we assume that ξ_t follows an $AR(1)$ process in logarithms, $\log \xi_t = \phi_\xi \log \xi_{t-1} + \overline{\omega}_t$, where $\overline{\omega}_t$ represents i.i.d. draws from a normal distribution with zero mean and standard deviation $\sigma_{\overline{\omega}}$. We calibrate the persistence of the shock ϕ_ξ and the standard deviation of innovations $\sigma_{\overline{\omega}}$ to match the observed autocorrelation and standard deviation of NZ's terms of trade. This requires setting $\phi_\xi = 0.3$ and $\sigma_{\overline{\omega}} = 0.28$.[32] As shown in table 3, when business cycles are driven by both productivity and terms-of-trade shocks, the model reproduces much more closely the observed volatility of imports and exports relative to GDP, as well as their contemporaneous correlation with output. The correlation of TOT_t with output is also in line with the data.

Table 6 compares again the stabilization properties of alternative monetary policy arrangements. Panel A considers only terms-of-trade shocks; panel B considers simultaneously productivity and terms-of-trade shocks. While the presence of terms-of-trade shocks

[31] On the supply side, ξ_t captures international, commodity-market-specific shocks. On the demand side, it can be interpreted as reflecting changes in world demand (preferences). The assumption that shocks to international prices, rather than domestic export price shocks, drive exogenous NZ's terms-of-trade fluctuations is consistent with the evidence in Karagedikli and Price (2012). Nevertheless, we obtain similar results if we model terms-of-trade shocks as exogenous shocks to the time-varying markup of Home exporters.

[32] Notice that this does not imply that terms-of-trade dynamics become fully exogenous in the model. It is only these two moments that are determined fully exogenously by calibration. The exogenous shock ξ_t and the endogenous nature of the terms of trade in our model then jointly affect the equilibrium path of TOT_t.

Table 6. Welfare Effects of Reforms, Sensitivity Analysis

	Inflation Targeting ($\tilde{P}_t/\tilde{P}_{t-1}$)		**Price-Level Targeting ($\tilde{P}_t$)**		**Nominal Income Targeting ($\tilde{P}_t Y_{R,t}$)**	
	Strict	**Hist.**	**Strict**	**Hist.**	**Strict**	**Hist.**
A. Δ^{BC} Welfare, Terms-of-Trade Shocks						
High Regulation	0.65	1.00	0.65	0.46	0.43	0.38
Market Reform						
Bargaining Power (η)	0.52	0.87	0.52	0.39	0.38	0.34
Tariffs (τ^* and τ)	1.02	1.71	1.02	0.73	0.66	0.60
B. Δ^{BC} Welfare, Productivity, and Terms-of-Trade Shocks						
High Regulation	1.41	1.87	1.41	1.21	0.45	0.46
Market Reform						
Bargaining Power (η)	0.95	1.37	0.95	0.91	0.38	0.38
Tariffs (τ^* and τ)	1.71	2.46	1.71	1.41	0.65	0.67

Notes: $P_t \equiv$ data-consistent CPI; $Y_{R,t} \equiv$ data-consistent GDP; Strict $\equiv$ strict targeting: $\varrho_i = 0$; $\varrho = 1,000$; $\varrho_{Yg} = 0$. Hist $\equiv$ historical rule: $\varrho_i = 0$; $\varrho = 1.44$; $\varrho_{Yg} = 0.18$. Δ^{BC} Welfare $\equiv$ change in welfare costs of business cycles (% of pre-reform steady-state consumption).

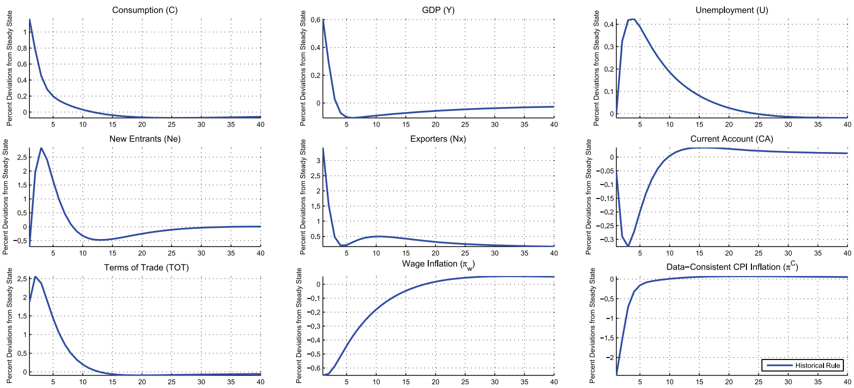
does not change the main message of the paper, two new results emerge. First, inefficient terms-of-trade fluctuations increase the welfare cost of business cycles for a given monetary policy regime and a given level of market regulation. Second, the opening of trade no longer decreases the welfare cost of business cycles. To understand these new results, it is useful to inspect the propagation of terms-of-trade shocks.

Figure 9 shows the impulse responses following a one-standard-deviation decrease in the Foreign export markup under historical monetary policy. The reduction in the Foreign markup appreciates NZ's terms of trade—the relative price of NZ exports in terms of NZ imports increases. In turn, cheaper imports increase demand for Foreign goods. At the same time, the appreciation of the terms of trade generates a positive wealth effect that sustains aggregate demand for domestic output. Thus, expenditure switching toward Foreign goods does not increase unemployment in the aftermath of the shock. NZ consumption increases by 0.9 percent at the peak. During the transition, the number of foreign exporters increases, while the terms of trade revert to their steady-state level. Unemployment temporarily increases, while GDP displays a modest decline below trend.

As shown in table 6, for any level of labor market regulation and trade integration, strict IT is approximately twice as costly relative to the benchmark model. The intuition for this result is that Foreign markup shocks exacerbate the monetary policy trade-offs faced by the model RBNZ. In particular, in order to offset falling CPI inflation, the monetary authority ends up increasing unemployment volatility and thus the welfare cost of business cycles. Thus, as for the case of productivity shocks, NIT reduces sub-optimally unemployment volatility.[33] With the opening of trade, the importance of terms-of-trade shocks increases, since a larger share of NZ demand falls on Foreign goods. As a result, the reduction in real distortions associated with lower trade barriers is no longer sufficient to lower the welfare cost of business cycles. While the overall effect remains modest under NIT, the welfare cost of business cycles increases to

[33]Notice that PLT is more efficient than IT. As explained before, the reason is that PLT results in higher inflation volatility, which ultimately implies more stable unemployment fluctuations.

Figure 9. Terms-of-Trade Shock, Historical Policy



1.7 percent under strict IT. The optimized rule continues to be strict NIT.

To conclude, we perform additional sensitivity analysis along two dimensions. First, we investigate whether our results are robust to the presence of forward-looking targets in the policy rules considered above. Specifically, we run all the simulations setting $k = 1$ in (21). Second, we consider alternative values for the parameters whose calibration is relatively controversial in the literature. For household preferences, we consider a higher Frisch elasticity of labor supply ($1/\gamma_h = 4$, as typically assumed in the business-cycle literature). We evaluate the importance of nominal rigidity by considering smaller values for the scale parameters of price and wage adjustment costs ($\nu = \vartheta = 20$). Finally, we consider an alternative value for the elasticity of the matching function ($\varepsilon = 0.4$, the lower bound of the estimates reported by Petrongolo and Pissarides 2006). We consider the effect of changing one parameter value at a time relative to the benchmark calibration. The main results of the paper are very robust to the alternative parameter values we consider. (Detailed results are available upon request.)

9. Conclusions

Was inflation targeting the best monetary policy regime for New Zealand prior to the increase in its trade integration and labor market flexibility since the early 1990s? Was it the best strategy to manage the transition dynamics generated by these changes in market characteristics? And is it the best option for a now flexible, highly integrated New Zealand? This paper addressed these questions using a New Keynesian model with micro-level producer and trade dynamics and labor market frictions. We found that nominal income targeting would have been preferable to inflation targeting in the distorted environment of a rigid labor market and low trade integration. Nominal income targeting would have also reduced the transition costs of labor market reform, though inflation targeting achieved a better response to trade integration. With New Zealand in its new long-run environment of integrated trade and flexible labor markets, the welfare gap between nominal income targeting and price/inflation targeting is smaller, as market reforms lower unemployment volatility.

As a final caveat, we should note that our analysis has focused on the two aspects of the reforms, labor market and trade, which we feel the model we employ is most appropriate to address. But New Zealand's reforms were very far reaching, including fiscal restructuring, energy policy, agriculture, transportation, privatization, financial liberalization, and liberalization of immigration policy, to name just a subset. Thus, in order to draw any definitive conclusions as to the merits of inflation targeting versus other monetary policies, one needs to address the roles played by these other aspects of the comprehensive reform program.

Appendix

Wage Determination

This appendix summarizes wage determination. Let J_t denote the real value of an existing productive match for the producer; then

$$J_t = \varphi_t Z_t h_t - \frac{w_t}{P_t} h_t - \frac{\vartheta}{2}\pi_{w,t}^2 + E_t \beta_{t,t+1}(1-\lambda)J_{t+1}. \tag{24}$$

That is, J_t equals the current marginal value product of the match, less the wage bill inclusive of wage adjustment costs, plus the expected discounted continuation value of the match next period.

Next, let W_t denote the worker's asset value of being matched, and $U_{u,t}$ the value of being unemployed. The value of being employed at time t equals the real wage the worker receives plus the expected future value of continuing to be matched to the firm. Thus,

$$W_t = \frac{w_t}{P_t} h_t + E_t \left\{ \beta_{t,t+1} \left[(1-\lambda) W_{t+1} + \lambda U_{u,t+1} \right] \right\}. \tag{25}$$

The value of being unemployed is

$$U_{u,t} = \frac{\nu(h_t)}{u_{C,t}} + b + E_t \left\{ \beta_{t,t+1} \left[\iota_t W_{t+1} + (1-\iota_t) U_{u,t+1} \right\} \right., \tag{26}$$

which equals the utility gain from leisure in terms of consumption, plus the unemployment benefit from the government, plus the expected discounted value of gaining reemployment next period (versus remaining unemployed), the probability of which occurring is $\iota_t \equiv M_t / U_t$. Combining (25) and (26), the worker's surplus, $H_t \equiv W_t - U_{u,t}$, is thus

$$H_t = \frac{w_t}{P_t} h_t - \left(\frac{v(h_t)}{u_{C,t}} + b \right) + (1 - \lambda - \iota_t) E_t (\beta_{t,t+1} H_{t+1}). \tag{27}$$

The Nash bargain maximizes the joint surplus $J_t^{\eta} H_t^{1-\eta}$ with respect to w_t. Carrying out the optimization yields

$$\eta H_t \frac{\partial J_t}{\partial w_t} + (1-\eta) J_t \frac{\partial H_t}{\partial w_t} = 0, \tag{28}$$

where

$$\frac{\partial J_t}{\partial w_t} = -\frac{h_t}{P_t} - \vartheta \frac{\pi_{w,t}}{w_{t-1}} + (1-\lambda) \vartheta E_t \left[\beta_{t,t+1} (1 + \pi_{w,t+1}) \frac{\pi_{w,t+1}}{w_t} \right],$$
$$\frac{\partial H_t}{\partial w_t} = \frac{h_t}{P_t}.$$

The sharing rule (28) can thus be written as

$$\eta_{w,t} H_t = (1 - \eta_t) J_{w,t}, \tag{29a}$$

where

$$\eta_{w,t} \equiv \frac{\eta}{\eta - (1-\eta)(\partial H_t / \partial w_t)(\partial J_t / \partial w_t)^{-1}}. \tag{29b}$$

Combining equations (28) and (29) yields equation (4) of the text.

Pricing Decisions

The representative final-sector firm sets the price of the output bundle for domestic sale, $P_{d,t}$, and the domestic currency price of the export bundle, $P_{x,t}^d$, letting the price in the foreign market be determined by $P_{x,t} = \tau_t P_{x,t}^d / S_t$. When choosing $P_{d,t}$ and $P_{x,t}^d$, the firm maximizes

$$E_t \sum_{s=t}^{\infty} \beta_{t,t+s} \left[\left(\frac{P_{d,s}}{P_s} - \frac{P_{d,s}^y}{P_s} \right) Y_{d,s} + \left(\frac{P_{x,s}^d}{P_s} - \frac{P_{x,s}^y}{P_s} \tau_s \right) Y_{x,s} - \frac{\Gamma_{d,s}}{P_s} - \frac{\Gamma_{x,s}^d}{P_s} \right], \tag{30}$$

where $\Gamma_{d,s} \equiv \nu \pi_{d,s}^2 P_{d,s} Y_{d,s}/2$, $\Gamma_{x,s}^d \equiv \nu \pi_{x,s}^{d^2} P_{x,s}^d Y_{x,s}/2$, $\pi_{d,s} \equiv (P_{d,s}/P_{d,s-1}) - 1$, $\pi_{x,s}^d \equiv (P_{x,s}^d / P_{x,s-1}^d) - 1$, and output bundle demands are determined by

$$Y_{d,s} = \left(\frac{P_{d,s}}{P_s} \right)^{-\phi} Y_t^C, \qquad Y_{x,s} = \left(\frac{\tau_s P_{x,s}^d}{Q_s P_s} \right)^{-\phi} Y_t^{C^*}.$$

First-order optimality conditions for $P_{d,t}$ and $P_{x,t}^d$ and straightforward, though tedious, algebra yield equations (13)–(16) in the text. (To obtain (15)–(16), recall that $P_{x,t} = \tau_t P_{x,t}^d / S_t$ and $Q_t \equiv S_t P_t^* / P_t$.)

Other Equilibrium Details

The aggregate stock of employed labor in the Home economy is determined by

$$l_t = (1 - \lambda) l_{t-1} + q_{t-1} V_{t-1}.$$

Wage inflation and consumer price inflation are tied by

$$1 + \pi_{w,t} = (w_t / P_t)(w_{t-1}/P_{t-1})^{-1}(1 + \pi_{C,t}).$$

The expression for the consumption price index implies

$$1 = \tilde{\rho}_{d,t}^{1-\theta} N_{d,t}^{\frac{1-\phi}{1-\theta}} + \tilde{\rho}_{x,t}^{*1-\theta} N_{x,t}^{\frac{1-\phi}{*1-\theta}}.$$

Finally, labor market clearing requires

$$l_t h_t = N_{d,t} \frac{\tilde{y}_{d,t}}{Z_t \tilde{z}_d} + N_{x,t} \frac{\tilde{y}_{x,t}}{Z_t \tilde{z}_{x,t}} \tau_t + N_{e,t} \frac{f_{e,t}}{Z_t} + N_{x,t} \frac{f_{x,t}}{Z_t}.$$

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