# 1 (Appendix B) A detailed overview of available models in Modelbase

1. SMALL CALIBRATED MODELS

| | | |
|---|---|---|
| 1.1.1 | NK_RW97 | Rotemberg and Woodford (1997) |
| 1.1.2 | NK_LWW03 | Levin et al. (2003) |
| 1.1.3 | NK_CGG99 | Clarida et al. (1999) |
| 1.1.4 | NK_CGG02 | Clarida et al. (2002) |
| 1.1.5 | NK_MCN99cr | McCallum and Nelson (1999), (Calvo-Rotemberg model) |
| 1.1.6 | NK_IR04 | Ireland (2004) |
| 1.1.7 | NK_BGG99 | Bernanke et al. (1999) |
| 1.1.8 | NK_GM05 | Gali and Monacelli (2005) |
| 1.1.9 | NK_GK11 | Gertler and Karadi (2011) |
| 1.1.10 | NK_CK08 | Christoffel and Kuester (2008) |
| 1.1.11 | NK_CKL09 | Christoffel et al. (2009) |
| 1.1.12 | NK_RW06 | Ravenna and Walsh (2006) |
| 1.1.13 | NK_MM10 | Meh and Moran (2010) |
| 1.1.14 | NK_KRS12 | Kannan et al. (2012) |

2. ESTIMATED US MODELS

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|---|---|---|
| 1.2.1 | US_FM95 | Fuhrer and Moore (1995a) |
| 1.2.2 | US_OW98 | Orphanides and Wieland (1998) equivalent to MSR model in Levin et al. (2003) |
| 1.2.3 | US_FRB03 | Federal Reserve Board model linearized as in Levin et al. (2003) |
| 1.2.3 | US_FRB08 | linearized by Brayton and Laubach (2008) |
| 1.2.3 | US_FRB08mx | linearized by Brayton and Laubach (2008), (mixed expectations) |
| 1.2.4 | US_SW07 | Smets and Wouters (2007) |
| 1.2.5 | US_ACELm | Altig et al. (2005), (monetary policy shock) |
| | US_ACELt | Altig et al. (2005), (technology shocks) |
| | US_ACELswm | no cost channel as in Taylor and Wieland (2011) (mon. pol. shock) |
| | US_ACELswt | no cost channel as in Taylor and Wieland (2011) (tech. shocks) |
| 1.2.6 | US_NFED08* | based on Edge et al. (2008), version used for estimation in Wieland and Wolters (2011) |
| 1.2.7 | US_RS99 | Rudebusch and Svensson (1999) |
| 1.2.8 | US_OR03 | Orphanides (2003) |
| 1.2.9 | US_PM08 | IMF projection model US, Carabenciov et al. (2008) |
| 1.2.9 | US_PM08fl | IMF projection model US (financial linkages), Carabenciov et al. (2008) |
| 1.2.10 | US_DG08 | De Graeve (2008) |
| 1.2.11 | US_CD08 | Christensen and Dib (2008) |
| 1.2.12 | US_IAC05 | Iacoviello (2005) |
| 1.2.13 | US_MR07 | Mankiw and Reis (2007) |
| 1.2.14 | US_RA07 | Rabanal (2007) |

* Currently only in the DYNARE 3 version.

Most models assume that expectations of future realizations of model variables such as for example future exchange rates, prices, interest rates, wages and income are formed in a model-consistent, rational manner. A few models assume backward-looking expectations formation, in particular the models from Rudebusch and Svensson (1999) and Orphanides (2003). Most, but not all models are linear, or linear approximations of nonlinear models. In this case the variables appear as percentage deviations from their steady state values. There are many differences in model structure, in terms of size, in terms of countries covered, or the extent of microeconomic foundations considered.

## 1.1 Small Calibrated Models

### 1.1.1 NK_RW97: Rotemberg and Woodford (1997)

The model and the estimation strategy is discussed in detail in Rotemberg and Woodford (1997). The equations of this model can be derived from the behavior of optimizing agents. The expectational IS equation and the policy rule together can be viewed as determining aggregate demand, while the New-Keynesian Phillips curve equation determines aggregate supply. The Phillips curve equation can be obtained as a log-linear approximation to the first-order condition of optimizing firms with either Calvo-style staggered price contracts (Yun, 1996) or convex costs of price adjustment (Rotemberg, 1982). The IS equation can be obtained as a log-linear approximation of the representative household's first-order equation in a model in which consumption, leisure, and real money balances are each additively separable in the utility function, and total consumption demand (private and government consumption) is equal to aggregate output.

- Aggregate Demand: Standard New Keynesian IS curve.

- Aggregate Supply: Standard New Keynesian Phillips curve.

- Shocks: A cost-push shock following an AR(1) process, the common monetary policy shock, a government spending shock representing the common fiscal policy shock.

- Calibration/Estimation: Rotemberg and Woodford (1997) match the empirical impulse response functions to a monetary policy shock in a VAR (detrended real GDP, inflation, funds rate) and the empirical variances with the variances and the theoretical impulse responses from the model to all three shocks. Quarterly U.S. data for the period 1980:Q1–1995:Q2 is used. The estimated parameters are taken from Woodford (2003) table 6.1. However, we do not have information on the calibration of the shock processes. Hence, we employ the estimation results from Adam and Billi (2006) for the NK_RW97 shock specifications.

### 1.1.2 NK_LWW03: Levin et al. (2003)

This model is used for comparison in the robustness analysis of monetary policy rules by Levin et al. (2003). Its structure is similar to the NK_RW97 model presented above, but without explicit treatment of government spending.

- Aggregate Demand: Standard New Keynesian IS curve.

- Aggregate Supply: Standard New Keynesian Phillips curve.

- Shocks: A cost-push shock, a shock to the real interest rate and the common monetary policy shock.

- Calibration/Estimation: In calibrating the model, the parameter values of Woodford (2003) adjusted for annualized variables as in Levin et al. (2003) are used.

### 1.1.3 NK_CGG99: Clarida et al. (1999), hybrid model

The model is similar to NK_RW97 but it features a hybrid Phillips curve with endogenous persistence in inflation. Also, government spending is not treated explicitly. The model and its implications for monetary policy are discussed in detail in Clarida et al. (1999) from page 1691 onwards.

- Aggregate Demand: Hybrid New Keynesian IS curve.

- Aggregate Supply: Hybrid New Keynesian Phillips curve.

- Shocks: A cost-push shock, a demand shock and the common monetary policy shock.

- Calibration/Estimation: We use the same parametrization as in in NK_RW97, however expected inflation enters the Phillips curve with a weight of 0.52 and lagged inflation with a weight of 0.48. In the IS curve the expected output gap has a weight of 0.56 and the lagged output gap has a weight of 0.44.

### 1.1.4 NK_CGG02: Clarida et al. (2002), two-country model

Clarida et al. (2002) derive a small-scale, two-country, sticky-price model to analyse optimal monetary policy. The two countries are symmetric in size, preferences and technology.

- Aggregate Demand: Households maximize their lifetime utility, where the utility function is separable in consumption and leisure, subject to an intertemporal budget constraint. They own the firms, are a monopolistically competitive supplier of labor to the intermediate firms and additionally hold their financial wealth in the form of one-period, state-contingent bonds, which can be traded both domestically and internationally.

- Aggregate Supply: Domestic production takes place in two stages. First there is a continuum of intermediate goods firms, each producing a differentiated material input under monopolistic competition using a production function that is linear in labor input and includes an exogenous technology parameter. They set nominal prices on a staggered basis à la Calvo and receive a subsidy in percent of their wage bill to achieve an undistorted steady state. Final goods producers then combine these inputs into output, which they sell to households under perfect competition. Wages are perfectly flexible. Thus, all workers will charge the same wage and work the same amount of hours. Clarida et al. (2002) introduce an exogenous time-varying elasticity of labor demand to vary the wage-mark-up over time. The system of equations is collapsed into an IS equation and a Phillips curve, which determine the output gap and inflation, conditional on the path of the nominal interest rate both for the domestic and the foreign economy.

- Foreign sector: Producer currency pricing is assumed so that the Law of one price holds for the final consumption good and the CPI based real exchange rate is unity. Together with the assumption of complete markets this ensures that the consumption levels are equal in both countries at any point in time.

- Shocks: A cost push shock and the common monetary policy shock.

- Calibration/Estimation: We take the parametrization of the small open economy model in Gali and Monacelli (2005) to calibrate the model. Gali and Monacelli (2005) calibrate the stochastic properties of the exogenous driving forces by fitting AR(1) processes to log labor productivity in Canada, which is their proxy for the domestic country, and log U.S. GDP, which they use as proxy for world output. The sample period comprises 1963:1–2002:4.

### 1.1.5 NK_MCN99cr: McCallum and Nelson (1999)

The model in McCallum and Nelson (1999) is used to monitor the performance of operational monetary policy rules. Two distinct variants of the model are used, mainly differing in the choice of the aggregate supply setup. In the first setup, aggregate supply is based on a standard Calvo-Rotemberg (NK_MCN99cr) specification of the Phillips curve where inflation is linked to expected inflation and the output gap. In the second setup of the model, the authors introduce the so-called P-bar price adjustment (NK_MCN99pb) where price changes occur in order to gradually eliminate deviations of actual from market clearing values of output.

- Aggregate Demand: Standard New Keynesian IS and LM curve.

- Aggregate Supply: Two setups: (i) Standard New Keynesian Phillips curve (NK_MCN99cr), (ii) P-bar price adjustment (NK_MCN99pb).

- Shocks: A shock to the IS curve which follows an AR(1) process, a shock to the LM curve, an investment shock, a shock on capacity output and the common monetary policy shock.

- Calibration/Estimation: The model equations are estimated individually by ordinary least squares and instrumental variable estimation for U.S. data. The sample period comprises 1955–1996.

### 1.1.6  NK_IR04: Ireland (2004)

Ireland (2004) develops a small New Keynesian model with real money balances entering both the forward-looking IS curve and the Phillips curve. The model is used to study the role of money in the U.S. business cycle.

- Aggregate Demand: A representative household maximizes expected utility, nonseparable between consumption and real money balances while separable in leisure, subject to a budget constraint. The optimizing behavior of this household leads to a forward-looking IS curve with real money balances entering the specification. This is due to the non-separability of real balances to consumption in the utility function, as real balances affect the marginal rate of intertemporal substitution.

- Aggregate Supply: A representative firm produces final goods according to a constant-returns-to-scale technology, using labor and intermediate goods as inputs. On the other hand, intermediate goods are produced under a linear technology using labor as input. The representative intermediate goods-producing firm has monopolistic power in the market, therefore acting as a price-setter. However, price setting is subject to Rotemberg quadratic adjustment costs. The optimizing behavior of this firm leads to a forward-looking Phillips curve with real money balances entering the specification.

- Shocks: An overall preference shock, a real money balances preference shock, a productivity shock and a monetary policy shock.

- Calibration/Estimation: Estimated via maximum likelihood using U.S. quarterly data over the period 1980:Q1–2001:Q3.

### 1.1.7  NK_BGG99: Bernanke et al. (1999)

Bernanke et al. (1999) introduce credit market imperfections into an otherwise standard New Keynesian model with capital and show that these financial frictions contribute to propagate and amplify the

response of key macroeconomic variables to nominal and real shocks. An agency problem arises due to asymmetries of information in borrower-lender relationships. The economy is inhabited by three types of agents, risk-averse households, risk-neutral entrepreneurs and retail firms.

- Aggregate Demand: Households gain utility from consumption, leisure and real money balances. Household optimization results in a standard dynamic IS equation. Entrepreneurs use capital and labor to produce wholesale goods that are sold to the retail sector. Each period, entrepreneurs have to accumulate capital that becomes available for production in the subsequent period. Entrepreneurs have to borrow from households via a financial intermediary to finance capital purchases. Since the financial intermediary has to pay some auditing costs to observe the idiosyncratic return to capital, an agency problem arises. The optimal contract leads to an aggregate relationship of the spread between the external finance costs and the risk-free rate and entrepreneurs' financial conditions represented by the leverage ratio.

- Aggregate Supply: Retail firms act under monopolistic competition. They buy wholesale goods produced by entrepreneurs in a competitive market and differentiate them at zero cost. Price stickiness is introduced via the Calvo framework. Bernanke et al. (1999) assume that reoptimizing firms have to set prices prior to the realization of shocks in that period, so that previous period's expectations of the output gap and future inflation enter the New Keynesian Phillips curve.

- Shocks: The model exhibits a technology shock, a demand shock and the common monetary policy shock. Since we have no information about the variances of the shock terms, we set all shock variances equal to zero.

- Calibration/Estimation: The model is calibrated at quarterly frequency.

### 1.1.8 NK_GM05: Gali and Monacelli (2005)

Gali and Monacelli (2005) develop a model of a small open economy which is part of a world economy comprised of a continuum of small open economies sharing identical preferences, technology and market structure but facing imperfectly correlated productivity shocks. With this framework, the authors analyze the macroeconomic implications of three different rule-based policy regimes for a small open economy, pointing out the trade-offs the authorities face between the stabilization of the nominal exchange rate, domestic inflation and the output gap.

- Aggregate Demand: The representative household in a small open economy seeks to optimize its utility separable between consumption and leisure subject to its budget constraint. Consumption is a composite of domestic and foreign goods, weighted by the degree of home bias

in preferences, which represents the index of country openness. The dynamic IS equation is similar to that found for a closed economy but with the degree of openness influencing the sensitivity of the output gap to interest rate changes. Furthermore, the natural interest rate depends on the expected growth of world output.

- Aggregate Supply: Differentiated goods are produced from a typical firm using a linear technology with labor as input. Firms face price stickiness a la Calvo as in the case of a closed economy. Importantly, marginal costs are increasing in the terms of trade and in world output. The degree of country openness affects the slope of the New Keynesian Phillips curve of the small open economy, thus affecting the response of inflation to variations in the output gap.

- The Foreign Sector: Purchasing Power Parity and the law of one price hold. There is prefect exchange rate pass-through. Under the assumption of complete international financial markets, an international risk sharing in the form of the uncovered interest rate parity is obtained.

- Shocks: A domestic productivity shock and a world demand shock.

- Calibration/Estimation: The model is calibrated mostly to fit some characteristics of the Canadian economy. In order to calibrate the stochastic properties of the exogenous driving forces, AR(1) processes are fitted, using quarterly, HP-filtered data over the sample period 1963:Q1–2002:Q4.

### 1.1.9 NK_GK11: Gertler and Karadi (2011)

Gertler and Karadi (2011) build a quantitative monetary DSGE model with financial intermediaries that face endogenously determined balance sheet constraints. The authors use the model to analyse unconventional monetary policy measures.

- Aggregate Demand: The representative household's utility is separable in consumption and leisure and allows for habit formation in consumption. Households postpone their consumption by holding deposits with the financial intermediaries. The amount of deposits is determined in such a way as to guarantee that the bankers' incentive constraint is satisfied. Expected-lifetime utility is maximized, choosing consumption and labor supply to the intermediate firms.

- Aggregate Supply: The financial intermediaries issue contingent claims to firms, financed by the deposits. An agency problem between the intermediaries and the depositors generates an endogenous leverage constraint with respect to the leverage ratio of the financial intermediaries. Competitive firms produce intermediate goods using labor services and capital, the latter of

which is produced by the capital producer. The retail firms have monopolistic power and re-package intermediate output. Nominal frictions are introduced in the form of Calvo sticky prices. Non-reoptimizing firms index their prices to previous periods inflation rate.

- Shocks: Capital quality shock, which affects the effective quantity of the capital stock.

- Calibration/Estimation:The financial sector parameters are chosen to satisfy a steady state interest rate spread of 100 basis points, a steady state leverage ratio of four, and an average horizon of bankers of a decade. The calibration of the conventional parameters is mostly following Christiano, Eichenbaum, and Evans (2005).

### 1.1.10 NK_CK08: Christoffel and Kuester (2008)

Christoffel and Kuester (2008) incorporate search and matching frictions à la Mortensen and Pissarides (1994) into an otherwise standard New Keynesian business cycle model.

- Aggregate Demand: There is a large number of identical families in the economy. Each family consists of unemployed and employed members with time-additive expected utility preferences and an external habit. The representative family pools the labor income of its working members, unemployment benefits of the unemployed members and financial income. The family maximizes its welfare function by choosing consumption and nominal bond holdings subject to its budget constraint.

- Aggregate Supply: There are three sectors of production in the economy. Firms in the first sector produce a homogeneous intermediate good where labor is the only production input. The production process is subject to matching frictions. Nominal wages in the labor sector are Calvo staggered. The wholesale sector demands labor as the only production input in a perfectly competitive market to produce differentiated goods using a constant-return-to-scale production technology. Subject to price-setting impediments à la Calvo, the intermediate good is sold under monopolistic competition to a final retail sector. Retailers bundle differentiated goods into a homogeneous consumption/investment basket. These goods are then sold to consumers and government.

- Shocks: Three shocks: a serially correlated shock to the risk premium that drives a wedge between the return on bonds held by the families and the interest rate set by the central bank, an AR(1) labor sector-wide technology shock process, and a government spending shock.

- Calibration/Estimation: The model is calibrated to US data from 1964:Q1 to 2006:Q3. The underlying data set used covers data on output, hours worked, total wages, wages per employee,

real hourly wages, vacancies, the civilian unemployment rate, the inflation rate and the interest rate.

### 1.1.11 NK_CKL09 and EA_CKL09: Christoffel et al. (2009)

Christoffel et al. (2009) explore the role of labor markets for monetary policy in the Euro Area in a closed-economy, single-country New Keynesian model with Mortensen and Pissarides (1994) type of matching frictions. To allow for a direct channel from wages to inflation, the model builds on the right-to-manage framework of Trigari (2006). Moreover, Christoffel et al. (2009) incorporate staggered wage-setting à la Calvo and account for job-related fixed costs as in Christoffel and Kuester (2008). The aim of the paper is to investigate to which extent a more flexible labor market would alter the business cycle behavior and the transmission of monetary policy, employing a genuine Euro Area calibration (NK_CKL09). Second, by estimating the model with Bayesian techniques (EA_CKL09) they analyze to which extent labor market shocks are important determinants of business cycle fluctuations. The results support current central bank practice to put considerable effort into monitoring Euro Area wage dynamics and treat some of the other market information as less important for monetary policy.

- Aggregate Demand: The demand as well as the supply structure follow closely the one described in Christoffel and Kuester (2008). The economy consists of a large number of identical families that comprise unemployed and employed members with time-additive expected utility preferences that exhibit an external habit. The representative family pools the labor income of its working members, unemployment benefits of the unemployed members and financial income from assets that family members hold via a mutual fund. Each household also owns representative shares of all firms in the economy. It maximizes the sum of unweighted expected utilities of its individual members, by taking consumption, saving, vacancy posting, and labor supply decisions on their behalf.

- Aggregate Supply: The economy consists of three production sectors. The labor packers use exactly one worker as input to produce a homogeneous intermediate good labeled labor good. The process of labor bargaining is governed by wage rigidities. The wholesale sector buys the labor good from the labor packers in a perfectly competitive market and produces differentiated goods using a constant-return-to-scale production technology. These goods are sold under monopolistic competition to a final retail sector at a price that is subject to impediments à la Calvo and to a partial indexation rule. Retailers bundle the differentiated goods into a homogeneous consumption/investment basket and sell it to the consumers and to the government.

- Shocks: Three labor market shocks: a shock to the costs of posting a vacancy, a shock to the

rate of separation, and a shock to the bargaining power of workers; a government spending shock; a wholesale sector cost-push shock.

- Calibration/Estimation: For the calibration exercise (NK_CKL09) a quarterly Euro Area data set from 1984:Q1 to 2006:Q3 is used. The model is also estimated with Bayesian techniques (EA_CKL09) employing output, year-on-year inflation, the nominal interest rate, wages per employee, unemployment and proxies for total hours worked and vacancies as observable variables.

### 1.1.12 NK_RW06: Ravenna and Walsh (2006)

Ravenna and Walsh (2006) build a New Keynesian model with a cost channel of monetary transmission and study optimal monetary policy.

- Aggregate Demand: The model economy consists of households, firms, the government, and financial intermediaries interacting in asset, goods, and labor markets. Households maximize their expected present discounted value of utility defined over a composite consumption good, a taste shock and leisure. The composite good consists of differentiated products produced by final goods producers. Households enter each period with cash holdings, receive their wage income and use it to make deposits at the financial intermediary. The remaining cash balances are available for the purchase of consumption goods. At the end of a period, households receive profit income from the financial intermediary and firms, and the principal and interest on their deposits at the intermediary.

- Aggregate Supply: The goods market is characterized by monopolistic competition, and the adjustment of prices follows the Calvo setting. Firms must borrow money from the financial intermediary at the gross nominal interest rate to pay for part of their wage bill.

- Shocks: A composite demand shock.

- Calibration/Estimation: The model is calibrated to the US economy.

### 1.1.13 NK_MM10: Meh and Moran (2010)

The NK_MM10 model is a medium-scale DSGE model with a banking sector where bank capital plays a crucial role in mitigating the moral hazard problem between bankers and their creditors. The model is developed to see whether or how significant the capital position of bank influences the business cycle through a bank capital channel. There are three groups of agents in the model: households, entrepreneurs, and banks.

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- Aggregate Demand: Households consume, allocate savings between currency and bank deposits, provide the differentiated labor services, choose a capital utilization rate, and buy capital goods. Entrepreneurs and bankers are risk neutral and they consume their accumulated wealth when exiting the economy. New agents with zero assets replace exiting ones. Monetary authority sets the short-term interest rate according to the Taylor rule.

- Aggregate Supply: Monopolistically competitive firms manufacture intermediate goods subject to nominal rigidities. Competitive firms produce final goods aggregating intermediate goods. Entrepreneurs produce capital goods with a technology that uses final goods as inputs and faces idiosyncratic uncertainty.

- Financial Contract: The optimal financial contract among three parties (an entrepreneur, a bank, an investor (household)) borrowed from Holmstrom and Tirole (1997) represents the financial sector in the model economy. There are two moral hazard problems presented in this framework due to the imperfect and costly monitoring technology of a bank. The certain levels of banks' net worth as well as entrepreneurial net worth are needed in order to incentivize banks and investors.

- Shocks: A technology shock, a monetary policy shock, a shock to bank capital

- Calibration/Estimation: Many of model parameters are calibrated following the previous DSGE literature such as Christiano et al. (2005). Parameters related to financial contract are calibrated such that the model's steady state meets several counterpart empirical moments.

### 1.1.14 NK_KRS12: Kannan et al. (2012)

The NK_KRS12 model is a DSGE model with housing in the spirit of Iacoviello (2005) and Iacoviello and Neri (2010) to study the role of monetary policy in mitigating the effects of house price booms. They find that a monetary policy rule with credit aggregates can help counter accelerator mechanisms that push up credit growth and house prices. They also study the effect of macroprudential polices on welfare.

- Aggregate Demand: There are two types of households, the borrowers ("impatient") and the savers ("patient"). They both derive utility from consumption, holdings of housing and leisure. The impatient households discount the future more heavily. This specification induces the impatient households to face borrowing constraints, which is consistent with standard lending criteria used in the mortgage market where the borrowing is limited to a fraction of the housing value. For both types of households, the holdings of housing are subject to housing adjustment costs.

- Aggregate Supply: There are two type of producers: Final good producers operating under perfect competition and intermediate good producers that supply their goods imperfectly. Price is set à la Calvo-type of restrictions.

- Financial Sector: Borrowers and savers can meet only through financial intermediaries, which charge a spread that depends on the net worth of borrowers. The determination of the spread follows the financial accelerator idea of Bernanke et al. (1999).

- Shocks: A housing demand shock, a financial shock and a technology shock.

- Calibration/Estimation: A mixture of calibrated and estimated parameters for the US economy. Parameters governing real and nominal rigidities are taken from Iacoviello and Neri (2010).

## 1.2 Estimated U.S. Models

### 1.2.1 US_FM95: Fuhrer and Moore (1995a)

The model is described in Fuhrer and Moore (1995a) and Fuhrer and Moore (1995b). We employ the parametrization used in Levin et al. (2003). Fuhrer and Moore introduce a new wage contracting model where agents care about relative real wages in order to match the strong inflation persistence observed in U.S. data.

- Aggregate Demand: The US_FM95 model represents aggregate spending by a single reduced-form equation corresponding to an IS curve. The current output gap depends on its lagged values over the past two quarters and the lagged value of the long-term real interest rate, which is defined as a weighted average of ex-ante short-term real interest rates with a duration of 40 quarters.

- Aggregate Supply: The aggregate price level is a constant mark-up (normalized to one) over the aggregate wage rate. The aggregate wage dynamics are determined by overlapping wage contracts. In particular, the aggregate wage is defined to be the weighted average of current and three lagged values of the contract wage rate. The real contract wage, that is the contract wage deflated by the aggregate wage, is determined as a weighted average of expected real contract wages, adjusted for the expected average output gap over the life of the contract. This specification yields a hybrid Phillips curve that depends additionally on current and past demand and expectations about future demand.

- Shocks: An ad hoc supply shock and the common monetary policy shock.

- Calibration/Estimation: Full-information maximum likelihood estimation on U.S. data from 1966–1994.

- Replication: We replicated the impulse response functions for annualized quarterly inflation and the output gap to a 100 basis point innovation to the federal funds rate in Figure 2 of Levin et al. (2003).

### 1.2.2 US_OW98: FRB Monetary Studies, Orphanides and Wieland (1998)

This is a small open economy model described in Orphanides and Wieland (1998) and used to investigate the consequences of the zero bound on nominal interest rates.

- Aggregate Demand: The US_OW98 model disaggregates real spending into five components: private consumption, fixed investment, inventory investment, net exports, and government purchases. The aggregate demand components exhibit partial adjustment to their respective equilibrium levels, measured as shares of potential GDP. Partial adjustments reflect habit persistence. Equilibrium consumption and fixed investment are functions of permanent income (discounted at 10 percent) and depend on the long-term real rate. The long-term nominal interest rate is an average of expected future nominal short-term rates. The long-term real rate is determined by the Fisher equation. Inventory investment depends on three lags of output. Government spending is an AR(1) process.

- Aggregate Supply: The structure is similar to the US_FM95 model. In US_FM95 and US_OW98, the aggregate price level is a constant mark-up over the aggregate wage rate.

- Foreign Sector: Net exports depend on domestic output, world output, the real exchange rate and lagged net exports. The exchange rate is determined by an UIP condition.

- Shocks: Five demand shocks including the common fiscal policy shock in the government spending equation, an ad hoc cost push shock to the nominal wage contracts and the common monetary policy shock.

- Calibration/Estimation: The model is estimated for the period 1980–1996 using U.S. data. The demand block is estimated via IV-estimation equation-by-equation. For the supply side simulation-based indirect inference methods are used.

- Replication: We replicated the impulse response functions for annualized quarterly inflation and the output gap to a 100 basis point innovation to the federal funds rate in Figure 2 of Levin et al. (2003).

### 1.2.3 US_FRB03: FRB-US model

The FRB model is a large-scale model of the U.S. economy with a relatively detailed representation of the supply side of the economy. The version US_FRB03 was linearized by Levin et al. (2003).

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- Aggregate Demand: Real spending is divided into five components: private consumption, fixed investment, inventory investment, net exports and government purchases. The broad components are disaggregated further i.e. spending on fixed investment is separated into equipment, nonresidential structures and residential construction. Government spending is divided into six sub-components, each of which follows a simple reduced-form equation that includes a counter-cyclical term. The specification of most non-trade private spending equations follows the generalized adjustment cost model due to Tinsley (1993).

- Aggregate Supply: Potential output is modeled as a function of the labor force, crude energy use, and a composite capital stock, using a three-factor Cobb-Douglas production technology. The equilibrium output price is a mark-up over a weighted average of the productivity-adjusted wage rate and the domestic energy price. The specification of the wage and price dynamics follows the generalized adjustment cost framework used in the aggregate demand block. Wage inflation depends on lagged wage inflation over the previous three quarters, as well as expected future growth in prices and productivity, and a weighted average of expected future unemployment rates. Price inflation depends on its own lagged values over the past two quarters, as well as expected future changes in equilibrium prices and expected future unemployment rates. In addition, both wages and prices error-correct to their respective equilibrium levels. A vertical long-run Phillips curve is imposed in estimation. The model contains a detailed accounting of various categories of income, taxes, and stocks, an explicit treatment of labor markets, and endogenous determination of potential output. Long-run equilibrium in the model is of the stock-flow type; the income tax rate and real exchange rate risk premium adjust over time to bring government and foreign debt-to-GDP ratios back to specified (constant) levels.

- Foreign sector: The full model includes detailed treatments of foreign variables. Twelve sectors (countries or regions) are modeled, which encompass the entire global economy. In the model used in the Modelbase the full set of equations describing the foreign countries is replaced by two reduced form equations for foreign output and prices, to reduce computational cost.

- Shocks: The model exhibits a large range of shocks to which we add the common monetary policy shock and a fiscal shock that equally affects all three components of federal government spending such that a unit fiscal policy shock affects output by 1 percent.

- Replication: We replicated the impulse response functions for annualized quarterly inflation and the output gap to a 100 basis point innovation to the federal funds rate in Figure 2 of Levin et al. (2003).

### 1.2.4 US_SW07: Smets and Wouters (2007)

Smets and Wouters (2007) develop a medium-scale closed economy DSGE-Model and estimate it for the U.S. with Bayesian techniques. The model features a deterministic growth rate driven by labor-augmenting technological progress, so that the data do not need to be detrended before estimation.

- Aggregate Demand: Households maximize their lifetime utility, where the utility function is nonseparable in consumption and leisure, subject to an intertemporal budget constraint. Smets and Wouters (2007) include external habit formation to make the consumption response in the model more persistent. Households own firms, rent capital services to firms and decide how much capital to accumulate given certain capital adjustment costs. They additionally hold their financial wealth in the form of one-period, state-contingent bonds. Exogenous spending follows a first-order autoregressive process with an iid-normal error term and is also affected by the productivity shock.

- Aggregate Supply: The final goods, which are produced under perfect competition, are used for consumption and investment by the households and by the government. The final goods producer maximizes profits subject to a Kimball (1995) aggregator of intermediate goods, which introduces monopolistic competition in the market for intermediate goods and features a non constant elasticity of substitution between different intermediate goods, which depends on their relative price. A continuum of intermediate firms produce differentiated goods using a production function with Cobb-Douglas technology and fixed costs and sell these goods to the final-good sector. They decide on labor and capital inputs, and set prices according to the Calvo model. Labor is differentiated by a union using the Kimball aggregator, too, so that there is some monopoly power over wages, which results in an explicit wage equation. Labor packers buy the labor from the unions and resell it to the intermediate goods producer in a perfectly competitive environment. Sticky wages à la Calvo are additionally assumed. The Calvo model in both wage and price setting is augmented by the assumption that prices that can not be freely set, are partially indexed to past inflation rates.

- Shocks: A total factor productivity shock, a risk premium shock, an investment-specific technology shock, a wage and a price mark-up shock and two policy shocks: the common fiscal policy shock entering the government spending equation and the common monetary policy shock.

- Calibration/Estimation: The model is estimated for the U.S. with Bayesian techniques for the period 1966:1–2004:4 using seven key macroeconomic variables: real GDP, consumption, investment, the GDP deflator, real wages, employment and the nominal short-term interest rate.

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- Replication: We replicated the impulse response functions to a positive one standard deviation monetary policy shock in Figure 6 of Smets and Wouters (2007). The variables include output, hours, quarterly inflation and the interest rate.

### 1.2.5 US_ACEL: CEE/ACEL by Altig et al. (2005)

The purpose of the authors is to build a model with optimizing agents that can account for the observed inertia in inflation and persistence in output (Christiano et al., 2005). In the version by Altig et al. (2005) firm-specific capital is introduced to get a Calvo parameter consistent with the microeconomic evidence of price re-optimizations on average once every 1.5 quarters. The Modelbase contains four different specifications of the CEE/ACEL model, labeled by m = monetary policy shock, t = technology shock and sw = SW assumptions, i.e. no cost channel and no timing constraints as in Taylor and Wieland (2009).

- Aggregate Demand: The representative household's utility is separable in consumption and leisure and allows for habit formation in consumption. Expected-lifetime utility is maximized, choosing optimal consumption and investment, as well as the amount of capital services supplied to the intermediate firms (homogenous capital model) and portfolio decisions. Investment adjustment costs are introduced. Furthermore, the household determines the wage rate for its monopolistically supplied differentiated labor services whenever it receives a Calvo signal. In those periods, in which it does not receive a signal, the wage is increased by the lagged inflation rate augmented by the steady state growth rate of a combination of the neutral technology shock and the shock to capital embodied technology. Labor services are sold to a competitive firm that aggregates the differentiated services and supplies the resulting aggregated labor to the intermediate goods firms.
In the firm-specific capital model, the capital stock is owned by the firms.

- Aggregate Supply: The final consumption good is produced under perfect competition using differentiated intermediate goods as inputs. Each intermediate good is produced by a monopolist employing capital (which is firm-specific in one variant of the model) and labor services. The production function is augmented by a technology shock. Capital is pre-determined. Hence, if capital is firm-specific, marginal costs depend positively on the firm's output level. Furthermore, it is assumed that the monopolistic firms have to pay the wage bill in advance which requires borrowing from a financial intermediary. Nominal frictions are introduced in the form of Calvo sticky prices. Non-reoptimizing firms index their prices to previous periods inflation.

- Shocks: The common monetary policy shock, a neutral technology shock and an investment

specific technology shock.

- Calibration/Estimation: The model has been estimated by matching the empirical impulse response functions to a monetary policy shock in a ten variable VAR with the theoretical impulse responses from the model to a monetary policy shock. Quarterly U.S. data from 1959:Q2–2001:Q4 is used.

- Replication: Using the US_ACELm model we replicated the impulse response functions for annualized quarterly inflation, output, annualized quarterly money growth and the annualized quarterly interest rate to a one standard deviation monetary policy shock.

### 1.2.6 US_NFED08: Edge et al. (2008)

The US_NFED08 is a version of the medium-scale closed economy model as in Edge et al. (2008) used for estimation in Wieland and Wolters (2011). In this model, specifications regarding production and expenditures are motivated by the long-run and cyclical properties observed in the U.S. data. Production sectors in Edge et al. (2008) differ in the rate of the technological growth while expenditures are categorized as business spending and household spending. The model as in Edge et al. (2008) is used at the Federal Reserve Board as a complimentary model for policy analysis along FRB/US and other small models.

- Aggregate Demand: Households derive utility from four sources: purchases of the consumer non-durable goods and non-housing services, the flow of services from their rental of consumer-durable capital, the flow of services from their rental of residential capital, and leisure. Internal habit persistence is present in all three components of consumption. Households supply differentiated labor to two production sectors. They face quadratic wage adjustment costs when setting wages. Furthermore, they face additional costs when changing the mix of labor supplied to each of the production sectors. The consumption components and the disutility from labor are subject to specific AR(1) aggregate shocks.

- Aggregate Supply: There are two production sectors in this model, differing on what type of final goods and services they are producing. One of the sectors (comprised of businesses and institutions) produces slow-growing "consumption" goods and services while the other sector (only businesses) produces fast-growing "capital" goods. Final goods are an aggregate (using Dixit-Stiglitz technology) of sector-specific differentiated intermediate goods. The latter are produced by intermediate goods producers by combining aggregated labor with utilized non-residential capital in a Cobb-Douglas production function. Labor input for each sector is aggregated using Dixit-Stiglitz technology. The level of productivity in the Cobb-Douglas

production function has a common and a sector specific factor. Based on historical data for the U.S., faster technological progress for capital-specific goods is assumed. Price setting decisions (under price adjustment costs) of intermediate goods firms deliver a New Keynesian Phillips curve with backward and forward-looking terms. Capital owners choose how much residential capital, non-residential capital and consumer durables will be invested in each production sector. These decisions are subject to investment and capital adjustment costs. In addition, the decision for the utilization of non-residential capital is subject to utilization costs.

- Shocks: A shock to preferences over durables, a shock to preferences over non-durables and non-housing services, a shock to preferences over residential capital, a shock to preferences over leisure, a shock to efficiency of investment in non-residential capital, a shock to efficiency of investment in residential capital, a shock to efficiency of investment in consumer durable goods, a mark-up shock, a shock to the elasticity of substitution between the differentiated intermediate goods inputs, an economy-wide productivity shock, a sector specific productivity shock, an intermediate labor substitution shock, a labor substitution shock, a monetary policy shock.

- Calibration/Estimation: Estimated with Bayesian methods, using quarterly U.S. data for the period 1984:Q1–2004:Q4.

### 1.2.7  US_RS99: Rudebusch and Svensson (1999)

Rudebusch and Svensson (1999) set up a simple linear model of the U.S. economy which is used to examine the performance of different policy rules taking into account an inflation targeting monetary policy regime. The model equations are backward looking.

- Aggregate Demand: An IS curve relates the output gap to its own lags and the difference between the average federal funds rate and the average inflation rate over the current and three preceding quarters.

- Aggregate Supply: Phillips curve of the accelerationist form.

- Shocks: A cost-push shock, a demand shock and the common monetary policy shock.

- Calibration/Estimation: The model equations are estimated individually by ordinary least squares for U.S. data. The sample period comprises 1961:1-1996:2.

### 1.2.8  US_OR03:Orphanides (2003)

Orphanides (2003) conducts a counterfactual analysis based on the historical experience of the United States economy to give an example of the difficulties in identifying robust policy strategies. The

counterfactual analysis gives an insight how inflation and the output gap would have evolved from the 1960s to the 1990s if the Federal Reserve had actually followed two distinct activist monetary policy rules taking into account the difference between realistic and non-realistic assumptions on the availability of information on the output gap.

- Aggregate demand: The demand side of the structural model of the economy is represented by an IS equation which relates the output gap to its own lags, lags of inflation and the federal funds rate.

- Aggregate supply: The supply side is represented by an accelerationist form of the Philips curve with an adaptive representation of inflation expectations.

- Shocks: A cost-push shock, a demand shock and the common monetary policy shock.

- Calibration/estimation: The Aggregate Demand and Aggregate Supply equation are estimated in a setup that can be interpreted as a mildly restricted structural vector autoregression (VAR) of up to four lags estimated using quarterly data from 1960 to 1993.

### 1.2.9   US_PM08 and US_PM08fl: Carabenciov et al. (2008)

Carabenciov et al. (2008) design and estimate two versions of a small projection model for the U.S. economy: one with financial real linkages, US_PM08fl and one without, US_PM08. These models are part of the IMF research agenda in developing a Small Quarterly Global Projection Model (GMP) which consists of many small country models integrated into a single global market. Both versions of the model consist of few behavioral equations, focusing on the joint determination of output, unemployment, inflation and the federal funds rate.

- Aggregate Demand: The behavioral IS curve relates the output gap to its past and expected future value, to the past value of the short interest rate gap and to a disturbance term. This specification allows for inertia and persistent effects of the shocks. In the model with financial linkages, US_PM08fl, the output gap is a function of a financial variable as well, constructed using information from FED's quarterly Senior Loan Officer Opinion Survey on Bank Lending Practices. This variable enters in the form of a shock and it is supposed to reflect the bank lending conditions (tightening or loosening). Thus, if lending conditions are tighter than anticipated, the effect will be a lower output gap and a weaker economy.

- Aggregate Supply: In the Phillips curve equation, inflation is linked to its past and expected future values, to the lagged output gap and a disturbance term. This representation reflects the way agents set their prices: a share of them uses indexation to past inflation and others

are forward looking. These expectations are based on model-consistent estimates of future inflation.

- Shocks: A shock to the level and the growth rate of potential output, a shock to the level and the growth rate of the equilibrium rate of unemployment, a shock to the equilibrium real interest rate. In the model with financial linkages, US_PM08fl, a financial shock is introduced in addition and cross correlations of the error terms between certain shocks are allowed.

- Calibration/Estimation: Both models are estimated with Bayesian techniques, using U.S. quarterly data over the period 1994:Q1–2008:Q1.

### 1.2.10  US_DG08: De Graeve (2008)

De Graeve (2008) uses a medium-scale New Keynesian model like in Smets and Wouters (2007) enriched with financial frictions as in Bernanke et al. (1999) to estimate and explore the role of the external finance premium in propagating shocks for the U.S. economy. Conditional on certain shocks, he finds that a framework with financial frictions and investment adjustment costs may give rise to a financial "decelerator".

- Aggregate Demand: As in Smets and Wouters (2007), households maximize their lifetime utility function, non-separable in consumption and leisure, subject to an intertemporal budget constraint. Preferences for consumption are subject to habit persistence. They own firms, hold financial wealth in the form of one-period, state-contingent bonds and supply labor monopolistically. Wage stickiness is introduced via the Calvo framework.

- Aggregate Supply: Apart from the intermediate and final goods firms as in Smets and Wouters (2007), a financial intermediary, capital goods producers and entrepreneurs are introduced in the model to match the structure as in Bernanke et al. (1999) and Christiano, Motto, and Rostagno (2003). Intermediate goods firms face price rigidity à la Calvo while capital good producers face convex investment adjustment costs. On the other side, the presence of entrepreneurs and the financial intermediary brings financial frictions into play. Entrepreneurs borrow from financial intermediaries to buy capital (from capital producers), decide on capital utilization, rent capital services to intermediate goods firms and sell non-depreciated capital back to capital producers. However, after the purchase of the capital stock, entrepreneurs are hit by an idiosyncratic shock, observable only by them. This leads to the costly state verification framework a la Bernanke et al. (1999), giving raise to extra costs, above the risk-free rate. The optimal contract between entrepreneurs and the financial intermediary leads to an aggregate relationship of the spread between the external finance costs and the risk-free rate and entrepreneurs' financial conditions represented by the leverage ratio.

- Shocks: A preference shock, a labor supply shock, a total factor productivity shock, an investment technology shock, a government spending shock, an inflation target shock, a monetary policy shock, a wage and price mark-up shock.

- Calibration/Estimation: The model is estimated using Bayesian methods on quarterly U.S. data for the period 1954:Q1–2004:Q4.

### 1.2.11   US_CD08: Christensen and Dib (2008)

Christensen and Dib (2008) develop and estimate a DSGE model characterized by price stickiness, capital adjustment costs and financial frictions with the aim of evaluating the importance of the financial accelerator in the amplification and propagation of the effects of the transitory shocks to the U.S. economy. US_CD08 is a closed economy model like in Ireland (2003) enriched with financial frictions as in Bernanke et al. (1999). The model is estimated in two versions, with and without the financial accelerator mechanism.

- Aggregate Demand: The representative household derives utility from consumption, real money balances and leisure. Consumption and real balances are subject to a preference shock and a money demand shock, respectively. The household keeps deposits at the financial intermediary, supplies labor to the entrepreneurs and earns dividends from retailer firms.

- Aggregate Supply: The production sector is comprised of entrepreneurs, capital producers and retailers. The set up introducing the financial frictions is similar to Bernanke et al. (1999), apart from the fact that the debt contracts in Christensen and Dib (2008) are written in terms of the nominal interest rate. This specification allows for debt inflation effects, as unanticipated changes in inflation will affect the real cost of debt payment and the entrepreneurial net worth. Entrepreneurs borrow from financial intermediaries to buy capital from capital producers and produce intermediate goods. Due to asymmetric information between the entrepreneurs and financial intermediaries, the demand for capital is dependent on the entrepreneurs' financial conditions. Capital producers combine efficient investment goods and existing capital to produce new capital, subject to capital adjustment costs, which slow down the response of investment to different shocks. On the other side, retailers buy wholesale goods from entrepreneurs, differentiate them at no cost and sell them in a monopolistic competitive market, subject to price stickiness as in Calvo (1983) and Yun (1996).

- Shocks: A preference shock, a money demand shock, a technology shock, an investment shock and a monetary policy shock.

- Calibration/Estimation: The model is estimated using a maximum-likelihood procedure with Kalman filter on quarterly U.S. data for the period 1979:Q3–2004:Q3.

### 1.2.12 US_IAC05: Iacoviello (2005)

Iacoviello (2005) develops a New Keynesian model with nominal and financial frictions, where debt contracts are written in nominal terms and some agents face collateral constraints tied to housing values. This gives rise to an accelerator effect for demand shocks and a decelerator effect for supply shocks. The model can match the response of the aggregate demand to housing price shocks and the hump-shaped dynamics of output to inflation surprises, observed from U.S. data.

- Aggregate Demand: There are two types of households, the "patient" and the "impatient" ones. They both derive utility from consumption, holdings of housing, real money balances and leisure. However they discount the future differently, with the impatient household discounting the future more heavily. This specification induces the impatient household to face borrowing constraints, consistent with standard lending criteria used in the mortgage market where the borrowing is limited to a fraction of the housing value. For both types of households, the holding of housing is subject to housing adjustment costs.

- Aggregate Supply: Entrepreneurs produce a homogeneous intermediate good using a Cobb-Douglas technology with labor from both types of households, capital and real estate as inputs. Housing and variable capital are subject to adjustment costs. Following Kiyotaki and Moore (1997), a limit on the obligation of the entrepreneurs is assumed. Entrepreneurs discount the future more heavily than the patient households. Both assumptions assure that the borrowing constraint is binding for entrepreneurs. In addition there are retailers who buy the intermediate goods from the entrepreneur, differentiate them at no cost and sell them at a price that can be re-optimized every period only with a certain probability. The optimization problem of the retailers yields a forward-looking Phillips curve.

- Shocks: A housing preference shock, an inflation shock, a technology shock and a monetary policy shock.

- Calibration/Estimation: A mixture of calibrated and estimated parameters. Estimation of parameters is done by minimizing a measure of the distance between the VAR impulse responses and model responses, using quarterly U.S. data for the period 1974:Q1–2003:Q2.

### 1.2.13 US_MR07: Mankiw and Reis (2007)

Mankiw and Reis (2007) develop a general equilibrium model where rigidities come from the fact that agents are inattentive and do not update information regularly when setting prices, wages and

deciding on consumption. US_MR07 is a model with information stickiness. Estimation of the model using U.S. data confirms the presence of such rigidities, especially for consumers and workers.

- Aggregate Demand: Infinitely lived households are of two types: consumers and workers. Their utility function is additively separable in consumption and leisure. They are able to save and borrow by trading bonds between themselves. Workers choose how much to work and what wage to charge for the particular variety of labor over which they hold a monopoly. Both consumers and workers take decisions but only a fraction of them, randomly drawn from their respective population, obtain new information and can re-optimize their actions. If they obtain new information, they revise their plans for future consumption and labor supply, respectively. Both, the aggregate demand (IS equation) and the equation of wages, depend on the sum of past expectations of current economic conditions, reflecting the fact that households have different sets of information. The stickier the information is (low share of informed households), the smaller the impact of shocks on spending and wages, since fewer consumers and workers are aware of them. The natural (long-run) equilibrium corresponds to a situation where all agents are perfectly informed.

- Aggregate Supply: Firms produce output using labor and sell their differentiated goods in a monopolistic competitive market. Firms are constrained in information gathering in the same fashion as households. Each period, a fraction of firms, randomly drawn from the population, obtains new information and recalculates the optimal price. The optimizing process of the firms leads to a Phillips curve equation where the price level is determined as a sum of past expectations of current economic conditions (prices, output, marginal costs, technology shocks). The summation captures the fact that firms have different sets of information. Shocks to the variables in the Phillips curve equation will have gradual effects as some firms remain unaware of these shocks and only react to them once they update their information set.

- Shocks: A mark-up good shock, a mark-up labor shock, a government shock, a technology shock and a monetary policy shock.

- Calibration/Estimation: Estimated with maximum likelihood and Bayesian methods, using quarterly U.S. data for the period 1954:Q3–2006:Q1.

### 1.2.14 US_RA07: Rabanal (2007)

Rabanal (2007) incorporates a cost channel of monetary transmission into an otherwise standard medium-scale New Keynesian DSGE model by assuming that a fraction of firms need to borrow money to pay their wage bill prior to their sales receipts. The model is estimated on US data in order to analyze whether the cost channel empirically accounts for the so-called price puzzle.

- Aggregate Demand: Households obtain utility from consuming the final good and disutility from supplying labor, they own intermediate firms, lend capital services to firms and make investment and capital utilization decisions. Moreover, their utility function displays external habit formation. Capital is predetermined at the beginning of a period, but households can adjust its utilization rate subject to adjustment costs. Financial markets are assumed to be complete.

- Aggregate Supply: Intermediate good producers combine labor and capital services to produce their goods while taking the capital utilization rate decision of households as given. A fraction of intermediate good producers have to pay their wage bill every period before they sell their product. These firms borrow at the riskless nominal interest rate. Goods and labor markets are characterized by monopolistic competition. Prices and wages are set in a staggered way, following the formalism of Calvo (1983). Indexation to last period's average inflation rate is assumed for firms and households whenever they are not allowed to reoptimize. A continuum of final good producers operating under perfect competition uses intermediate goods for the production of final goods.

- Shocks: Four orthogonal structural shocks are introduced in the model. The government spending and technology shocks follow an AR(1) process. The monetary and the price markup shock are assumed to be iid processes.

- Calibration/Estimation: The model is estimated using Bayesian techniques on quarterly US data. The data set used comprises four key macroeconomic variables: real output, real wage, inflation rate and the nominal interest rate over the period 1959:Q1–2004:Q4.

### 1.2.15 US_CCTW10: Cogan et al. (2010)

Cogan et al. (2010) examine the effect of fiscal policy stimulus using the Smets-Wouters model of the US economy (US_SW07). They extend Smets and Wouters (2007) by introducing to the model rule-of-thumb consumers who spend all their disposable income. As the Ricardian equivalence property does not hold due to the presence of rule-of-thumb consumers, a fiscal policy rule is also included for determining a particular path for taxes.

- Aggregate Demand: There are two types of consumers. One is rule-of-thumb consumers and the other is forward-looking consumers identical to a representative household in Smets and Wouters (2007). The rest of model is the same as in US_SW07.

- Aggregate Supply: As in US_SW07.

- Shocks: As in US_SW07.

- Calibration/Estimation: The model is reestimated via Bayesian inference method with the same data set on US macroeconomic aggregates as in Smets and Wouters (2007).

### 1.2.16 US_IR11: Ireland (2011)

Ireland (2011) estimates a New Keynesian model for the US economy in order to compare the Great Recession of 2007-09 with its two immediate predecessors, the milder recessions of 1990-91 and 2001.

- Aggregate Demand: The utility function of the representative household is additively separable in consumption, real money balances and hours worked, and features habit formation in consumption. The household enters each period with money and bonds. At the beginning of each period, it receives a lump-sum nominal transfer from the central bank. Moreover, the household decides about the purchase of new bonds, the supply of labor and the consumption of finished goods. At the end of each period, the household receives nominal dividend payments resulting from the ownership of intermediate-goods-producing firms.

- Aggregate Supply: During each period, the representative intermediate-goods-producing firm hires labor to manufacture intermediate goods according to a constant-return-to-scale technology. The representative intermediate-goods-producing firm has monopolistic power, acting as a price-setter. However, price setting is subject to Rotemberg quadratic adjustment costs. The intermediate goods are then used by the finished-goods-producing firms to manufacture final goods under perfect competition.

- Shocks: An AR(1) preference shock, a cost-push shock in form of a shock to the price mark up, a technology shock that follows a random walk with drift and a monetary policy shock.

- Calibration/Estimation: The model is estimated via maximum likelihood using U.S. quarterly data on output growth, the inflation rate and the short-term nominal interest rate over the period 1930:Q1–2009:Q4.

### 1.2.17 US_IN10: Iacoviello and Neri (2010)

The US_IN10 model is based on various dynamic equilibrium models with neoclassical core and real and nominal rigidities (e.g. Smets and Wouters (2007) model). The main goal of this model is to explain the development of the price and the quantity side of the housing market and to examine the spillovers from the housing market to the rest of the economy. The model features a multi-sector structure with housing and non-housing goods, financial frictions in the household sector (introduced through a collateral constraint imposed on a fraction of households), and rich set of shocks which

take the model to the data.

- Aggregate demand: There are two types of households according to their discount factors: patient (lenders) and impatient (borrowers). A representative household within each group obtain utility from consumption and housing and disutility from supplying labor in an additively-separable way. Habit formation and balanced growth in consumption are considered. Imperfect labor mobility is introduced across sectors. Patient households accumulate housing and capital, make loans to impatient households, rent capital and land to firms, and choose the capital utilization rate. Impatient households work, consume, accumulate housing and borrow against the value of their housing. Impatient households accumulate housing and borrow the maximum possible amount against its collateral value in equilibrium.

- Aggregate Supply: Wholesale firms consists of two production units. Housing sector produces new houses (using capital, labour, land and intermediate goods). Non-housing sector produces consumption goods, investment goods and intermediate goods (using capital and labour). It is allowed for price rigidities in the consumption sector and for wage rigidities in both the consumption and housing sectors, but there are no price rigidities in the housing market.

- Shocks: An intertemporal preference shock, a labor supply shock, a housing preference shock, a cost-push shock, a monetary policy shock, a shock on the central bank's inflation target, sectoral productivity shocks (housing, consumption and non-residential sector)

- Calibration/Estimation: The model is estimated with Bayesian methods using ten US observables over the period 1965:Q1 to 2006:QIV.

### 1.2.18 US_CMR10, US_GMR10fa: Christiano et al. (2010)

, The US_GMR10 model combines a standard DSGE model like Smets and Wouters (2003) and Smets and Wouters (2007) with a detailed financial sector based on agency problem borrowing from Bernanke et al. (1999) to investigate the role of financial factors in business cycles. Several mechanism are imbedded into the baseline model due to several apparatus for financial frictions: the financial accelerator channel, the Fisher deflation channel and the bank funding channel. The economy consists of households, intermediate-good producing firms, final-goods producing firms, capital producers, entrepreneurs, bank and government. The US_GMR10fa model considers the financial accelerator channel shutting down the bank funding channel, namely ignoring the bank's supply of liquidity and household's demand for money.

- Aggregate Demand: Households obtain utility from having consumption and liquidity services and disutility from supplying labor services and adjusting real currency holdings. Household provide labor supply labor under monopolistic competition and make a portfolio decision over high powered money, bank deposits, short-term marketable securities and other financial securities.

- Aggregate Supply: Monopolistically competitive intermediate-good producing firms maximize profit using labor and capital (rented from entrepreneurs) subject to a Calvo price setting. They have to pay for working capital in advance of production. Perfectly competitive final-good producing firms aggregate a variety of intermediate goods. The final goods are then converted into consumption, investment and government goods. Capital producers combine investment goods with used capital purchased from entrepreneurs to produce new capital facing the convex investment cost function. Entrepreneurs own the stock of physical capital, buy new capital using their own wealth as well as bank loans, provide capital services while choosing the capital utilization rate. Government spending is modeled as a certain fraction of final good and are financed by lump-sum taxes levied to households.

- Financial System: Since a shock on entrepreneurial investments is idiosyncratic and privately-observable, it incurs the monitoring cost to banks.

- Shocks: The model include 16 shocks: a banking technology shock, a bank reserve demand shock, a term premium shock, a investment specific shock, a money demand shock, a government consumption shock, a persistent productivity shock, a transitory productivity shock, a financial wealth shock, a risk shock, a consumption preference shock, a shock on marginal efficiency of investment, an oil price shock, a price mark-up shock and an inflation target shock. All shocks are assumed to follow AR(1) process but an inflation target shock and a monetary policy shock which are treated as an i.i.d process.

- Calibration/Estimation: The model is estimated by standard Bayesian methods using quarterly data from 1985Q1 to 2008Q2 for the Euro Area (EA) and for the United States (US). In the baseline estimation 16 variables are used with consideration of a measurement error: GDP, Consumption, Investment, GDP deflator, real wages, hours worked, the relative price of investment, the relative price of oil, the short-term interest rate, the stock market, a measure of the external finance premium, real credit, two definitions of real money growth, bank reserves and the term spread.

### 1.2.19   US_VMDno, US_VMDop: Verona et al. (2013)

The US_VMD model is an extended model of Christiano et al. (2010) with a shadow banking system to account for the pattern of financial and economic boom-bust. Two versions of the model are calibrated based on the bond spread over the long run and during the 2000s' boom: the model for normal times (US_VMDno model) and the model for times of over-optimism (US_VMDop model).

- Aggregate Demand: As in US_CMR10

- Aggregate Supply: As in US_CMR10

- Financial System: It consists of loan market (traditional banking system) and bond market (shadow banking system). The loan market is modeled as a risky debt contract between the entrepreneurs and perfectly-competitive retail banks under monitoring cost in the form of costly state verification as Bernanke et al. (1999). Retail banks can diversify the idiosyncratic risk of many entrepreneurs and thus can generate a safe return on households' deposit. In the bond market, there are a continuum of safer entrepreneurs who are assumed not to default and investment banks who has some monopolistic power. The coupon rate of bonds issued is determined as a time-varying markup over the risk-free interest rate, which is a function of the elasticity of the demand for funds in the bond market. The elasticity of the demand in times of over-optimism is calibrated to be more elastic than one in normal times.

- Shocks: A monetary policy shock

- Calibration/Estimation: The model is calibrated for the U.S. economy. The parameters related to the bond market and entrepreneurs who rely on bond finance are calibrated to match empirical statistics to their counterpart of the model. The values of the remaining parameters are taken from other studies, especially from Christiano et al. (2010).

## 1.3   Estimated Euro Area Models

### 1.3.1   EA_CW05: Coenen and Wieland (2005)

Coenen and Wieland (2005) develop a small-scale macroeconomic model for various staggered pricing schemes. We use a version with the nominal contract specification of Taylor (1980), labeled EA_CW05ta, and a version with the relative real wage contract specification of Fuhrer and Moore (1995a), labeled EA_CW05fm.

- Aggregate Demand: The aggregate demand equation is backward looking: two lags of aggregate demand (should account for habit persistence in consumption, adjustment costs and

accelerator effects in investment) and one lag of the long-term interest rate (allows for a transmission lag of monetary policy). The long-term nominal interest rate is an average of expected future nominal short-term rates. The long-term real rate is determined by the Fisher equation.

- Aggregate Supply: As in US_FM95 and US_OW98.

- Shocks: A demand shock, a contract wage shock and the common monetary policy shock.

- Calibration/Estimation: The model has been estimated on data from the ECB Area Wide Model data set from 1974:1–1998:4. The contract wage specifications have been estimated by a limited information indirect inference technique while the IS equation has been estimated by means of the GMM.

### 1.3.2   EA_AWM05: Area Wide model linearized by Dieppe, Kuester and McAdam (2005)

The model is described in Fagan, Henry, and Mestre (2005). It was one of the first models to treat the Euro area as a single economy. In the Modelbase we use the linearized version from Dieppe, Kuester and McAdam (2005) that is also used in Kuester and Wieland (2005). The EA_AWM05 is an open economy model of the Euro area. Expectation formation is largely backward-looking. Activity is demand-determined in the short-run but supply-determined in the long-run with employment having converged to a level consistent with the exogenously given level of equilibrium unemployment. Stock-flow adjustments are accounted for, e.g., the inclusion of a wealth term in consumption.

- Aggregate Demand: Demand is disaggregated into private consumption, government consumption, investment, variation of inventories, exports, and imports. The term structure (12-year bond) is forward-looking. Private consumption is specified as a function of households' real disposable income and wealth, where the latter consists of net foreign assets, public debt and the capital stock. The change in the log of the investment/output ratio depends on the real interest rate, the real GDP/capital stock ratio and the lagged investment/output ratio. The authors stress that this investment equation represents the key channel through which interest rates affect aggregate demand. Government consumption is treated as exogenous.

- Aggregate Supply: Output follows a whole economy production function. Short-run employment dynamics are driven by output growth and real wages. The deflator for real GDP at factor costs, which according to Fagan et al. (2005) is the key price index of the model, is a function of unit labor costs, import prices, the output gap and inflation expectations. The growth rate of wages depends on consumer price inflation, productivity and the unemployment gap, defined as the deviation of the current unemployment rate from the NAIRU.

- Foreign sector: Besides extra-area flows, exports and imports also include intra-area flows. World GDP and world GDP deflator are treated as exogenous variables. The exchange rate is a forward-looking variable determined by uncovered interest rate parity.

- Shocks: Employment shock, factor cost-push shock, private consumption cost-push shock, gross investment cost-push shock, gross investment shock, exports cost-push shock, imports cost-push shock, private consumption shock, term structure shock, common fiscal policy shock and common monetary policy shock.

- Calibration/Estimation: Estimation on Euro area data equation by equation from 1970:1–1997:4, whereas the estimation period of some equations starts later, but not later than 1980:1.

### 1.3.3 EA_SW03: Smets and Wouters (2003)

The EA_SW03 model of Smets and Wouters (2003) is a medium-scale closed economy DSGE model with various frictions and estimated for the Euro area with Bayesian techniques.

- Aggregate Demand: Households maximize their lifetime utility, where the utility function is separable in consumption, leisure and real money balances, subject to an intertemporal budget constraint. Smets and Wouters (2003) include external habit formation to make the consumption response in the model more persistent. Households own firms, rent capital services to firms and decide how much capital to accumulate given certain capital adjustment costs. They additionally hold their financial wealth in the form of cash balances and one-period, state-contingent bonds. Exogenous spending is introduced by a first-order autoregressive process with an iid-normal error term.

- Aggregate Supply: The final goods, which are produced under perfect competition, are used for consumption and investment by the households and by the government. The final goods producer maximizes profits subject to a Dixit-Stiglitz aggregator of intermediate goods, which introduces monopolistic competition in the market for intermediate goods and features a constant elasticity of substitution between individual, intermediate goods. A continuum of intermediate firms produce differentiated goods using a production function with Cobb-Douglas technology and fixed costs and sell these goods to the final-goods sector. They decide on labor and capital inputs, and set prices according to the Calvo model. Labor is differentiated over households using the Dixit-Stiglitz aggregator, too, so that there is some monopoly power over wages, which results in an explicit wage equation. Sticky wages a la Calvo are additionally assumed. The Calvo model in both wage and price setting is augmented by the assumption that prices that can not be freely set, are partially indexed to past inflation rates.

- Shocks: Ten orthogonal structural shocks are introduced in the model. Three preference shocks in the utility function: a general shock to preferences, a shock to labor supply and a money demand shock. Two technology shocks: an AR(1) process with an iid shock to the investment cost function and a productivity shock to the production function. Three cost push-shocks: shocks to the wage and price mark-up, which are iid around a constant and a shock to the required rate of return on equity investment. And finally two monetary policy shocks: a persistent shock to the inflation objective and a temporary common monetary policy shock. In addition, the common fiscal policy shock is added in the form of a government spending shock. Since government spending is expressed in output units, we set the coefficient which scales the shock to unity to achieve a shock size of one percent of GDP.

- Calibration/Estimation: The model is estimated using Bayesian techniques on quarterly Euro area data. The data set used is comprised of seven key macroeconomic variables consisting of real GDP, real consumption, real investment, the GDP deflator, real wages, employment and the nominal interest rate over the period 1970:1–1999:4.

### 1.3.4 EA_SR07: Euro Area Model of Sveriges Riksbank, Adolfson et al. (2007)

Adolfson et al. (2007) develop an open economy DSGE model and estimate it for the Euro area using Bayesian estimation techniques. They analyse the importance of several rigidities and shocks to match the dynamics of an open economy.

- Aggregate Demand: Households maximize lifetime utility subject to a standard budget constraint. Preferences are separable in consumption, labor and real cash holdings. Persistent preference shocks to consumption and labor supply are added to the representative utility function. Internal habit formation is imposed with respect to consumption. Aggregate consumption is specified as a CES function, being composed of domestically produced as well as imported consumption goods. Households rent capital to firms. Capital services can be increased via investment and via an increase in the capital utilization rate, where both options are involved with costs. Total investment in the domestic economy is represented by a CES aggregate consisting of domestic and imported investment goods. Households are assumed to be able to save through acquiring domestic bonds and foreign bonds in addition to holding cash and accumulating physical capital. A premium on foreign bond holdings assures the existence of a well-defined steady state. Households monopolistically supply a differentiated labor service. Wage stickiness is introduced in the form of the Calvo model augmented by partial indexation. Government consumption of the final domestic good is financed via taxes on capital income, labor income, consumption and payroll. Any surplus or deficit is assumed to be carried over as a lump-sum transfer to households.

- Aggregate Supply: The final good is produced via a CES aggregator using a continuum of differentiated intermediate goods as inputs. The production of intermediate goods requires homogeneous labor and capital services as inputs and is affected by a unit-root technology shock representing world productivity as well as a domestic technology shock. Fixed costs are imposed such that profits are zero in steady state. Due to working capital, (a fraction of) the wage bill has to be financed in advance of the production process. Price stickiness of intermediate goods is modeled as in the Calvo (1983) model. In addition, partial indexation to the contemporaneous inflation target of the central bank and the previous periods inflation rate is included for those firms that do not receive a Calvo signal in a given period. This results in a hybrid new Keynesian Phillips curve.

- Foreign sector: Importing firms are assumed to buy a homogeneous good in the world market and differentiate it to sell it in the domestic market. Similarly, exporting firms buy the homogeneous final consumption good produced in the domestic economy and differentiate it to sell it abroad. Specifically, the differentiated investment and consumption import goods are aggregated in a second step via a CES function, respectively. The same applies to the export goods. Calvo pricing is also assumed for the import and export sector, allowing for incomplete exchange rate pass-through in the short run. The foreign economy is described by an identified VAR model for foreign prices, foreign output and the foreign interest rate.

- Shocks: Unit root technology shock, stationary technology shock, investment specific technology shock, asymmetric technology shock, consumption preference shock, labor supply shock, risk premium shock, domestic mark-up shock, imported consumption mark-up shock, imported investment mark-up shock, export mark-up shock, inflation target shock, the common monetary policy shock, shocks to the four different tax rates and a government spending shock which represents the common fiscal policy shock and which we have adjusted so that we achieve a shock size of one percent of GDP.

- Calibration/Estimation: The model is estimated using Bayesian estimation techniques for the Euro area using quarterly data from 1970:1–2002:4 in order to match the dynamics of 15 selected variables. According to the authors, they calibrated those parameters that should be weakly identified by the 15 variables used for estimation.

### 1.3.5 EA_QUEST3: Ratto et al. (2009)

Ratto et al. (2009) develop and estimate an open economy DSGE model for the euro area with emphasis on monetary and fiscal rules, in order to explore their stabilization properties. The role of

fiscal policy is explored in an environment with rules for government consumption, investment and transfers and with financial frictions in the form of liquidity-constrained households.

- Aggregate Demand: There are two types of households: liquidity- and non-liquidity-constrained households. They posses the same utility function, non-separable in consumption and leisure with habit persistence in both consumption and leisure. Liquidity-constrained households do not optimize, they just consume their labor income. On the other side, non-liquidity-constrained households have access to domestic and foreign currency denominated assets, accumulate capital subject to investment adjustment costs and rent it to firms, earn profits from owning the firms and pay taxes. Income from foreign financial assets is subject to an external financial intermediation risk premium while real asset holdings are subject to an equity risk premium. Both types of households supply differentiated labor to a trade union which sets the wages by maximizing their joint utility (weighted by the share of each type). The wage setting process is subject to a wage mark-up and to slow adjustments in the real consumption wage. The wage mark-up arises because of wage adjustment costs and the fact that a part of workers index the growth rate of wages to past inflation.

- Aggregate Supply: The final goods, which are produced from monopolistically competitive firms, are used for household consumption, investment, government consumption and export. These goods are produced with a Cobb-Douglas production function with capital and production workers (labor adjusted for overhead labor) as inputs. These firms face technological and regulatory constraints, restricting their price setting, employment and capacity utilization decisions. The final goods producer maximizes profits subject to these specific adjustment costs (all having convex functional forms) and demand conditions. Investment good producers combine domestic and foreign final goods using a CES aggregator to produce investment goods which are sold to non-liquidity-constrained households in a perfectly competitive market.

- The Foreign Sector: Demand behavior is considered the same for the home country and the rest of the world, therefore export demand and import demand are symmetric. Both equations are characterized by a lag structure in relative prices which captures delivery lags. Export firms buy domestic goods, transform them using a linear technology and sell them in the foreign market, charging a mark-up over the domestic prices. The same situation is faced by importer firms. Mark-up fluctuations arise because of price adjustment costs in both sectors. Mark-up equations are given as a function of past and future inflation and are also subject to random shocks.

- Shocks: A wage mark up shock, a price mark-up shock, a monetary policy shock, a fiscal policy shock, world demand shock, a risk premium shock, a technology shock, an investment shock,

a consumption shock, a trade shock, a labor demand shock, a foreign monetary policy shock.

- Calibration/Estimation: Estimated with Bayesian methods, using quarterly data for the euro area for the period 1981:1–2006:1.

### 1.3.6 EA_GE10: Gelain (2010)

The model of Gelain (2010) incorporates financial frictions à la Bernanke et al. (1999) into a New Keynesian DSGE model which closely follows the structure of the model developed in Smets and Wouters (2003). The structural model allows for a dynamic analysis of the external finance premium. The paper shows that the estimated premium is not necessarily countercyclical as suggested by former studies on the Euro Area external finance premium. In the presence of certain shocks the premium responds procyclically.

- Aggregate Demand: A representative household maximizes its intertemporal utility function choosing the level of consumption, hours worked and the amount of bank deposits, subject to a budget constraint. The household's consumption preferences exhibit habit formation.

- Aggregate Supply: Each household is a monopolistic supplier of differentiated labor services requested by the domestic firms. After setting their wages in a Calvo staggered way, households inelastically supply the firms' demand for labor at the ongoing wage rate. An indexation rule is assumed for those households who are not allowed to re-optimize.

  The production sector consists of three types of firms: entrepreneurs, capital producers and retailers. Entrepreneurs hire labor from households and buy capital from capital producers to produce intermediate goods using a Cobb-Douglas production technology. Entrepreneurs have a finite expected lifetime horizon. The capital purchases are financed partly by the entrepreneur's net worth and partly by borrowing from a financial intermediary. The presence of asymmetric information between entrepreneurs and lenders creates a financial friction as in Bernanke et al. (1999). Entrepreneurs can reoptimize their prices only from time to time, as in Calvo (1983).

  Capital producers buy final goods to produce capital subject to investment adjustment costs. Retailers operate in a perfectly competitive market, they use a Dixit-Stiglitz technology using the entrepreneurs' intermediate goods as inputs.

- Shocks: The model exhibits eight shocks. Two preference shocks, a shock to investment adjustment costs, a technology shock in entrepreneurs' production function, a wage and a price mark up shock, a government spending shock and a monetary policy shock.

- The model is estimated using Bayesian techniques on quarterly Euro Area data for 1980:Q1 to 2008:Q3. The data set used is comprised of seven key macroeconomic variables aggregated for the Euro Area consisting of real GDP, real consumption, real gross investment, hours worked, the nominal short term interest rate, real wages per head and inflation rate.

### 1.3.7  EA_GNSS10: Gerali et al. (2010)

The model of Gerali et al. (2010) incorporates an imperfect competitive banking sector in a DSGE model with financial frictions à la Iacoviello (2005). The model allows to asses the role of both financial frictions and banking intermediation in shaping business-cycle dynamics.

- Aggregate Demand: There are two type of households, patient (savers) and impatient (borrowers) and entrepreneurs. A representative household maximizes its intertemporal utility function choosing the level of consumption, hours worked and housing services, subject to a budget constraint. Impatient households face in addition a borrowing constraint, linked to the expected value of their collateralizable housing stock. The household's consumption preferences exhibit external habit formation. Households supply differentiated labor services through unions. Wage-setting is subject to adjustment costs, à la Rotemberg with indexation to both past and steady state inflation. Entrepreneurs maximize their utility by choosing consumption, physical capital, loans from banks, the degree of capacity utilization and labor. Entrepreneurs face also a borrowing constraint, linked to the value of their holdings of physical capital.

- Aggregate Supply: The production sector consists of three types of firms: entrepreneurs, capital good producers and retailers. Entrepreneurs hire labor from households and buy capital from capital good producers to produce intermediate goods. Capital producers buy final goods to produce capital subject to investment adjustment costs. Retailers buy intermediate goods from entrepreneurs and differentiate them. Pricing is subject to nominal rigidities.

- Banking Sector: Banks enjoy market power in conducting their intermediation activity. Bank loans should be met by deposits and/or bank capital. Each bank has three parts, two "retail" branches (giving out differentiated loans to impatient households and to entrepreneurs and raising differentiated deposits from patient households) and one "wholesale" unit (managing the capital position of the group).

- Shocks: The model exhibits a technology shock, price and wage markups shocks, a consumption preferences shock, a housing demand shock, an investment-specific technology shock, a monetary policy shock, shocks to the loan-to-value ratios on loans to firms and households, shocks to the markup on bank interest rates and balance sheet shocks.

- The model is estimated with Bayesian techniques, for the euro area for 1998:Q1-2009:Q1. For estimation twelve observables are used: real consumption, real investment, real house prices, real deposits, real loans to households and firms, overnight rate, interest rates on deposits, loans to firms and households, wage inflation and consumer price inflation.

## 1.4 Estimated/Calibrated Multi-Country Models

### 1.4.1 G7_TAY93: Taylor (1993) G7 countries

Taylor (1993) describes an estimated international macroeconomic framework for policy analysis in the G7 countries: USA, Canada, France, Germany, Italy, Japan and the UK. The model consists of 98 equations and a number of identities. This model was the first to demonstrate that it is possible to construct, estimate, and simulate large-scale models for real-world policy analysis (Yellen, 2007). Taylor (1993) argues that a multicountry model is appropriate for the evaluation of policy questions like the appropriate mix of fiscal and monetary policy or the choice of an exchange rate policy.

- Aggregate Demand: The IS components are more disaggregated than in the US_OW98 model. For example, spending on fixed investment is separated into three components: equipment, nonresidential structures, and residential construction. The specification of these equations is very similar to that of the more aggregated equations in the US_OW98 model. The aggregate demand components exhibit partial adjustment to their respective equilibrium levels. In G7_TAY93, imports follow partial adjustment to an equilibrium level that depends on U.S. income and the relative price of imports, while exports display partial adjustment to an equilibrium level that depends on foreign output and the relative price of exports. Uncovered interest rate parity determines each bilateral exchange rate (up to a time-varying risk premium); e.g., the expected one-period-ahead percent change in the DM/U.S.\$ exchange rate equals the current difference between U.S. and German short-term interest rates.

- Aggregate Supply: The aggregate wage rate is determined by overlapping wage contracts. In particular, the aggregate wage is defined to be the weighted average of current and three lagged values of the contract wage rate. In contrast to the US_FM95 model and the US_OW98 model, G7_TAY93 follows the specification in Taylor (1980), where the current nominal contract wage is determined as a weighted average of expected nominal contract wages, adjusted for the expected state of the economy over the life of the contract. This implies less persistence of inflation than in the US_FM95 and the US_OW98 model. The aggregate price level is not set as a constant mark-up over the aggregate wage rate as in US_FM95 and US_OW98. Prices are set as a mark-up over wage costs and imported input costs. This mark-up varies and prices adjust slowly to changes in costs. Prices follow a backward-looking error-correction specification.

Current output price inflation depends positively on its own lagged value, on current wage inflation, and on lagged import price inflation, and responds negatively (with a coefficient of -0.2) to the lagged percent deviation of the actual price level from equilibrium. Import prices adjust slowly (error-correction form) to an equilibrium level equal to a constant mark-up over a weighted average of foreign prices converted to dollars. This partial adjustment of import and output prices imposes somewhat more persistence to output price inflation than would result from staggered nominal wages alone.

- Foreign sector: G7_TAY93 features estimated equations for demand components and wages and prices for the other G7 countries at about the level of aggregation of the U.S. sector. Financial capital is mobile across countries.

- Shocks: Interest rate parity shock, term structure shock, durable consumption shock, non-durable consumption shock, services consumption shock, total consumption shock, aggregate consumption shocks for Germany and Italy, for the other countries disaggregated, nonresidential equipment investment shock, nonresidential structures investment shock, residential investment shock, inventory investment shock, fixed investment shock, inventory investment shock, real export shock, real import shock, contract wage shock, cost-push shock, import price shock, export price shock, fiscal policy shock, where we have adjusted the size of the fiscal policy shock for the U.S. - the common fiscal shock - so that a unit shock represents a 1 percent of GNP shock and a monetary policy shock where again the common Modelbase monetary policy shock enters the monetary policy rule for the U.S..

- Calibration/Estimation: The model is estimated with single equation methods on G7 data from 1971–1986.

### 1.4.2   G3_CW03: Coenen, Wieland (2002, 2003) G3 countries

In this model different kinds of nominal rigidities are considered in order to match inflation and output dynamics in the U.S., the Euro area and Japan. Staggered contracts by Taylor (1980) explain best inflation dynamics in the Euro area and Japan and staggered contracts by Fuhrer and Moore (1995a) explain best U.S. inflation dynamics. The authors evaluate the role of the exchange rate for monetary policy and find little gain from direct policy response to exchange rates.

- Aggregate Demand: The open-economy aggregate demand equation relates output to the lagged ex-ante long-term real interest rate and the trade-weighted real exchange rate and additional lags of the output gap. The demand equation is very similar to the G7_TAY93 model without any sectoral disaggregation. Lagged output terms are supposed to account for habit persistence

in consumption as well as adjustment costs and accelerator effects in investment. The lagged interest rate allows for lags in the transmission of monetary policy. The exchange rate influences net exports and thus enters the aggregate demand equation. The long term nominal interest rate is an average of expected future nominal short-term rates. The long-term real interest rate is determined by the Fisher equation.

- Aggregate Supply: For the U.S., relative real wage staggered contracts by Fuhrer and Moore (1995a) are used (see the US_FM95 model for a detailed exposition). For the Euro area and Japan the nominal wage contracts by Taylor (1980) are used. Note that Taylor contracts, with a maximum contract length exceeding two quarters, result in Phillips curves that explicitly include lagged inflation and lagged output gaps. Thus, the critique that with Taylor contracts inflation persistence is solely driven by output persistence (Fuhrer and Moore, 1995a) is mitigated.

- Foreign sector: All three countries are modeled explicitly. The Modelbase rule replaces monetary policy for the U.S.. For the Euro area and Japan the original interest rules remain. Foreign output does not affect domestic output directly, but indirectly via the exchange rate in the demand equation. The bilateral exchange rates are determined by UIP conditions.

- Shocks: Contract wage shocks, demand shocks and the common monetary policy shock which is added for the U.S..

- Calibration/Estimation: Euro area data, (fixed GDP weights at PPP rates from the ECB area-wide model database), U.S. data and Japanese data. For the U.S. and Japan OECD's output gap estimates are used. For the Euro area log-linear trends are used to derive potential output. The estimation is robust to different output gap estimations. Demand block: GMM estimation where lagged values of output, inflation, interest rates, and real exchange rates are used as instruments. Supply side: simulation-based indirect inference methods. Estimation period: U.S. 1980:1–1998:4, Euro area 1980:1–1998:4 and Japan 1980:1–1997:1.

### 1.4.3 EACZ_GEM03: IMF model of Euro Area and Czech Republic, Laxton and Pesenti (2003)

The model is a variant of the IMF's Global Economy Model (GEM) and consists of a small and a large open economy. The authors study the effectiveness of Taylor rules and inflation-forecast-based rules in stabilizing variability in output and inflation. They check if policy rules designed for large and relatively closed economies can be adopted by small, trade-dependent countries with less developed financial markets and strong movements in productivity and relative prices and destabilizing exposure

to volatile capital flows. In contrast to Laxton and Pesenti (2003) we focus on the results for the large open economy (Euro area) rather than the small open economy (Czech Republic).

- Aggregate Demand: Infinitely lived optimizing households; government spending falls exclusively on nontradable goods, both final and intermediate. Households face a transaction cost if they take a position in the foreign bond market.

- Aggregate Supply: Monopolistic intermediate goods firms produce nontradeable goods and tradable goods. It exists a distribution sector consisting of perfectly competitive firms. They purchase tradable intermediate goods worldwide (at the producer price) and distribute them to firms producing the final good (at the consumer price). Perfectly competitive final good firms (Dixit-Stiglitz aggregator) use nontradable and tradeable goods and imports as inputs. Households are monopolistic suppliers of labor and wage contracts are subject to adjustment costs. Households own domestic firms, nonreproducable resources and the domestic capital stock. Markets for land and capital are competitive. Capital accumulation is subject to adjustment costs. Labor, capital and land are immobile internationally. Households trade a short-term nominal bond, denominated in foreign currency. All firms exhibit local currency pricing, thus exchange rate pass-through is low.

- Shocks: Risk premium shock, productivity shock, shock to the investment depreciation rate, shock to the marginal utility of consumption, government absorption shock where the one affecting the large foreign economy represents the common fiscal policy shock, shock to the marginal disutility of labor, preference shifter. We add the common monetary policy shock to the policy rule of the large economy.

- Calibration/Estimation: Calibrated to fit measures of macro-variability of the Euro area (1970:1–2000:4) and Czech Republic (1993:1–2001:4).

- Notes: Due to the symmetric setup of the model, we use the same policy rule in both countries.

### 1.4.4  G2_SIGMA08: FRB-SIGMA by Erceg et al. (2008)

The SIGMA model is a medium-scale, open-economy, DSGE model calibrated for the U.S. economy. Erceg et al. (2008) in particular take account of the expenditure composition of U.S. trade and analyse the implications for the reactions of trade to shocks compared to standard model specifications.

- Aggregate Demand: There are two types of households: households that maximize a utility function separable in consumption, with external habit formation and a preference shock, leisure and real money balances, subject to an intertemporal budget constraint (forward-looking

households) and the remainder that simply consume after-tax disposable income (hand-to-mouth households). Households consume, own the firms and accumulate capital, which they rent to the intermediate goods producers. Erceg et al. (2008) introduce investment adjustment costs a la Christiano et al. (2005), where it is costly for the households to change the level of gross investment. Households also choose optimal portfolios of financial assets, which include domestic money balances, government bonds, state-contingent domestic bonds and a non-state contingent foreign bond. It is assumed that households in the home country pay an intermediation cost when purchasing foreign bonds, which ensures the stationarity of net foreign assets. Households rent their labor in a monopolistic market to firms, where forward-looking households set their nominal wage in Calvo-style staggered contracts analogous to the price contracts and hand-to-mouth households simply set their wage each period equal to the average wage of the forward-looking households.

- Aggregate Supply: Intermediate-goods producers have an identical CES production function and rent capital and labor from competitive factor markets. They sell their goods to final goods producers under monopolistic competition and set prices in Calvo-style staggered contracts. Firms, who don't get a signal to optimize their price in the current period, mechanically adjust their price based on lagged aggregate inflation. Final good producers in the domestic and foreign market assemble the domestic and foreign intermediate goods into a single composite good by a CES production function of the Dixit-Stiglitz form and sell the final good to households in their country. Erceg et al. (2008) introduce quadratic import adjustment costs into the final goods aggregator, which are zero in steady state. It is costly for a firm to change its share of imports in a final good relative to their lagged aggregate shares. Thus the import share of consumption or investment goods is relatively unresponsive in the short-run to changes in the relative price of imported goods even while allowing the level of imports to jump costlessly in response to changes in overall consumption or investment demand. Government purchases are assumed to be a constant fraction of output. Government revenue consists of income from capital taxes (net of the depreciation write off), seignorage income and revenue from lump-sum taxes (net of transfers). The government issues bonds to finance the difference between government revenue and expenditure. Lump-sum taxes are adjusted both in response to deviations of the government debt/GDP ratio from a target level and to the change in that ratio.

- Foreign sector: Local currency pricing is assumed. Intermediate goods producers price their product separately in the home and foreign market leading to an incomplete exchange rate pass-through. Erceg et al. (2008) point out, that empirically imports and exports in the U.S. are heavily concentrated, with about 75 percent in capital goods and consumer durables, but the

production share of capital goods and consumer durables is very low. To account for this fact in the two-country model they allow the import share in the final good aggregator for investment goods to be higher than the import share in the final good aggregator for consumption goods.

- Shocks: Since we have no information about the variances of the shock terms, we set all shock variances equal to zero. The government spending shock of the home country represents the common fiscal policy shock. The common monetary policy shock is added for the home country.

- Calibration/Estimation: The model is calibrated at a quarterly frequency. Parameters of the original monetary policy rule are estimated using U.S. data from 1983:1–2003:4.

### 1.4.5   EAUS_NAWM08: Coenen et al. (2008)

Coenen et al. (2008) use a calibrated, two-country version of the New Area-Wide Model developed at the European Central Bank to examine the Euro Area tax structure and the potential benefits and spillovers of a tax reform (reducing labor market distortions). The real effects of fiscal policies are analyzed in an environment with heterogeneous households. Countries in Coenen et al. (2008) are symmetric but of different size where the U.S. represents the rest of the world.

- Aggregate Demand: Only a share of households have access to domestic and international financial markets, accumulates capital and holds money. The other part of households do not have access to financial markets and neither holds capital. They smooth consumption solely by adjusting their money holdings. Both types of households maximize a lifetime utility function with external habit in consumption and supply differentiated labor services with monopoly power in wage setting. Wages are determined in a la Calvo (1983) fashion. Households that receive permission to re-optimize their wages choose the same wage while the other part follows an indexation scheme, with wages being a geometric average of past changes in the price of the consumption good. Households gross income is subject to a rich taxation structure. They pay taxes on consumption purchases, on wage income, on rental capital income and on dividend income. Furthermore, they pay social security contributions, a lump-sum tax and receive transfers. Purchases of consumption, financial investment in international markets and capital utilization are subject to specific proportional costs.

- Aggregate Supply: Producers are distinguished between producing tradable and non-tradable goods. The intermediate goods firm produces a single, tradable differentiated good using an increasing-returns-to-scale Cobb-Douglas technology with capital services and labor as inputs. These goods are sold both in domestic and foreign market under monopolistic competition.

Price setting is subject to staggered price contracts a la Calvo (1983). Firms that receive permission to re-optimize their prices choose the same price (be it for the domestic or for the foreign market) while the other firms follow an indexation scheme, with prices being a geometric average of past changes in the aggregate price indexes. The final goods firms produce three non-tradable final goods: private consumption goods, investment goods and public consumption goods. Final non-tradable private consumption and private investment goods are modeled in an analogous manner. These final goods are assembled with CES technology, combining intermediate domestic and imported foreign goods. Varying the use of imported intermediate goods in the production process is subject to adjustment costs, therefore changes in the relative price of imported goods go unreflected in the short-run. These final goods are sold taking the price as given. On the other side, the public consumption good is a composite of only domestically produced intermediate goods.

- The Foreign Sector: The demand for imported goods is equal to the sum of the respective demands for intermediate goods for private consumption and investment. These intermediate goods are sold in the home market by the foreign intermediate-good producer. The price of the intermediate good imported from abroad is equal to the price charged by the foreign producer (local currency pricing).

- Shocks: A government spending shock, a transfer shock, a productivity shock, a monetary policy shock. (Distortionary tax rates on consumption, on dividends, on rental capital income, on labor income and payments on social security contributions are given as exogenous processes but constant).

- Calibration/Estimation: The model is calibrated to the Smets and Wouters (2003) model, with steady-state ratios based on observed data for the euro area and U.S., respectively.

### 1.4.6 EAES_RA09: Rabanal (2009)

Rabanal (2009) uses a two-country, two-sector DSGE model of a currency union with nominal rigidities to study the sources of persistent inflation differentials between the EMU and one of its member countries, Spain. Moreover, the paper aims at explaining the first moments of the data by introducing time trends for the country- and sector-specific technology shock processes that can give rise to permanent inflation differentials in the model.

- Aggregate Demand: Households in Spain and in the rest of EMU have utility functions separable in consumption and leisure and displaying external habit formation in consumption. The composite consumption good is defined as a CES aggregate consisting of domestic tradable

and nontradable, and foreign tradable goods. Preferences are assumed to be the same across countries, but countries differ with respect to the composition of their consumption basket.

- Aggregate Supply: Each economy is characterized by two sectors. Monopolistic intermediate firms use labor, supplied by the households, as the only input to produce tradable and nontradable goods. They set prices to maximize profits subject to a set of demand equations. Price setting follows a modified version of the Calvo framework with two indexation mechanisms in place that account for the fact that steady state inflation might be non-zero. Across countries the same production technologies are deployed but countries differ in the degree of wage and price stickiness and in the degree of indexation.

- Foreign sector: Rabanal (2009) models two countries in the European monetary union of unequal size. They produce differentiated tradable goods that are imperfect substitutes of each other, but there is no price discrimination for the same type of good across countries.

- Shocks: Ten shocks are introduced in the model: sector- and country-specific AR(1) shock processes for the government spending and the technology shock with an Euro Area tradable shock component, and an iid monetary policy shock.

- Calibration/Estimation: The model is estimated using Bayesian estimation techniques using quarterly euro area data for the period 1996:Q1–2007:Q4.

### 1.4.7 EAUS_NAWM08CTWW13: Cogan et al. (2013)

Cogan et al. (2013) use a version of the EAUS_NAWM08 model of Coenen et al. (2008) to study the fiscal consolidation plan on the U.S.economy. In EAUS_NAWM08CTWW13, the US economy is calibrated following Cogan et al. (2010).

- Aggregate Demand: As in EAUS_NAWM08.

- Aggregate Supply: As in EAUS_NAWM08.

- The Foreign Sector: As in EAUS_NAWM08.

- Shocks: As in EAUS_NAWM08.

- Calibration/Estimation: Differently from the EAUS_NAWM08 model, parameters for the US are calibrated with reference to other estimated models, including the Cogan et al. (2010).

## 1.5 Estimated Models of Other Countries

### 1.5.1 CL_MS07: Medina and Soto (2007)

Medina and Soto (2007) develop a small-open economy DSGE model for the Chilean economy. The CL_MS07 is structurally similar to models developed by Christiano et al. (2005), Altig et al. (2005), and Smets and Wouters (2007). Still, a richer specification for the production sector and for fiscal policy is designed to account for special characteristics of the Chilean economy.

- Aggregate Demand: There are two types of households, Ricardian and non-Ricardian households. The Ricardian type households maximize a utility function separable in consumption, leisure and real money balances subject to their intertemporal budget constraint. They have access to three types of assets, namely money and one-period non-contingent foreign and domestic bonds. Each of these households is a monopolistic supplier of differentiated labour and only a fraction of them can re-optimize their nominal wage. Rigidity a la Calvo in wage setting follows Erceg, Henderson, and Levin (2000). Households that cannot re-optimize their wages follow an updating rule considering a geometric weighted average of past CPI inflation and the inflation target. On the other side, the non-Ricardian households do not have access to any of the assets and own no shares in domestic firms. They simply consume the after-tax disposable income and set their wage equal to the average wage of the Ricardian households. The aggregate consumption for both types of households is a composite of a core consumption bundle (domestic and foreign goods, given by a CES aggregator) and oil consumption.

- Aggregate Supply: The economy is characterized by three types of firms: intermediate tradable-goods producers, import goods retailers and commodity good producers. Intermediate-goods producers have monopoly power and maximize profits by choosing the prices of their differentiated goods subject to the corresponding demands, and the available technology with labor, capital and oil as inputs. Capital is rented to them from a representative firm which accumulates capital and assembles new capital goods subject to investment adjustment costs. Optimal price setting of intermediate-goods producers is subject to a Calvo probability. Firms that cannot re-optimize their price follow a rule with partial indexation to past inflation and the inflation target. The pricing structure leads to a hybrid New Keynesian Phillips curve. A commodity good producer is introduced in the model to match a particular relevant sector for the Chilean economy, namely the cooper sector. This firm produces a homogeneous commodity good only for export. The production technology follows an exogenous stochastic process that does not require any input. The price of the homogeneous commodity good is determined in the foreign market.

- Foreign sector: Local currency pricing is introduced through a la Calvo price stickiness faced

by import goods retailers, which resale foreign goods in the domestic market. This allows for incomplete exchange rate pass-through in the short-run, important for expenditure-switching effects of the exchange rate. A CES technology is used to combine a continuum of differentiated imported varieties to produce a final foreign good, which is consumed by households and used for assembling new capital goods.

- Shocks: a transitory productivity shock, a permanent productivity shock, a commodity production shock, a labor supply shock, an investment adjustment cost shock, a preference shock, a government expenditure shock, a monetary policy shock, a foreign commodity price shock, a foreign oil price shock, a foreign output shock, a foreign interest shock, a foreign inflation shock and a price of imports shock.

- Calibration/Estimation: The model is estimated using Chilean quarterly data for the period 1987:1–2005:4.

### 1.5.2  CA_ToTEM10: Murchison and Rennison (2006)

CA_ToTEM10 represents the 2010 vintage of ToTEM (Terms-of-Trade Economic Model) which is an open-economy, DSGE model developed by Murchison and Rennison (2006). The Bank of Canada uses this model as a tool for policy analysis and projections for the Canadian economy.

- Aggregate Demand: Households are classified as "lifetime income" consumers and "current income" consumers, reflecting the fact that not all consumers can access credit markets. Lifetime income consumers smooth their consumption across time through borrowing and saving while "current income" consumers consume their current income each period. Lifetime income consumers choose consumption, domestic and foreign bond holdings, labor supply and wages to maximize a utility function non-separable in consumption and leisure subject to a dynamic budget constraint. Both types of households supply differentiated labor services giving them power when negotiating the wages with the domestic producers. However, renegotiation of the wages is allowed only once in six months, on average, and only a constant proportion of wage contracts are renewed every period. The dynamic wage equation is a function of past and expected future wage inflation and an error-correction component.

- Aggregate Supply: The production sector is comprised of final good producers, an import sector and a commodity sector. Final goods firms produce consumption goods and services, investment goods, and export goods. The production process of these goods is analogous, differing only on the share of imported goods used in production. In this process, first a capital-labor composite is produced using CES technology, which is then combined with a commodity input

to produce the domestic good. Final goods then are a combination of the domestic good and the imported good. Through these steps, the firm faces capital adjustment costs, investment adjustment costs and labor adjustment costs. Final goods firms sell their differentiated goods in a monopolistic competitive fashion having power over prices. However, not all firms can re-optimize their prices every period. A share of firms updates prices according to a geometric average of lagged core inflation and expectations of the inflation target. In ToTEM, pricing decisions are considered as strategic complements, where firms have a strong incentive to follow what other firms do. The commodity sector is represented by a domestic firm operating in a competitive market, producing commodities using capital services, labor and land under a CES technology. These raw goods are either sold to a continuum of imperfectly competitive commodity distributors or exported (for the world price of the commodity denominated in Canadian currency). The commodity distributors repackage the commodity goods and sell them to households and to the final goods producers. These distributors face nominal rigidities a la Calvo in price setting, which limits the degree of exchange rate pass-through to consumer prices in the short-run.

- The Foreign Sector: The import sector is represented by firms who buy imported goods in the world market for a given world price (law of one price holds). These goods are sold to domestic firms, which use them as inputs in their respective production functions. Imperfect exchange rate pass-through in the short-run is present as the price of imports is temporarily fixed in the currency of the importing country and because import firms face nominal rigidities a la Calvo when setting prices. As in other sectors, imported goods inflation is a function of past and expected future imported goods inflation and an error-correction component. Export goods firms are part of the final good producers sector as discussed above. They have some degree of market power and therefore face a downward-sloped demand curve (rest of the world demand).

- Shocks: A demand shock, a risk-premium shock, an inflation target shock, a commodity price shock, a technology shock, world demand shock and a price mark-up shock.

- Calibration/Estimation: Calibrated with parametrization chosen to match univariate autocorrelations, bivariate correlations and variances estimated using Canadian data for the period 1980–2004.

### 1.5.3 BRA_SAMBA08: Gouvea et al. (2008)

Gouvea et al. (2008) build and estimate a small open economy model for the Brazilian economy. The BRA_SAMBA08 model is developed at the Central Bank of Brazil to provide support for its

policy decisions. This version of the model is used as a tool to analyze the response of the Brazilian economy when subject to different shocks.

- Aggregate Demand: There are two types of households: optimizers and rule-of-thumbers. Both maximize a similar utility function separable in consumption and leisure but subject to different budget constraints. Unlike the optimizers, the rule-of-thumb households do not have access to credit, asset and capital markets. They just consume their wage income. The optimizers have access to domestic and foreign currency denominated bonds, accumulate capital subject to capital adjustment costs, earn from renting the capital and pay taxes. On the other hand, both types of households supply labor in a competitive market.

- Aggregate Supply: The production sector is comprised of producers and assemblers. Monopolistic competitive firms are the ones producing differentiated goods under a Cobb-Douglas technology with labor, capital services and imported goods as inputs. Following Gali and Gertler (1999), only a fraction of firms are allowed to adjust prices optimally ("forward-looking firms"). The remaining firms follow a rule of thumb. The homogeneous final good is assembled by a representative firm using a CES aggregator and is sold in a competitive market. The final good can be used for private consumption, government consumption, investment and exports.

- The Foreign Sector: The world is assumed to be populated by a continuum of small open economies as in Gali and Monacelli (2005), each of them producing a differentiated good in the global market. The demand for home country's exports is obtained from the aggregation of the demands from foreign countries, expressed in a world currency. The domestic importing firm takes the demand for its goods from the producers' input choices.

- Shocks: An inflation target shock, a fiscal target shock, a preference shock, a labor supply shock, an investment shock, a foreign investor's risk aversion shock, a country risk premium shock, a technology shock, a monetary policy shock, a fiscal policy shock, a world imports shock, a world inflation shock and a world interest rate shock.

- Calibration/Estimation: Estimated with Bayesian methods, using quarterly Brazilian data for the period 1999:Q2–2007:Q4.

### 1.5.4   CA_LS07: Lubik and Schorfheide (2007)

Lubik and Schorfheide (2007) estimate four small-scale open economy DSGE models with Bayesian techniques for Canada, Australia, New Zealand and the UK. The paper studies to what extent central banks respond to exchange rate movements when setting nominal interest rates, finding that the Bank

of Canada and the Bank of England do include the nominal exchange rate in their policy rule. The database contains the model for Canada.

- Aggregate Demand: The model treats the world economy as a continuum of small open economies. The representative household maximizes its utility separable between consumption and leisure subject to its budget constraint. Consumption is a composite of tradable home and foreign goods.

- Aggregate Supply: Differentiated goods are produced by monopolistic-competitive firms using a linear technology with labor being the only production input. The firms set their prices in a Calvo staggered way. The marginal costs depend positively on the terms of trade and world output.

- The Foreign Sector: Purchasing power parity and the law of one price hold. There is perfect exchange rate pass-through. The securities markets are assumed to be complete, and hence international risk sharing in the form of the uncovered interest rate parity is obtained.

- Shocks: A nominal interest rate shock, a terms of trade shock, a shock to world demand and a shock to the world inflation rate are introduced in the model.

- Calibration/Estimation: The model is estimated with Bayesian methods using quarterly Canadian data for the period 1983:Q1–2002:Q4.

### 1.5.5 HK_FPP11: Funke et al. (2011)

Funke et al. (2011) develop a small open economy DSGE model and estimate it for Hong Kong with Bayesian techniques. The model adopts the perpetual youth approach and allows for wealth effects from the stock market on consumption behavior.

- Aggregate Demand: The economy consists of an indefinite number of cohorts facing a constant probability of dying each period, which implies a constant expected effective decision horizon of consumers. Given the lifetime uncertainty, agents' consumption pattern is affected by their expected lifetime wealth (in terms of the wealth in stock market), where the stock price is modeled as the discounted sum of future dividends. In this open economy the consumers are free to allocate their consumption between domestic goods and foreign goods, and the intertemporal allocation is characterized by an otherwise conventional Euler equation that captures the impact of stock-price dynamics.

- Aggregate Supply: Domestic firms act under monopolistic competition and produce consumption goods. Nominal frictions are introduced in the form of Calvo sticky prices. Non-reoptimizing firms index their prices to previous period's domestic producer price inflation.

- The Foreign Sector: The rest of the world is modeled exogenously. Foreign output affects domestic output through international risk sharing directly, and also indirectly via the terms of trade channel.

- Shocks: A productivity shock, a foreign demand shock, a cost push shock and a stock-price gap shock.

- Calibration/Estimation: The model is estimated using Bayesian methods. Funke et al. (2011) employ quarterly data on four observables for the sample 1981:Q1–2007:Q3: the real GDP of Hong Kong, the Hang Seng index, the consumer price index of Hong Kong and US GDP. The last series is used as a proxy for foreign demand.

### 1.5.6   HK_FP13: Funke and Paetz (2013)

Funke and Paetz (2013) develop a two-agent, two-sector, open-economy DSGE model and estimate it for Hong Kong with Bayesian methods. The model introduces credit market frictions as a form of a binding collateral constraint on borrowers and adopts a fixed exchange-rate regime as monetary policy.

- Aggregate Demand: Households consists of borrowers and savers. They both obtain utility from consuming non-housing goods and housing and disutility from providing labor. There is habit formation in consumption, both non-housing goods and housing are CES indices of domestically-produced goods and foreign-produced ones. Borrowers are not able to access to the international financial markets and face the collateral constraint linking to the value of housing and the loan-to-value ratio. Savers can purchase both domestic bonds foreign bonds. A symmetric steady state and perfect international risk/sharing are assumed.

- Aggregate Supply: Each sector has a two-stage structure of production. Perfectly competitive retailers produce final goods by aggregating intermediate goods according to a CES technology, and monopolistically competitive frims produce intermediate goods subject to nominal rigidity a la Calvo.

- The Foreign Sector: The rest of the world is modeled exogenously. Foreign output affects domestic output through international risk sharing directly, and also indirectly via the terms of trade channel.

- Shocks: Sector-specific productivity shocks, housing preference shocks, a loan-to-value shock, a government expenditure shock, sectoral cost push shocks, a foreign consumption shock, a foreign housing shock and shocks on foreign price distortions.

- Calibration/Estimation: The model is estimated with Bayesian methods using quarterly data for seven macroeconomic variables ranging from 1981:Q1 to 2007:Q3.

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