ESSAYS ON TREND INFLATION IN THE OPEN-ECONOMY

A THESIS SUBMITTED TO
THE GRADUATE SCHOOL OF SOCIAL SCIENCES
OF
MIDDLE EAST TECHNICAL UNIVERSITY

BY

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IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR
THE DEGREE OF DOCTOR OF PHILOSOPHY
IN
THE DEPARTMENT OF ECONOMICS

AUGUST 2020

Approval of the Graduate School of Social Sciences

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ABSTRACT

ESSAYS ON TREND INFLATION IN THE OPEN ECONOMY

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August 2020, 202 pages

The existing new Keynesian open economy literature tends to make a simplifying assumption that there is no trend inflation. The dissertation is composed of two essays which incorporate positive trend inflation into Open Economy New-Keynesian Models. In the first essay, a standard small open economy model is reformulated to account for positive trend inflation. Then, the model is used to understand the effects of macroeconomic shocks in a small open economy when trend inflation is positive. The main finding is that allowing for trend inflation significantly affects the implications of the dynamics of real exchange rate. Specifically, higher trend inflation induces more persistent real exchange rate responsiveness to shocks. Furthermore, adding trend inflation to the standard model improves the model in the direction of resolving the Purchasing Power Parity and Delayed-overshooting Puzzles. In the second essay, two-open and identical economy model is extended to account for positive trend inflation and heterogeneity-in price stickiness. Then, this model is used to analyse the effect of increased trade openness on the determinacy region at different rates of trend inflation. It is found that positive trend inflation shrinks the determinacy region more as the degree of openness increases. The shrinkage is higher in the version of the model with heterogeneity in price stickiness. Moreover, it is discussed how monetary policy transmission mechanism differs to that in closed-economy model and how those differences affect the dynamics of macroeconomics variables.

Keywords: Trend Inflation, Trade Openness, New-Keynesian Philips Curve, Equilibrium Determinacy

ÖZ

AÇIK EKONOMİDE TREND ENFLASYON ÜZERİNE İKİ MAKALE

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Mevcut Yeni Keynesyen açık ekonomi literatürü, trend enflasyonu sıfır varsayar. Bu tez, Açık Ekonomi Yeni Keynesyen modele pozitif trend enflasyonu dahil eden iki makaleden oluşmaktadır. İlk makalede, pozitif trend enflasyonun etkilerini açıklamak için, standart küçük açık ekonomi (standard small open economy) modeli yeniden geliştirilmiştir. Daha sonra, bu model trend enflasyonun pozitif olduğu durumlarda makroekonomik şokların küçük açık ekonomi üzerindeki etkilerini açıklamak için kullanılmıştır. Makaledeki en önemli bulgu, pozitif trend enflasyon, reel döviz kuru dinamiğini önemli ölçüde etkilemesidir. Yüksek trend enflasyon şokların daha kalıcı ve daha yüksek reel döviz kuru tepkilerini üretmesine yol açar. Ayrıca, standart modele trend enflasyonun eklenmesi, modeli Satın Alma Gücü Paritesi ve Gecikmiş Sıçrama bilmecelerini çözme yönünde hareket ettirmektedir. İkinci makalede, pozitif trend enflasyon ve fiyat yapışıklığında heterojenlik varsayımlarından yararlanarak, açık ve özdeş iki ekonomi modeli geliştirilmiştir. Daha sonra bu model, artan dış ticaret açıklığının farklı trend enflasyon oranlarında denge belirliliği bölgesi üzerindeki etkisini analiz etmek için kullanılmıştır. Pozitif trend enflasyonun açıklık derecesi arttıkça denge belirliliği bölgesini daha da daralttığı görülmüştür. Fiyat yapışkanlığında heterojenliği olan modelin, fiyat yapışkanlığında homojen olan modele kıyasla, pozitif trend enflasyonda denge belirliliği bölgesi daha dardır. Ayrıca makalede, para politikası aktarım mekanizmasının kapalı ekonomi modelindekinden farklı olduğunu ve bu farklılıkların makroekonomik değişkenlerin dinamiklerini nasıl etkilediğini tartışılmıştır.

Anahtar Kelimeler: Trend Enflasyon, Ticaret Açıklığı, Yeni-Keynesyen Philips Eğrisi, Denge Belirliliği

To My Beloved Parents

ACKNOWLEDGMENTS

I would like to express my deepest gratitude to my supervisor Associate Prof. Dr. Gül İpek Tunç and co-supervisor Prof. Dr. Engin Kara for their guidance, criticisms, encouragements and insight throughout each step of my dissertation. Without their helps, this dissertation would not have been finalized. I would also like to thank my dissertation committee members, Prof. Dr. Elif Akbostancı Özkazanç, Prof. Dr. Ozan Eruygur, Associate Prof. Dr. Esma Gaygısız Lajunen and Associate Prof. Dr. Ayşegül Çorakçı for their thoughtful and valuable comments which help me to improve my dissertation.

Besides, I would like to thank to my friends, Cumhur Çiçekçi, Songül Şiva Çelik and Tuğba Sağlamdemir for their priceless helps through each step of my Ph.D.

I would like to express my sincere appreciation to my wife, Yektanurşin Duyan Yılmaz for her endless encouragements through my dissertation.

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CHAPTER 1

INTRODUCTION

Dynamic Stochastic General Equilibrium (DSGE) modelling offers an economic methodology to evaluate economic events like business-cycles, monetary and fiscal policy issues and growth. Basically, dynamicity comes from infinite horizon specification, stochasticity arises from influences of random shocks on models, general equilibria signify the balances between demands and supplies interdependently achieved in all markets. The emergence of DSGE models stems from *Lucas Critique* in 1976. Lucas (1976) addresses a revolutionary criticism against macroeconomic thinking of that time. He states that macroeconomic models based on aggregate observed data may mislead, since models are built on certain hypothesises rather than micro-foundations. It can be claimed that Dynamic Stochastic General Equilibrium (DSGE) models are born in response to this criticism.

DSGE models can be categorized under two schools, the Real Business Cycle (RBC) school and the New-Keynesian (NK) school. Both schools share similarities like representative agents, rational expectations, optimization-based structures and infinite horizons, but they differ in the structures of markets, the role of money and the degree of prices' flexibility. RBC models have features like perfectly competitive markets, flexible prices and neutrality of money. On the other hand, NK models have features like monopolistic competition, nominal rigidity and non-neutrality of money.

In this thesis, the models developed are based on NK school. Therefore, main features of the NK models are elaborated in this thesis. The earliest studies on the New-

Keynesian models, are like Yun (1996), Rotemberg and Woodford (1995), Gali (2002) and Woodford (2003), start from the mid 1990s. The standard New-Keynesian models are structured upon closed-economies, zero-trend inflation and homogeneity-in price stickiness. These features provide analytical simplifications for the NK models. However, observed positive average CPI inflation rates, positive degree of openness and evidence of heterogeneity in price stickiness provided by Bils and Klenow (2004) make these aspects counterfactual. Thus, they become main concern of this thesis and are incorporated into our standard New-Keynesian model. In particular, positive trend inflation is incorporated into small open economy in the first essay, and positive trend inflation and heterogeneity-in price stickiness are incorporated into two open and identical economy in the second essay.

The first essay is titled as "*The Macroeconomic Effects of Positive Trend Inflation in a Small Open Economy*". In the first essay, a small open economy model in Gali and Monacelli (2005) is extended with positive trend inflation rate as in Ascari and Sbordone (2014). The model is calibrated for Canada and the United Kingdom. The main findings of the model can be summarized as follows: With the increased trend inflation, the importance of current variables on New-Keynesian Philips Curve (NKPC) decreases and the importance of the expected variables increases. Price dispersion matters for the dynamics of the model and an extra expected marginal cost (or revenue) enters into the dynamics of the NKPC. However, the degree of openness does not have any effect on the NKPC. It affects the model with trend inflation through the real exchange rate dynamics. The effects of higher trend inflation on variables are evaluated in response to different types of shock, which are monetary policy shocks, demand shocks and cost-push shocks. Then, the effects of openness on variables are analyzed with increased trend inflation. Further it is discussed whether increased trend inflation solves Delayed-Overshooting Puzzle and Purchasing Power Parity Puzzle or not[1].

[1] For discussiosn of Delayed Overshooting Puzzle and Purchasing Power Party Puzzle, one can refer to Kim et al (2017), Eichenbaum and Evans (1995) and Rogoff (1996).

The second essay is titled as "*Trade Openness, Trend Inflation and Aggregate Instability*". Two open and identical economy version of the model by Gali and Monacelli (2005) is extended with positive trend inflation rate and heterogeneity-in-price stickiness as in Kara and Yates (forthcoming). The model is calibrated for the U.S. economy. Initially, the effects of trend inflation, trade openness and heterogeneity in price stickiness on New-Keynesian Philips Curve are analysed. Then, how trade openness affect equilibrium determinacy at positive trend inflation rates is discussed. The results obtained are compared with the results of the homogenous price stickiness model. It is found that determinacy regions shrink as trade openness increases at positive trend inflation rates. Determinacy regions are narrower in the model with heterogeneity-in price stickiness compared to the model with homogeneity-in price stickiness at positive trend inflation rates.

The thesis is organized as follows: Chapter 2 presents an overview about the related literature. In particular, the related literature and the empirical evidence about the main features focused on the thesis-positive trend inflation, trade openness and heterogeneity in price stickiness are presented. Chapter 3 presents the first essay while, Chapter 4 presents the second essay. Chapter 5 concludes the thesis.

CHAPTER 2

DESCRIPTIONS

2.1. Introduction

As a relatively recent strand of macroeconomic modelling, Dynamic Stochastic General Equilibrium (DSGE) model is an optimization-based macroeconomic method which is employed to understand economic events like business cycles, economic growth and to propose policies by central banks and governments. These models branch off two main grounds: the neoclassical growth models that are based on Real Business Cycle (RBC) models and New-Keynesian models. These schools mainly differ in market structure, degree of price stickiness and importance of money. The new classical theory inherited several features of classical conception like perfect competition, high degree of flexibility in prices, wages and neutrality of money. Earlier studies on this theory are made by Lucas (1972), (1973) and (1975). With these complementing papers, rational expectation theory is initially embraced into the macroeconomic model. Lucas (1976) known as Lucas Critique, argues that macroeconomic forecasting models based on aggregate observed data may mislead, since they are not based on micro-foundations. Kydland and Prescott (1982) respond to this criticism with a model, called as Real Business Cycle model. The model is featured for perfectly competitive markets, flexible prices and neutrality of money, and it attributes all business cycles in an economy to real variables rather than nominal variables. On the other hand, Keynesians reform the Keynesian theory emphasizing monopolistic competition, nominal price rigidity and short-run non-neutrality of money.

In this chapter after the discussion of DSGE models extensively, we present the distinctive features of Real Business and New-Keynesian schools with empirical evidence. In the second part of the chapter we concentrate on the extensions of the standard NK model especially relevant for the models developed in this study. In this context both empirical evidence and detailed literature survey for 'trend inflation', 'open economy' and 'heterogeneity in price stickiness' are discussed.

2.2. Dynamic Stochastic General Equilibrium (DSGE) Models

One of the objectives behind the formation of dynamic stochastic general equilibrium (DSGE) models is to explain and understand macroeconomic fluctuations using an interrelated and a coherent theoretical framework. Fundamental features of these models can be summarized as follows:

- *Dynamic* implies that models are structured upon infinite horizon opposed to finite horizon like one or two periods.
- *Stochastic* implies that economy is influenced by random shocks.
- *General* implies that the model is constructed for the whole economy.
- *Equilibrium* implies that in every market equilibrium is achieved by interaction of demand and supply. These models are built on microeconomic foundations and emphasize agents' intertemporal choice.

The dependence of current choices on uncertain future events makes the models dynamic and assigns a central role to agents' expectations in the determination of current outcomes. In addition, the models' general equilibrium nature captures the interaction between policy actions and agents' behaviours. Furthermore, a detailed specification of the stochastic shocks enables tracing the transmission mechanisms of them to the economy explicitly. In this way, random components which are important in explanation of cyclical behaviour of the economy can be incorporated.

DSGE framework is constructed upon three blocks, which are the demand block, supply block and the central bank. Agents rationally and optimally behave in these blocks. Agents solve dynamic optimization problems. Equations in demand block and supply block are based on micro-foundations. In demand block, households provide capital and labour to firms, and use output produced by firms as consumption goods. Households maximize their utilities with respect to consumption and labour supply. In supply block, firms use labour and capital, and produce goods. The prices of capital and labour are exogenously determined. By using them, firms aim to maximize their profits. In the economy, all markets clear. The amount of labour demanded by firms equals the amount of labour supplied by households. Similarly, the amount of goods demanded by households equals the amounts of goods supplied by firms.

Basic DSGE models mainly assume that agents are identical. Thus, they are represented by a representative agent. In particular, a representative household represents all households and a representative firm represents all firms. This assumption provides theoretical simplification to models. Otherwise, heterogeneity among agents would make modelling very complex. The output and price levels determined in the demand and supply blocks are fed into the central bank block to establish the monetary policy rule. In turn the nominal interest rate revealed by the central bank affects the real activity in the demand and supply blocks.

DSGE models are based on rational expectations theory. It is assumed that agents make predictions about future events using all available information. Predictions might not be correct in every period, but agents learn from their past mistakes. On average, predictions are fulfilled and they would be the same as actual results obtained from future events.

Initially DSGE models are empirically tested without formal statistical methods. The estimation methods carry very restrictive assumptions compared to econometric models with less restrictive assumptions (An and Schorfheide (2007)). In this respect the path of the modelling framework progress to employ many econometric methods like Generalized Method of Moments (GMM), Simulated Generalized Method of Moments Bayesian Estimation and Maximum Likelihood Estimation (MLE) to are integrated to remove misspecifications in calibration approach. ln this way the quantitative evaluation of theoretical models and their forecasting abilities are improved over time significantly. Therefore, they become useful tools for policy makers, especially for central bankers.

For calibration purposes, most or sometimes all of the values of structural parameters of the model are taken from other micro-econometric studies previously found. Kydland and Prescott (1996) note that those values are taken from "*findings in other applied areas of economics*." The remaining parameters, if not all found previously, are predicted. Plosser (1989) notes*: "The remaining free parameters are chosen to yield, as close as possible, a correspondence between the moments predicted by the model and those in the sample data.*[2]*"*

The most influential studies are written by Smets and Wouters (2005), and Smets and Wouters (2007). Smets and Wouters (2005) estimate the values of structural parameters between 1974 and 2002 using a DSGE model. Smets and Wouters (2007) estimate the values of structural parameters for US economy using a DSGE model between 1996 and 2004.

2.2.1. Real Business Cycle Model

Kydland and Prescott (1982) develop Real Business Cycle model. It is a kind of frictionless model which attempts to explain macroeconomic fluctuations, like recessions, depressions and growth via real shocks, like shocks to technology,

[2] Among others one can refer to Ruge-Murcia (2007), and Fernandez-Villaverde (2010) for a detailed discussion.

consumer preferences and productivity levels in a typical economy. On the other hand, nominal shocks, like interest rate, exchange rate shocks have no impact on the model. According to this theory, economic recession is a natural slowdown of an economy followed by economic expansion. Since there is no friction in the model, the model yields efficient results.

Basic RBC model composes of two agents, which are households and firms. Neither governments nor central banks have an impact on the economy. The representative household maximizes the present value of total utility over infinite horizon subject to budget constraints. The optimization results yield demand for goods and supply for labour. The representative firm maximizes profit at each period subject to an aggregate production function, results in labour demand. Supply for goods is vertical. In the literature, studies where the basic RBC model is extended with government, a foreign sector and financial institutions can be found[3].

The distinctive features of RBC models can be summarized as follows: perfectly competitive markets, flexible prices and neutrality of money. In the framework of a RBC model, all types of markets, which are goods market and labour market, are perfectly competitive. It is a kind of market structure in which there are a continuum of identical firms and labour. Each firm (worker) sells (hires) identical an product (labour force). All firms (workers) in market are price (wage)-takers. Firms (worker) do not have any influence on the equilibrium prices (wages). Moreover, all prices including wages are perfectly flexible. They instantaneously respond to real shocks to clear goods and labour markets in an economy. All markets are complete and there is no information asymmetry. Lastly, 'neutrality of money' implies that changes in money supply only affect nominal variables; prices, wages and exchange rate, but real variables, output, consumption and employment are not affected.

[3] Christiano and Eichenbaum (1992), Baxter and King (1993), Braun (1994), and McGrattan (1994) study the effects of fiscal policies on business cycles. Cooley and Hansen (1989) introduce monetary sector into standard RBC model. Altig *et al.* (2011) and Gali *et al.* (2004) incorporate the monetary policy into RBC model. Mendoza (1991) introduces openness into the standard RBC model and Schmitt-Grohe and Uribe (2003) and Aguiar and Gopinath (2007) study open-economy RBC model.

2.2.2. New-Keynesian Model

A New-Keynesian model emanates from another school of Dynamic Stochastic General Equilibrium model as the one of which is affected by both real and nominal shocks. New-Keynesian models compose of three types of agents, which are households, firms and the monetary authority. Household behaviour is similar to one in RBC model. Optimization results yield aggregate demand for goods and aggregate supply of labour force. There are two types of firms which are intermediate goods producing firms and retail firms. Intermediate goods producing firms produce differentiated goods in monopolistically competitive markets and sell them to retail firms. Retail firms aggregate these goods and sell the final goods to consumers in a perfectly competitive market. Optimization results yield aggregate supply of goods. Aggregate production function is used to obtain aggregate demand for labour. Lastly, the Central Bank controls nominal interest rate. All markets are assumed to be complete. Since the model incorporates frictional features, like price rigidity, wage rigidity, optimization results are inefficient are opposed to a Real Business Cycle model.

2.2.2.1. The Distinctive Features of New-Keynesian Models

The distinctive features of New-Keynesian models are monopolistic competition, nominal price rigidity and short-run non-neutrality of money.

2.2.2.1.1. Monopolistic Competition

In monopolistic competition, there are *N* different firms each producing not perfectly substitute but differentiated goods. This provides some degree of market power to firms. Thus, firms can operate on the elastic side of their demand curves. In line with the empirical findings of nominal price rigidity, it can be claimed that even if some of firms reset their nominal prices at levels to maximize their profits in the face of changing conditions, the rest of them may keep their prices constant. The pricing-resetting firms do not lose all their demands to the rest of firms which keep prices stable.

2.2.2.1.2. Nominal Rigidity

Nominal Rigidity (NR) is one of the most important features of the New-Keynesian models. NR refers to a case where a nominal variable, like price or wage level, is resistant to change in response to nominal or real shocks. In other words, prices (wages) do not immediately respond to changing conditions.

Table 2.1 Summary of Literature on Monthly Frequency and Price Spell Across Countries

Country	Duration	Type of Measurement	Period	Source
Belgium	16.9	Monthly Frequency	1989:01-2001:01	Aucremanne and Dhyne (2005)
Brazil	37.2	Monthly Frequency	1996:03-2008:12	Barros *et al*. (2009)
Canada	6.8	Price Spell[4]	2002:07-2003:04	Amirault *et al*. (2006)
The Euro Area	12.3	Price Spell	2003-2004	Fabiani *et al*. (2005)
The Euro Area	15.1	Monthly Frequency	1996:01-2001:01	Dhyne *et al*. (2006)
The UK	8.2	Price Spell	September 1995	Hall *et al*. (2000)
The USA	29.9	Monthly Frequency	1988:02-2005:01	Klenow and Kryvtsov (2008)
The USA	4.6	Price Spell	1995:01-1997:12	Bils and Klenow (2004)

[4] Price-spell is a time duration along which nominal prices remain constant.

Table 2.1 (Con't) Summary of Literature on Monthly Frequency and Price Spell Across Countries

The UK	15	Monthly Frequency	1996:01-2006:01	Bunn and Elis (2009)

Source: Klenow & Malin (2011, pg 236, 239)

Table 2.1 presents a sample of empirical studies on monthly frequency and price-spell of different countries, Belgium, Brazil, Canada, the Euro Area' countries, the UK and the USA.

Aucremanne and Dhyne (2005) study the monthly frequency for Belgium, Barros *et al.* (2009) study for Brazil, Amirault *et al.* (2006) study for Canada and Hall *et al.* (2000 study for the UK. On the other hand, Fabiani *et al.* (2005) and Dhyne *et al.* (2006) study for Euro Area and, Klenow and Kryvtsov (2008), and Bils and Klenow (2004) study for the USA. All studies indicate the presence of NPR in different countries.

Dhyne *et al.* (2006) also study frequency of price change across sectors for the Euro Area and conclude that heterogeneity-in price stickiness across sectors is present. They find that the highest frequency of price change is in energy sector with 78 percent and the lowest frequency of price change is in service sector with 5.6 percent in the Euro Area. Bils and Klenow (2004) indicate that the frequency of price change is heterogenous across sectors for the USA. They find that the highest frequency of price change is in raw materials with 54.3 percent and the lowest frequency of price change is in medical care with 9.4 percent in the USA.

On the other hand, there are also studies which indicate the presence of nominal wage rigidity. Druant et al. (2009) analyse the wage behaviour in EU countries and the survey is conducted between the end of 2007 and the first half of 2008. They find that 54 percent of firms adjust wages in a particular month. They find that nominal prices are more rigid than nominal wages and mean duration of price spell is in every 15 months and mean duration of wage spell is in every 10 months.

Sigurdsson and Sigurdardottir (2011) analyse the wage setting behaviour of Iceland between 1998 and 2010. The wage spell is 8.9 months. Mean frequency of wage change is monthly 10.8. They find that half of wages are re-set in January in Ireland. Lünnemann and Wintr (2009) evaluate the wage setting behaviour of Luxemborg between 2001:01 and 2007:01. They find that the adjusted monthly frequency of wage change is between 5 and 7 percent, price changes are more often wage changes and that firms set their nominal wages around January in Luxembourg.

According to the NK literature, Nominal Price (or Wage) Rigidity can be classified either as time-dependent pricing or state-dependent pricing, depending on the motivation of price change.

2.2.2.1.2.1. Time-Dependent Nominal Rigidity

It is a type of nominal rigidity in which timing of price change is exogenously determined, regardless of the macroeconomic situation. There are two different types of time-dependent nominal rigidities, which are Calvo style and Taylor style.

2.2.2.1.2.1.1. Calvo Style Nominal Rigidity

Calvo (1983) proposes the following pricing rule: In period t, (1- θ) fraction of firms adjust their prices under profit maximization and θ fraction of firms keep their prices at the level which they set at time $(t-1)$. The other firms do not know exactly when they update their prices. They only know a probability distribution over the price spells. Thus, timing of price change for firms is random.

2.2.2.1.2.1.1.1. Homogeneity in Price Stickiness

All the firms face the same probability distribution for price change. Each firm changes its price with the same probability. Yun (1996) formulizes Calvo Pricing Rule as follows without indexation:

$$P_t^{1-\epsilon} = (\theta)P_{t-1}^{1-\epsilon} + (1-\theta)(P_t^*)^{1-\epsilon} \qquad (2.1)$$

where P_t is the price level at time *t*, P_{t-1} is the price level at time $t-1$ and P_t^* is the reset price level at time t and ϵ is the elasticity of substitution among differentiated goods.

Table 2.2 Summary of Literature on the Degree of Price Stickiness Across Countries

Country	Calvo Price Stickiness	Period	Source
The USA	0.588	1954:I and 2003:IV	Cogley and Sbordone (2008)
The USA	0.593	1960:I and 2012:IV	Ascari and Sbordone (2014)
The Euro Area	0.912	1985:I and 2004:IV	Sahuc and Smets (2008)
The USA	0.908	1966:I and 2004:IV	Smets and Wouters (2003)
Australia	0.89	1991:I and 2006:II	Nimark (2009)
The UK	0.70	1992:III and 2008:II	Fragetta and Kirsanova (2010)

Table 2.2 (Con't) Summary of Literature on the Degree of Price Stickiness Across Countries

The USA	0.83	1954:III and 2004:I	Del Negro *et al.* (2007)

Table 2.2 presents Calvo Price Stickiness θ for the USA, the EU, Australia and the UK for different periods. As can be seen from Table 2, there is a heterogeneity in price stickiness among countries.

2.2.2.1.2.1.2. Taylor Style Nominal Rigidity

The initial model by Taylor (1980) for wage-setting is generalized for price resetting for multiple periods. All firms are divided into *N* cohorts. In each cohort, $\frac{1}{N}$ fraction of firms reset their prices. Firms in the first cohort can re-set their prices in the next $(N+1)^{th}$ cohort.

2.2.2.1.2.2. State Dependent Nominal Rigidity

It is a type of nominal rigidity in which timing of price change depends on circumstances rather than duration as in Taylor (1980) and Calvo (1983). Timing of price-change is endogenously determined, depending on the benefits and costs of price change, particularly menu cost. Once supply-demand changes require a new equilibrium, firms consider benefits and costs of nominal price change to decide whether resetting prices is effective or not. If the benefits surpass the costs, firms reset their nominal prices where supply and demand are in balance. In the opposite case, firms do not adjust their nominal prices, even though the demand-supply equilibrium requires price adjustment (Mankiw (1985)). Thus, menu cost leads to nominal price rigidity.

There are a variety of empirical studies employing different methods to explore the relationship between menu costs and nominal price rigidity. Golosov and Lucas (2007) develop a model featured by menu cost and indicate that the model with menu cost match the price behaviour of micro-data for the US economy. Fishman and Simhon (2005) develops a model in which even very small menu costs yield price rigidity in a decentralized search market. Dixon and Hansen (1999) indicate that menu cost incurred by a sector influences the rest of economy. Levy *et al.* (1997) analyse menu-cost for US economy between 1991 and 1992. They find that menu costs are so high that they may prevent firms from resetting nominal price levels. The results obtained through their analysis are non-trivial in the light of Blanchard and Kiyotaki (1987) and Ball and Romer (1990)' menu cost models. Anderson et al. (2015) analyse menu cost by using the data of a large US retailer between 2005 and 2009 and indicate that menu costs yield lower price changes. Levy *et. al* (1998) analyse price adjustment behaviour for five large supermarkets and one drugstore between 1991 and 1992 for the US economy and find that frequency of price change is lower in stores where the item-pricing laws are applied. Dutta *et al.* (1999) analyse the cost of price change between July and October 1992 in an US drugstore and find that menu costs are non-trivial and note that price changes in the drugstore are weakly basis. On the other hand, Gautier and Bihan (2018) analyse nexus between menu cost and price rigidity using large French dataset between 1994 and 2014 and find that menu cost explains nominal price rigidity to some extent. Hall *et al.* (2000) analyse the price behaviour of the UK firms using the survey conducted in 1995 and report that menu cost is not a significant factor for nominal price rigidity.

2.2.2.1.3. Short-run Non-Neutrality of Money

Another important deviation from the Real Business Cycle model of the New-Keynesian model is the short-run non-neutrality of money. This implies that real variables like output and consumption are induced by changes in nominal interest rate. In other words, Classical Dichotomy is abandoned in the framework of the New-Keynesian model.

According to the New-Keynesian framework, non-neutrality of money can be attributed to nominal price rigidity. In particular, due to nominal rigidity, monetary policy shock does not bring about one-to-one change in the expected inflation rate. Therefore, real interest rate does not remain the same, and then real variables such as output, consumption and investment are affected. Shortly we can claim that nominal rigidity is beneath the non-neutrality of money.

The role of money for in an economy can be described by monetary policy rules. Among the most popular ones, Taylor Rule can be cited.

2.2.2.1.3.1. Taylor Rule

Taylor (1993) proposes a fixed policy rule where the Central Bank adjusts nominal interest rate in response to macroeconomic conditions. In particular, nominal interest rate is a function of output gap and inflation rate deviation from the target level. The standard Taylor Rule can be expressed as follows:

$$i_t = \pi_t + r_t^* + a_\pi(\pi_t - \pi_t^*) + a_y(y_t - \bar{y}_t) \qquad (2.2)$$

where i_t is the nominal interest rate, π_t is the inflation rate, r_t^* is the equilibrium real interest rate, π_t^* is the target rate of inflation, y_t is the log of output and $\bar{y}_t$ is the log of potential output. In his paper a_π, and a_y are parameters for interest rate deviation from trend inflation and output gap, respectively and both are suggested to be 0.50.

Equation (2.2) implies that in case of any deviation from the target rate of inflation, the Central Bank responds by raising nominal interest rate. This interpretation is also valid for output gap.

In the literature, there exist several modified versions of the Taylor rule. These depend on either contemporaneous variable(s), forward-looking variable(s), backward-looking variable(s), its inertia and/or combinations of them.

Clarida *et al.* (1998) extend the standard Taylor Rule with forward-looking and backward-looking behaviour. In this case, nominal interest rate depends on the expected inflation rate, contemporaneous output and inertial interest rate as shown below. They econometrically analyse this monetary policy rule through GMM method for the US, Japan, the UK, Germany, France and Italy[5]. They find that Central Bank (CB)s of Germany, Japan and US weakly respond to inertial interest rate, but they strongly respond to expected inflation with nominal interest rate. For the rest of countries, monetary policies are influenced by Bundesbank.

$$i_t = (1-\rho)\left(\theta + \phi_\pi \pi_{t+1} + \phi_y \tilde{y}_t\right) + \rho i_{t-1} \qquad (2.3)$$

where ρ is the coefficient of backward-looking variable.

Taylor (2001) re-visit the papers of Ball (1999), Taylor (1999) and Svensson (2000). The novelty of these studies is inclusion of real exchange rate into the standard Taylor rule as follows:

[5] The samples for Italy, France, Japan, Germany, US and the UK are 1981-1989, 1983-1989, 1979-1994,1979-1993,1979-1994 and 1979-1990, respectively.

$$i_t = \phi_\pi \pi_t + \phi_y \tilde{y}_t + h_o e_t + h_1 e_{t-1} \tag{2.4}$$

where e_t is the real exchange rate, h_o and h_1 are the coefficients of the real exchange rate at current and previous periods, respectively.

Ball (1999) finds that the volatility of inflation rate is lower in the open-economy than in the model without exchange rate. This implies that Taylor rule performs better in the open economy model. Taylor (1999) finds that the rule shows better performance for Italy and France, but lower performance to some extent for Germany. More specially, Taylor (1999) compares the standard Taylor rule results for Germany, Italy and France with the standard Taylor rule extended with nominal exchange rate over the period between 1971 and 1994. He finds that the standard deviation of inflation rate decreases for all countries in the latter compared to the former. However, the volatility of output decreases only in France and Italy in the second model compared to the first model.

Judd and Rudebusch (1998) estimate the modified Taylor rule with error correction model in equations 2.5 and 2.6. They analyse this rule over the Burns, Volcker and Greenspan periods for the US economy using different definitions of inflation and output[6].

$$i_t^* = \pi_t + r^* + \lambda_1(\pi_t - \pi^*) + \lambda_2 y_t + \lambda_3 y_{t-1} \tag{2.5}$$

$$\Delta i_t = \gamma(i_t^* - i_{t-1}) + \rho \Delta i_{t-1} \tag{2.6}$$

[6] Arthur Burns is the governor of Federal Reserve Bank over the period between 1970 and 1978, Paul Volcker is the governor of Federal Reserve Bank over the period between 1979 and 1987. Alan Greenspan is the governor of Federal Reserve Bank over the period between 1987 and 2006.

where r^* is equilibrium real federal funds rate, π^* is target inflation rate, λ_1 is the coefficient of inflation rate deviation from inflation targeting, λ_2 and λ_3 are the coefficient of output gap at time t and time t-1, γ is the coefficient for error correction term variable and ρ is the coefficient of difference variable for interest rate between time t-1 and t-2.

They conclude that the estimated standard Taylor rule matches the data for Greenspan period, it does not match for Burns and Volcker periods. Furthermore, they find that fund rate weakly responds to inflation rate in Burns period and fund rate gradually responds to reach inflation target in Volcker period. For Greenspan period, they find that the data better fits the modified Taylor rule than the standard Taylor rule.

2.2.2.1.3.2. Taylor Rule with Zero-Lower Bound (ZLB)

ZLB is an economic situation where the nominal interest rate is at or very near to zero. This circumstance stays an academic exercise until the financial crisis of 1991 in Japan. Subsequent to the crisis, the Bank of Japan radically reduces the nominal interest rate near to zero to overcome the burdens of financial crisis. Krugman (1998, 1999) and Svensson (2000) state that perpetual decline in nominal interest rates in the US and the Euro Area shrink room where Central Banks can manoeuvre to reduce the nominal interest rates even more. Thus, ZLB may leap to these economies. This forecast becomes valid with the Global Financial Crisis of 2007. This policy is widely followed by the most of the developed countries' Central Banks, *i.e.* the FED, the ECB, Bank of England and Bank of Canada in the Credit Crunch in 2007 and more recently in the Covid-19 Pandemic in 2020. Their nominal interest rates approach or hit zero. The main reasons of applying this policy are to increase credit demand for firms and to urge households to save less and consume more. In short, the aim is to start recovery in their economies by boosting. The related monetary policy rule can be expressed as follows:

$$i_t = \max\left[\, \phi_\pi(\pi_t - \pi^*) + \phi_y \tilde{y}_t, 0\right]$$

However, in this case, they lose their abilities to affect economic conditions by lowering the nominal interest rate even more. In other words, the Central Bank can not apply Taylor rule.

2.2.2.1.3.3. Taylor Rule with Determinacy Region

Determinacy region is a set of Taylor-rule parameters such as ϕ_π, ϕ_y and ϕ_e within which Taylor rule leads the model to unique equilibrium in response to a shock. Within this region, economy is on unique equilibrium path and converges to the unique point. To show how Taylor rule parameter affect determinacy, following Blanchard and Kahn (1980), we employ a basic NK model.

$$\hat{\pi}_t = \kappa \hat{y}_t + \beta \hat{\pi}_{t+1}$$

$$\hat{y}_t = \hat{y}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1})$$

$$\hat{\imath}_t = \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + v_t$$

When we solve equations above, the following determinacy condition is reached[7]:

$$(\phi_\pi) + \frac{(1-\beta)\phi_y}{\kappa} > 1$$

This condition implies that one-percent sunspot increase in inflation expectation requires more than one-percent increase in interest rate to reach unique equilibrium; otherwise, multiple equilibria arise. When the Central Bank does not sufficiently respond by raising inflation rate through Taylor rule, this sun-spot increase becomes self-fulfilling reciprocity. In other words, an increase in current inflation is observed next period. The area of determinacy region not only depends on different versions of Taylor Rule parameters but also other features like homogeneity (heterogeneity) in price-stickiness, indexation to price level or trend inflation, trend inflation rates. Relative to the standard Taylor rule, determinacy region enlarges or shrinks with enriching these features into the standard model. In Chapter 4 detailed discussion about determinacy region is provided.

2.3. Extensions to Standard New-Keynesian Model

To sum up it can be claimed that the standard New-Keynesian model is generated by assuming zero-trend inflation rate, closed-economy and homogeneity-in-price stickiness. However, as discussed in detail and supported with empirical evidence, below all of these assumptions are counterfactual. These assumptions namely trend inflation, open-economy and heterogeneity in price stickiness are incorporated into the papers in this thesis. In particular, positive trend inflation and openness are the main contributions for both papers, but heterogeneity in price-stickiness is integrated in the second paper. In the rest of the chapter, a brief literature review on the effects of these features on the dynamics of NK model is presented also. It is initially discussed why

[7] Detailed solution is exhibited in the appendix.

these features are important for models developed in these papers. Then, it is analysed how these features change the dynamics of New-Keynesian Philips Curve (NKPC)[8], specifically the importance of current (*i.e.* the slope of NKPC) and forward-looking variables.

2.3.1. Positive Trend Inflation (*Inflation Targeting*)

Following the Global Financial Crisis in 2008-9, trend inflation gains importance once more with ZLB phenomenon. As discussed above the Central Banks have strongly reduced interest rates near zero which is known as ZLB. Exactly at this point, higher inflation targeting becomes a debate, whether to use monetary policy tools to prevent interest rates hitting ZLB or not. Broadly two opposite views can be cited on this debate. Briefly, Blanchard *et al.* (2010), Williams (2009) and Ball (2013) suggest that higher inflation targeting leads to higher inflation environment and so higher nominal interest rates. Thus, in case of a deflationary shock, the Central Bank has more room to decrease inflation rate to combat with this shock. On the other hand, Bernanke (2010) responds to this suggestion as follows:

> *Inflation expectations appear reasonably well-anchored, and both inflation expectations and actual inflation remain within a range consistent with price stability. In this context, raising the inflation objective would likely entail much greater costs than benefits. Inflation would be higher and probably more volatile under such a policy, undermining confidence and the ability of firms and households to make longer-term plans, while squandering the Fed's hard-won inflation credibility. Inflation expectations would also likely become significantly less stable, and risk premiums in asset markets – including inflation risk premiums – would rise.*[9]

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[8] The slope of the NKPC is important for the transmission of shocks and determines the output-inflation trade-off faced by policymakers.

[9] Chairman Ben S. Bernanke, "The Economic Outlook and Monetary Policy," Remarks at the Federal Reserve Bank of Kansas City Economic Symposium, Jackson Hole, Wyoming, August 27, 2010, http://www.federalreserve.gov/newsevents/speech/bernanke20100827a.pdf

He underlines that higher inflation targeting damages inflation expectations and so the pricing behaviour of firms. In turn, higher contemporaneous inflation and higher volatility in inflation occur. For this reason, starting with the studies of King and Wolman (1996), Ascari (2000, 2004) and Ascari and Ropele (2007), trend inflation becomes a research topic in the New-Keynesian models.

2.3.1.1. Evidence

Figure 2.1 represents the average CPI inflation rates for four advanced economies, Canada, Germany, the UK and the USA, between 2000 and 2018. It is seen that the average CPI inflation rates are above zero inflation rate with the exemption of unique case for the USA in 2009. Figure 2.2. represent inflation target rates for Canada, EU, the UK and the USA between 1991 and 2020. The Bank of Canada sets inflation target at 2 percent ±1, the ECB set inflation target right below 2 percent, and the FED and Bank of England set inflation target at 2 percent in 2020. Therefore, zero-trend inflation rate assumption becomes counterfactual and might lead to misestimation and misinterpretation of macroeconomic models.

Source: World Bank (2020). Retrieved from
https://data.worldbank.org/indicator/FP.CPI.TOTL.ZG?end=2019&start=1960&view=chart

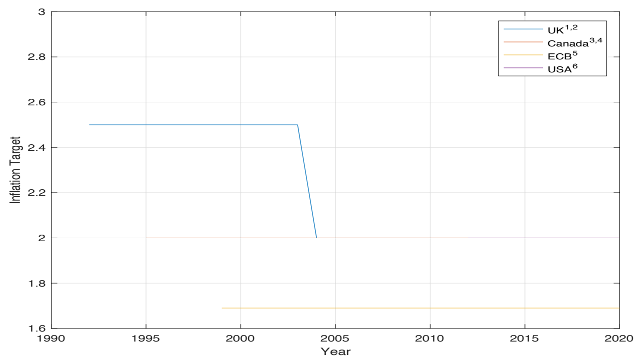
Figure 2.1 CPI Inflation Rates

Empirically, the effects of trend inflation on contemporaneous inflation, inflation expectations and output are widely analysed in the literature. Petursson (2004), Vega and Winkelried (2005), and Mishkin and Schmidt-Hebbel (2007) discuss the effects of trend inflation on inflation[10]. Even though different econometric methods are employed, they have similar results regarding the implications of trend inflation on inflation and volatility. They find that inflation targeting helps to reduce both inflation rate and volatility in the countries. Moreover, Levin *et al.* (2004), Batini and Laxton (2006), Gurkaynak *et al.* (2007) estimate the effect of inflation targeting on anchoring inflation expectations[11]. Among those studies, only Gürkaynak et al. (2007) is utilized a NK model. The authors reach a consensus and find that inflation targeting significantly anchors inflation expectations with exemptions of Emerging Markets Economies in Levy et al (2007) and US in Gurkaynak et al. (2007). Gurkaynak et al. (2007) conclude that forward inflation compensation depends on macroeconomic news and announcements in US.

From the empirical evidence it is evident that incorporating positive trend inflation into the standard NK model is not just an academic exercise, but it is also important to enlighten the actual effects of positive trend inflation on macroeconomic dynamics.

[10] Petursson (2004) uses Seemingly Unrelated Regression method for a group of developed countries over the period between 1981 and 2002 except for the Czech Republic. Its data set starts from 1990. Vega and Winkelried (2005) use difference-in-difference estimator method for a different group of countries. Mishkin and Schmidt-Hebbel (2007) use the pooled OLS and IV methods for a group of countries over the period between 1989 and 2004.

[11] Levin, Natalucci and Piger (2004) use a pooled regression for Australia, Canada, New Zealand, Sweden, the United Kingdom, the United States, Japan, Denmark, France, Germany, Italy, and the Netherlands over the period between 1994:Q1 and 2004:Q2. Batini and Laxton (2007) use OLS method for a group of 44 emerging countries over the period between 1985 and 2004. Gurkaynak et al. (2007) use daily bond yield data for Canada, the USA and Chile. They employ a standard NK model in Clarida, Galí, and Gertler (2000) and a model with backward-looking variables in Rudebusch (2001). The data covers the period between 1998 and 2005 for the US and Canada, and the period between 2002 and 2005 for Chile.



Sources: [1]Bank of England (2019) Retrieved from https://www.bankofengland.co.uk/monetary-policy/inflation; [2] Alexander (2006, pg 398);[3] Bank of Canada. (n.d.) Retrieved from https://www.bankofcanada.ca/core-functions/monetary-policy/inflation/; [4]Bank of Canada. (2011). Retrieved from https://www.bankofcanada.ca/wp-content/uploads/2011/11/background_nov11.pdf ;[5]European Central Bank. (n.d.). Retrieved from https://www.ecb.europa.eu/mopo/html/index.en.html,[6] Federal Reserve Bank (2020) Retrieved from https://www.federalreserve.gov/faqs/money_12848.htm

Figure 2.2 Inflation Target Rates for the Countries[12],

2.3.1.2. Literature

Since King and Wolman (1996) and Ascari (2000), the effects of positive trend inflation have been one of the most appealing topics in the NK framework. Ascari and different co-authors (2004, 2007 2009, 2014), Sahuc (2006) and Bakhshi (2007) discuss the effects of positive trend inflation on the dynamics of NK models.

Ascari (2004) initially incorporates positive trend inflation into the standard NK model and discusses the effects of it on short-run and long-run dynamics of the model in his influential paper. He finds that steady-state of output decreases as trend inflation increases. On the other hand, he analyses the effects of money supply shock on the

[12] The Bank of Canada started inflation targeting in 1991 and set to 3 percent. The target midpoint continuously changed between 1991 and 1995. Thus, target rate is shown since 1995 in Figure 2.2. (See Bank of Canada. (2011, pg 5). Retrieved from https://www.bankofcanada.ca/wp-content/uploads/2011/11/background_nov11.pdf)

dynamic properties of output at different rates of trend inflation and concludes that trend inflation has significant effects on the dynamics of output. Ascari (2004) finds that as trend inflation increases, the slope of NKPC decreases and the effect of trend inflation on NKPC is weak when indexation is introduced into the model.

Ascari and Ropele (2007) discuss the effects of positive trend inflation on welfare under optimal monetary policies and on the dynamics of variables. As trend inflation increases, total welfare loss increases under both commitment and discretionary policies. In particular, volatility of inflation rate increases, while volatility of output decreases in both types of monetary policy at higher trend inflation rates.

Ascari and Ropele (2009) analyse the effect of positive trend inflation determinacy region under contemporaneous Taylor rule and inertial versions of Taylor rule in case of no-indexation, partial indexation and full-indexation.[13] They find that trend inflation rate has implications on the determinacy region under all types of monetary policy rule in the cases of no-indexation and partial indexation. In case of full-indexation, trend inflation does not affect determinacy region.

Ascari and Sbordone (2014) discuss the effect of positive trend inflation on both determinacy region and the dynamics of the model in response to types of shocks. They find that higher trend inflation shrinks determinacy region. On the other hand, they analytically indicate how trend inflation affects variables in response to shocks.
All papers mentioned above reach a consensus that positive trend inflation has implications on the dynamics of the NK model. The driving reason behind this result is how positive trend inflation affects the importance of current variables and importance of forward-looking variables on the NKPC. For current variables', it can

[13] Full indexation means that firms, which do not update their nominal prices through optimization, make their nominal prices fully index to inflation rate in time t-1. Partial indexation means that firms, which do not update their nominal prices through optimization, make their nominal prices partially index to inflation rate in time t-1. No-indexation means that firms, which do not update their nominal prices through optimization, keep their nominal prices unchange at time t-1.

be called as the slope of NKPC. As trend inflation increases, NKPC becomes flatter. On the other hand, the importance of forward-looking variables on current inflation increases at higher trend inflation rate. The intuition behind this dynamics is that higher trend inflation makes price-resetting firms more forward-looking and these firms increase their nominal prices more than the average nominal prices when they have opportunity to increase. Otherwise, their relative prices decrease as trend inflation rate increases.

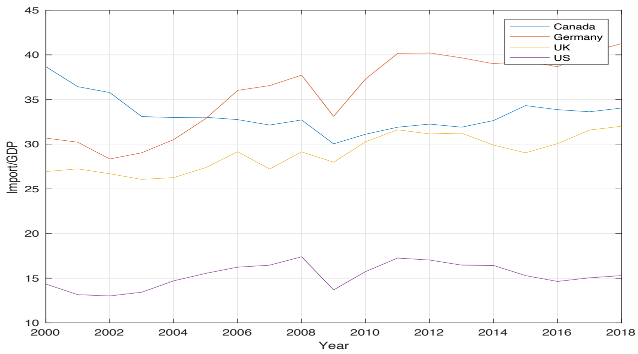
The effect of higher trend inflation on the NKPC is also econometrically discussed. Cogley and Sbordone (2008) in their influential paper on the NK model estimate structural parameter values, which are price indexation parameter, Calvo parameter and elasticity of substitution of intermediate goods by following two-step estimation procedure. The first step is to fit the data unrestricted VAR and the second step is to estimate the parameters based on these estimates in the first step. They use the sample period between 1954 and 2003 for the US economy. They find that the importance of current variables and importance of forward-looking variables vary as trend inflation rate increases. Higher trend inflation flattens the slope of NKPC, but increases the importance of forward-looking variables on NKPC. Their findings are consistent with the studies mention above.

Ascari and Sbordone (2014) estimate structural parameters, price indexation parameter, Calvo parameter and elasticity of substitution of intermediate goods, in NK model by following the method proposed by Cogley and Sbordone, (2008). The data covers the period between 1960 to 2012 for the US economy. They reach the similar results with Cogley and Sbordone (2008). Then, they find that as trend inflation increases, the importance of current variables (*i.e.* the slope of NKPC) decreases, while forward-looking variables' increases.

2.3.2. Open Economy

Starting from Smith and Ricardo, the implications of international trade on domestic economy has been extensively discussed in economics literature from many different aspects. Although international trade is not only the subject matter of economic development, and international finance, but also international relations, politics and sociology, most of the models in New-Keynesian framework neglect the importance of international trade and are based on closed-economy assumption. However, it is an inevitable fact that international trade is not an ignorable parameter in today's global world. In Figure 2.3, the share of imports to GDP is shown for four developed countries for 2000-2018 period. Except for the US an increasing trend in the share of imports is observed in this period.

International trade feature has been incorporated into models through 'degree of openness' measure. Degree of openness is the importance of non-domestic transaction in the GDP of a country. It can be measured in two different ways. While the first one is the ratio of trade volume (import + export) to GDP, the other is the ratio of imports to GDP. In this analysis, the second definition of openness is employed.



Source: World Bank (2020) Retrieved from https://data.worldbank.org/indicator/NE.IMP.GNFS.ZS

Figure 2.3 the Import/GDP Ratios of the Countries

2.3.2.1. Literature

Gali and Manocelli (GM) (2005) develop an influential small open economy version of the standard New-Keynesian model. In their paper, they analytically discuss the effects of openness on the slope of Small Open Economy NK model, dynamic IS curve and the dynamics of a variable, marginal cost. Then, they analyse the macroeconomic implications of four regimes, optimal monetary policy, domestic inflation-based Taylor rule, CPI inflation-based Taylor rule and pegging. We benefit from GM (2005) model in both of the papers in this thesis. While the standard GM (2005) model is employed in the first paper, two-open and identical economy version of GM (2005) is employed in the second paper.

2.3.3. Heterogeneity in Price Stickiness

2.3.3.1. Evidence

Bils and Klenow (2004) for the U.S. economy and Dhyne et al. (2006) for the Euro Area and the US economies evaluate the degree of price stickiness. Bils and Klenow (2004) estimate the frequency of price changes for 350 categories of goods and services using the US CPI data over the years of 1995 and 1997. Dhyne et al. (2006) conduct the same analysis for 50 consumer product categories between 1996 and 2001. Both papers indicate that the degree of nominal rigidity across sectors is not homogenous. In other words, the frequency of price change across sectors varies.

2.3.3.2. Literature

In the light of these evidence, Carvalho (2006) generalizes the standard Calvo equation for sectoral heterogeneity in the following way:

$$P_{k,t}^{1-\epsilon} = (\theta_k)P_{k,t-1}^{1-\epsilon} + (1-\theta_k)\left(P_{k,t}^{*}\right)^{1-\epsilon} \qquad (2.7)$$

where θ_k is the sectoral Calvo parameter, $P_{k,t}$ is the sectoral price level at time *t*, $P_{k,t-1}$ is the sectoral price level at time $t-1$ and P_t^* is the sectoral reset price level at time t, and ϵ is the elasticity of substitution among differentiated goods at sector *k*.

Kara and Yates (forthcoming) discuss how heterogeneity-in-price stickiness changes the effect of positive trend inflation on the dynamics of NKPC. They find that a more rigid sector induces even flatter sectoral NKPC at higher rates of trend inflation compared to the standard NK model. In particular, the importance of current variables decreases even more, while the importance of forward-looking variables increases even more at higher rates of trend inflation on the NKPC.

CHAPTER 3

THE MACROECONOMIC EFFECTS OF POSITIVE TREND INFLATION IN A SMALL OPEN ECONOMY

3.1. Introduction

Most of the popular New-Keynesian models make a simplifying assumption and presume that there is no inflation in the steady state. However, even during the Great Moderation, average inflation rates in the developed economies have been around 2.5 percent. Accordingly, starting with King and Wolman (1996) and Ascari (2000), several authors relax the zero-trend inflation rate assumption and allow for positive trend inflation in their models.

When analysing trend inflation so far, the existing literature has focused on the implications of higher trend inflation target using closed economy models. However, in today's global world openness could not be ignored for almost all countries. Therefore, using closed economy models to examine the effects of trend inflation may be misleading.

In this paper, the challenge of extending a small open economy model proposed by Gali and Monacelli (2005) is taken to account for positive trend inflation. Then the new model is used to study the effects of trend inflation on macroeconomic dynamics for Canada and the UK. The reasons behind why Canada and the UK are chosen are as follows. First, both economies are good examples of small-open economy. They are significantly affected by a large economy. For example, Credit Crunch in the USA adversely impresses both economies. However, any policy change in those economies does not stimulate the rest of the world. Second, both economies are inflation-targetters. Third, the Bank of Canada and Bank of England reduced their nominal interest rates near zero level to combat the deflationary effect of Global Financial Crisis. However, the reason why two economies are chosen is that both countries have similar features, but different openness rates and different Calvo parameters. It is thought that different openness rates and Calvo parameters may significantly change the effect of trend inflation on macroeconomic variables. In the model, when trend inflation is zero, it collapses to that in Gali and Monacelli (2005). It is analytically discussed the effects of positive trend inflation on the dynamics of the model and the ways in which it differs from the one in closed-economy model proposed by Ascari and Sbordone (2014). We then turn to analyse the effects of positive trend inflation on the short-run dynamics of the model and the effect of openness at a given level of positive trend inflation in response to monetary policy, demand and cost-push shocks.

To explain the intuition behind the results below, it is first discussed how positive trend inflation affects price-resetting behaviour of domestic firms and how openness alleviates (aggravates) the effects of trend inflation on the short-run dynamics of the variables. First, as Ascari and Ropele (2009) emphasise, the effect of trend inflation on price-resetting behaviour firms works through two channels. The first channel is that positive trend inflation makes domestic firms more forward-looking on resetting their prices and the second channel is that domestic firms set their prices higher than the average domestic price level. The reason behind the second channel is that price-resetting firms may not be able to re-set their nominal prices instantaneously and their nominal prices would be eroded relative to the average domestic price level. To hedge their prices against inflation, they set a higher price when they get opportunity to do so. Openness provides another channel through which positive trend inflation affects the dynamics of model. For a given degree of openness, prices of domestic goods become more expensive relative to imported goods and real exchange rate decreases with higher trend inflation. Since imported goods are cheaper, the effect of trend inflation on Consumer Price Index (CPI) is reduced. Second, openness does not cause any change in the effect of positive trend inflation on the process of price-resetting and the relative importance of current and future variables in the New-Keynesian Philips Curve (NKPC). However, the interaction between openness and trend inflation affects the dynamics of the model through the real exchange rate dynamics. For a given level of openness, the effect of shock on the real exchange rate increases with the increased trend inflation, leading domestic economy to import from the rest of the world more and this decreases the impact of the increased trend inflation on CPI inflation. On the other hand, the response of real exchange rate to shock becomes more persistent, as trend inflation rate increases.

The effects of positive trend inflation in response to monetary policy, demand and cost-push shocks are quantitatively studied. It is found that higher trend inflation decreases (increases) the effect of monetary policy (demand) shock on domestic inflation while it increases the effect of monetary policy (demand) shock on output. The reason is that increase in trend inflation rate flattens New-Keynesian Philips Curve. Thus, reduction in current output has smaller impact on domestic inflation. On the other hand, foreign goods become relatively cheaper as trend inflation rises. The effect of positive trend inflation on CPI inflation is limited for both types of shock. In the case of the cost-push shock, higher trend inflation makes domestic inflation increase and output decrease more. This is because positive trend inflation destabilises domestic inflation expectations. Thus, domestic price level rises more and output drops more with increasing trend inflation. Since foreign goods become cheaper with higher trend inflation, the effect of trend inflation on CPI inflation is lower relative to that on domestic inflation in response to the shock.

Further it is examined whether the model developed can provide an explanation for the Delayed-Overshooting Puzzle and the Purchasing Power Parity (PPP) Puzzle under alternative scenarios. It is found that higher trend inflation yields more persistent and volatile dynamics of the real exchange rate under all scenarios excluding independent and identically distributed (*i.i.d.*) demand shock with the inertial policy rule. Moreover, it is found that trend inflation induces the delayed-overshooting of the real exchange rate in response to the persistent cost-push shock with/out inertial policy rule and persistent demand shock.

In Section 3.2 the model is introduced. In Section 3.3 the Impulse Response Functions (IRF)s are presented in response to monetary policy, demand and cost-push shocks and the effects of these shocks at higher levels of trend inflation are discussed. In Section 3.4 the IRFs in response to the shocks implied by the open-economy case relative to that implied by closed economy case are plotted and the effects of these shocks at higher levels of trend inflation are discussed. In section 3.5, whether positive trend inflation solves Delayed-Overshooting Puzzle and Purchasing Power Parity (PPP) Puzzle or not under alternative scenarios is examined. Section 3.6 presents the results of Robustness analysis. Section 3.7 compares the findings with the existing literature and Section 3.8 concludes the study.

3.2. General Setting[14]

In the model, there are a continuum of countries and a typical and infinitely-lived household residing in a country. The countries initially have identical conditions (*i.e.* zero-net asset holdings and ex-ante environment) at time-0. There is no friction in the labour market. The household provides labour force to domestic intermediate firms and purchase composite consumption index including both domestically produced and imported goods. The household can purchase internationally traded state contingent bonds without transaction cost. Moreover, in every country, there are a continuum of monopolistically competitive intermediate firms indexed by $j \in [0,1]$ and a final good producing firm. The firms produce differentiated goods and they use the Calvo rule on resetting prices.

[14] Full model and all derivations are detailed in Appendix II-A.1.

Note that the variables with subscript $i \in [0,1]$ indicate belongingness of those variables to country i. The variables without any index notation show belongingness of the variables to domestic economy. The variables which represent the world economy are indicated by a star superscript.

3.2.1. The Model

In this section, the demand, equilibrium and monetary policy parts are introduced. The demand side and equilibrium parts of the model is identical to the model in Gali and Monacelli (2005). For the monetary policy part, the standard Taylor rule is followed.

The utility function of the typical household and its budget constraint are as follows:

$$U(C_t, N_t) = E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_{t+k}^{1-\sigma}}{1-\sigma} - \frac{N_{t+k}^{1+\varphi}}{1+\varphi}\right) \tag{3.1}$$

subject to

$$P_t C_t + E_t\left(Q_{t,t+1} B_{t+1}\right) = W_t N_t + B_t + D_t \tag{3.2}$$

where C_t is the composite consumption index, N_t is labour hours and B_{t+1} is nominal pay-off in period *t+1* of the portfolio purchased at time *t*. P_t is the Consumer Price Index (CPI). $Q_{t,t+1} = (1+i_t)^{-1}$ is the stochastic discount factor between the periods *t* and *t+1* where i_t is the nominal interest rate. D_t is dividend. E_t is the expectation operator on time *t* information. σ and φ, positive constants, are the relative risk aversion parameter and the inverse Frisch elasticity of labour supply, respectively. $\beta \in (0,1)$ is the intertemporal discount factor.

3.2.1.1. Optimality Conditions

The household maximises the expected present discounted value of the utility function by choosing $\{C_t, N_t\}_{t=0}^{\infty}$. The following optimality conditions are obtained.

$$Euler\ Equation\colon\ E_t\{\ \beta\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma}\left(\frac{P_t}{P_{t+1}}\right)\} = E_t\ \{Q_{t,t+1}\} \tag{3.3}$$

$$Labour\ Supply\colon\ C_t^{\sigma} N_t^{\varphi} = \frac{W_t}{P_t} \tag{3.4}$$

$C_t = [(1-\alpha)^{\frac{1}{\eta}}\left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + (\alpha)^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}$ is the composite consumption index where $C_{H,t} = [\int_0^1 \left(C_{H,j.t}\right)^{\frac{\epsilon-1}{\epsilon}} dj]^{\frac{\epsilon}{\epsilon-1}}$ is the index of domestic consumption goods, $C_{F,i,t} = [\int_0^1 \left(C_{F,i,j,t}\right)^{\frac{\epsilon-1}{\epsilon}} dj]^{\frac{\epsilon}{\epsilon-1}}$ is the index of imported consumption goods from country i and, $C_{F,t} = [\int_0^1 \left(C_{F,i,t}\right)^{\frac{\gamma-1}{\gamma}} di]^{\frac{\gamma}{\gamma-1}}$ is the index of imported goods. Note that ϵ is the elasticity of substitution among differentiated goods, η is the substitutability between domestic and imported goods and γ is the substitutability between goods produced in different foreign countries. α is the degree of trade openness and j is good variety.
Using cost-minimisation, the following demand functions are obtained:

$$C_{H,j,t} = \left(\frac{P_{H,i,t}}{P_{H,t}}\right)^{-\epsilon} C_{H,t};$$

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t$$

$$C_{i,j,t} = \left(\frac{P_{i,j,t}}{P_{F,i,t}}\right)^{-\epsilon} C_{i,t};\ C_{i,t} = \left(\frac{P_{F,i,t}}{P_{F,t}}\right)^{-\gamma} C_{F,t};$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t$$

$P_t = [(1-\alpha)\left(P_{H,t}\right)^{1-\eta} + \alpha\left(P_{F,t}\right)^{1-\eta}]^{\frac{1}{1-\eta}}$ is Consumer Price Index where $P_{H,t} = [\int_0^1 \left(P_{H,j,t}\right)^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ is the price index of domestic goods, $P_{F,i,t} = [\int_0^1 \left(P_{F,i,j,t}\right)^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ is the price index of imported goods from country *i*, $P_{F,t} = [\int_0^1 \left(P_{F,i,t}\right)^{1-\gamma} di]^{\frac{1}{1-\gamma}}$ is the aggregate price index for imported goods, $P_{H,j,t}$ is the price of domestic good *j* and $P_{F,i,j,t}$ is the price of imported good *j* from country *i*.

Some important definitions as in Gali and Monacelli (2005) are repeated. The terms of trade between domestic country and country *i* is defined as $S_{i,t} = \frac{P_{F,i,t}}{P_{H,t}}$ and the aggregation of the terms of trade over *i* means the (effective) terms of trade and shown as $S_t = \frac{P_{F,t}}{P_{H,t}}$.

The law of one price (LOOP) is assumed to hold for all varieties of goods.

$$P_{i,j,t} = \varepsilon_{i,t} P^{i}_{F,i,j,t} \tag{3.5}$$

where $P_{F,i,j,t}$ is the price of good *j* imported from country i in terms of the domestic currency, $\varepsilon_{i,t}$ is the bilateral nominal exchange rate between domestic country and country i, and $P^{i}_{F,i,j,t}$ is the price of good *j* produced in country *i* in terms of the country *i*' currency.

Using the LOOP definition, the price index of imported consumption goods from country i is the same in terms of domestic currency in both domestic country and in the imported country *i*. The price index of imported goods from the rest of the world is the same in terms of the nominal exchange rate across the world.

$$P_{F,t} = \varepsilon_t P^{*}_t \tag{3.6}$$

where ε_t is the (effective) nominal exchange rate and P^{*}_t is the world price index.

The bilateral real exchange rate with country *i* is $Q_{i,t} = \varepsilon_{i,t} \frac{P^{i}_t}{P_t}$ where P^{i}_t is the CPI for country *i* expressed in country i's currency. Since the international financial market is complete, the stochastic discount factors are the same in terms of the same currency across all countries. Thus, the international risk sharing condition is as follows:

$$C_t = C^{*}_t (Q_t)^{\frac{1}{\sigma}} \tag{3.7}$$

where C_t^* is the world consumption level and Q_t is the (effective) real exchange rate.

Households can add foreign bonds into their portfolio without any transaction cost. Under the assumption of no arbitrage, the uncovered interest rate parity is written as follows:

$$(1+i_t) = (1+i_t^*)\frac{E_t\{\varepsilon_{t+1}\}}{\varepsilon_t} \qquad (3.8)$$

where i_t^* is the world nominal interest rate.

In domestic economy, the central bank is assumed to follow the interest rate rule.

$$\frac{(1+i_t)}{(1+\bar{\imath})} = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} e^{v_t} \qquad (3.9)$$

where π_t is the CPI inflation, Y_t is the domestic output, $\bar{\imath}, \pi$ and $\bar{Y}$ are the steady state values of nominal interest rate, CPI inflation and domestic output, respectively. v_t is the monetary policy shock and follows AR(1). ϕ_π and ϕ_y are monetary policy coefficients of CPI inflation and output, respectively.

The equilibrium part is similar to the equilibrium part of the model in Gali and Monacelli (2005). Total demand for domestic good j is

$$Y_{j,t} = \left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} ((1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha \int_0^1 \left(\frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i}\right)^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di) \tag{3.10}$$

where $Y_{j,t}$ is the quantity of good j produced by the domestic economy, $P_{H,j,t}$ is the price of domestically produced good j, $P_{F,t}^i$ is the country i's domestic price index expressed in country i's currency, C_t^i is the country i's composite consumption index. Aggregate domestic output is

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t((1-\alpha) + \alpha \int_0^1 \left(S_t^i S_{i,t}\right)^{\gamma-\eta} (Q_{i,t})^{\eta-\frac{1}{\sigma}} di) \tag{3.11}$$

where S_t^i is the (effective) terms of trade for country i.

In the particular case of σ, γ and η = 1, the aggregate domestic output becomes:

$$Y_t = C_t S_t^{\alpha} = C_t \frac{P_t}{P_{H,t}} \tag{3.12}$$

Net exports are defined as $nx_t \equiv \frac{1}{Y}(Y_t - C_t \frac{P_t}{P_{H,t}})$ in terms of a fraction of the steady state output Y. Balanced trade condition holds and so $Y_t = \frac{P_t}{P_{H,t}} C_t$.

The aggregate domestic output analogously holds for country i and the aggregation of all countries' output over i yields the following equilibrium condition.

$$Y_t^* = C_t^* \tag{3.13}$$

3.2.2. Price Setting

There is one representative firm in the final good sector. This firm buys differentiated intermediate goods $Y_{j,t}$ produced by intermediate good producing firms to use them as inputs and then produces the final good Y_t using the Dixit-Stiglitz production function. The firm sells this final good to consumers in a perfectly competitive market. The aggregate domestic output, demand function for good *j* and domestic price index $P_{H,t}$ are shown as follows, respectively:

$$Y_t = (\int_0^1 Y_{j,t}^{\frac{1-\epsilon}{\epsilon}} dj)^{\frac{\epsilon}{\epsilon-1}} \tag{3.14}$$

$$Y_{j,t} = (\frac{P_{H,j,t}}{P_{H,t}})^{-\epsilon} Y_t \tag{3.15}$$

$$P_{H,t} = (\int_0^1 P_{H,j,t}^{1-\epsilon} dj)^{\frac{1}{1-\epsilon}} \tag{3.16}$$

Intermediate firms produce differentiated goods in a monopolistically competitive market with an identical technology. The production function for firm *j* is as follows:

$$Y_{j,t} = A_t N_{j,t} \tag{3.17}$$

where A_t is exogenously given aggregate technology and it follows AR (1), and $N_{j,t}$ is labour demand of firm j.

Intermediate firm j maximises the expected discounted value of the following profit function with respect to $P^*_{H,j,t}$:

$$\max_{P^*_{Hj,,t}} E_t \sum_{k=0}^{\infty} Q_{t,t+k}\, \theta^k [P^*_{H,j,t} Y_{H,j,t+k} - W_{t+k} \frac{Y_{H,j,t+k}}{A_{t+k}}] \tag{3.18}$$

subject to the demand constraint $Y_{H,j,t+k} = \left(\frac{P^*_{H,j,t}}{P_{H,t+k}}\right)^{-\epsilon} Y_{t+k}$

where $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+k}}$ is the stochastic discount factor between time t and time $t+k$. The balanced trade condition holds. $P^*_{H,j,t}$ is the optimal reset price for firm j. $W_{j,t}$ equals W_t across all intermediate firms since nominal wage levels are determined in a perfectly competitive labour market under constant return to scale assumption.

The profit maximisation problem yields the following pricing rule:

$$p^*_{H,j,t} = \mu \frac{E_t \sum_{k=0}^{\infty} (\beta\theta)^k mc^r_{H,t+k}\, \Pi^{\epsilon}_{H,t,t+k}}{E_t \sum_{k=0}^{\infty} (\beta\theta)^k\, \Pi^{\epsilon-1}_{H,t,t+k}} \tag{3.19}$$

where $p^*_{Hj,t} = \frac{P^*_{Hj,t}}{P_{H,t}}$ is the relative optimal reset price for firm j, $mc^r_{H,t} = \frac{W_t}{P_{H,t}A_t}$ is real marginal cost and $\mu = \frac{\epsilon}{\epsilon-1}$ is the mark-up. $\Pi_{H,t,t+k}$ is the cumulative domestic inflation between the periods t and $t+k$. Note that since the mark-up is constant and the marginal cost is the same across intermediate firms, the relative reset prices are the same across firms (i.e. $p^*_{H,j,t} = p^*_{H,t}$).

$$\Pi_{H,t,t+k} = 1 \; for \; k = 0$$

$$\Pi_{H,t,t+k} = \frac{P_{H,t+1}}{P_{H,t}} \frac{P_{H,t+2}}{P_{H,t+1}} \ldots \ldots .. \frac{P_{H,t+k}}{P_{H,t+k-1}} \; for \; k > 0$$

$$p^*_{H,t} = \frac{\epsilon}{\epsilon - 1} \frac{\psi_t}{\phi_t} \tag{3.20}$$

where

$$\psi_t = mc^r_{H,t} + \theta\beta E_t[\pi^{\epsilon}_{H,t+1}\psi_{t+1}]$$

$$\phi_t = 1 + \theta\beta E_t[\pi^{\epsilon-1}_{H,t+1}\phi_{t+1}]$$

3.2.2.1. Aggregate Price Dynamics

Following Calvo (1983), in each period, $1 - \theta$ of firms update their nominal prices independent of when they update their prices last time and θ of firms keep their prices unchanged (Calvo Rule).

$$P_{H,t}^{1-\epsilon} = [\int_{\theta}^{1} \left(P_{H,j,t}^{*}\right)^{1-\epsilon} dj + \int_{0}^{\theta} \left(P_{H,j,t-1}\right)^{1-\epsilon} dj] \tag{3.21}$$

$$P_{H,t}^{1-\epsilon} = [(1-\theta)\left(P_{H,t}^{*}\right)^{1-\epsilon} + \theta P_{H,t-1}^{1-\epsilon}] \tag{3.22}$$

3.2.2.2. Aggregate Production Function

Labour demand over j is aggregated, then plugging production function for good j and demand function for good j into this aggregation leads to the following expression:

$$N_t = \int_0^1 N_{j,t} dj = \int_0^1 \left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} dj \frac{Y_t}{A_t} \tag{3.23}$$

$z_t = \int_0^1 \left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} dj$ is the measure of price dispersion. Then, using this definition, the aggregate output equation is obtained:

$$Y_t = \frac{A_t N_t}{z_t} \tag{3.24}$$

Schmitt-Grohe and Uribe (2007) indicate that price dispersion z_t with the presence of trend inflation can be re-written using the Calvo rule as follows:

$$z_t = (1-\theta)(p_{H,t}^{*})^{-\epsilon} + \theta \pi_{H,t}^{\epsilon}\, z_{t-1} \tag{3.25}$$

3.2.3. Log-linearization

Log-linearization of equation (3.20) is as follows:

$$\hat{p}^*_{H,t} = \hat{\psi}_t - \hat{\phi}_t \tag{3.26}$$

where

$$\hat{\psi}_t = (1 - \theta\beta\pi^{\epsilon})\left(\widehat{mc}^r_{H,t}\right) + (\theta\beta\pi^{\epsilon})E_t(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1}) \tag{3.27}$$

$$\hat{\phi}_t = (\theta\beta\pi^{\epsilon-1})E_t((\epsilon - 1)\hat{\pi}_{H,t+1} + \hat{\phi}_{t+1}) \tag{3.28}$$

$\hat{\psi}_t$ and $\hat{\phi}_t$ imply the present value of the discounted marginal cost and the present value of the discounted marginal revenue, respectively.

Log-linearization of Calvo rule in equation (3.22) is:

$$\hat{p}^*_{H,t} = \frac{\theta\pi^{\epsilon-1}}{1 - \theta\pi^{\epsilon-1}}\hat{\pi}_{H,t} \tag{3.29}$$

Log-linearization of price dispersion equation (3.25) is:

$$\hat{z}_t = (-\epsilon(1 - \theta\pi^{\epsilon}))(\,\hat{p}^*_{H,t}) + \theta\pi^{\epsilon}(\epsilon\hat{\pi}_{H,t} + \hat{z}_{t-1}) \tag{3.30}$$

Production function is given by

$$\hat{n}_t = \hat{y}_t + \hat{z}_t - \hat{a}_t \tag{3.31}$$

Log-linearization of the monetary policy rule is as follows:

$$\hat{\imath}_t = \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + v_t \tag{3.32}$$

where $v_t = \rho_v v_{t-1} + e_{v,t}$,$\rho_v < 1$ and $e_{v,t} \sim WN(0, \sigma^2)$.

The rest of following equations until equation (3.45) are standard as in Gali and Monacelli (2005).

Log-linearizing the bilateral terms of trade and then aggregating over i yields the log-linearized terms of trade as follows:

$$\hat{s}_t = \hat{p}_{F,t} - \hat{p}_{H,t} \tag{3.33}$$

The log-linearization of CPI with this equation (3.33) yields the following equation: $\hat{p}_t = \hat{p}_{H,t} + \alpha \hat{s}_t$.

Using this equation, the relation between CPI inflation and domestic inflation is written as follow

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha \Delta \hat{s}_t \tag{3.34}$$

Equation (3.6) is log-linearized, and then using the log-linearized terms of trade, the following expression is obtained:

$$\hat{s}_t = \hat{e}_t + \widehat{p_t}^* - \hat{p}_{H,t} \tag{3.35}$$

$$\hat{s}_t = \hat{s}_{t-1} + \widehat{\pi_t}^* - \hat{\pi}_{H,t} \tag{3.36}$$

Initially, the bilateral real exchange rate is log-linearized and then it is aggregated over i. Then combining this result with $\hat{p}_t = \hat{p}_{H,t} + \alpha \hat{s}_t$ and equation (3.35) yields the following relation between the real exchange rate and the terms of trade.

$$\hat{q}_t = (1 - \alpha)\hat{s}_t \tag{3.37}$$

Log-linearization of Euler equation and labour-supply is given by

$$\hat{c}_t = \hat{c}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1}) + d_t \tag{3.38}$$

where

$d_t = \rho_d d_{t-1} + e_{d_t}$ is the demand shock and

$e_{d_t} \sim WN(0, \sigma^2)$.

$$\sigma \hat{c}_t + \varphi \hat{n}_t = \widehat{w}_t^r \tag{3.39}$$

The international risk sharing condition is as follows:

$$\hat{c}_t - \hat{c}_t^* = \frac{1}{\sigma}\hat{q}_t \tag{3.40}$$

Log-linearization of the market clearing condition expressed in equation (3.11) is as follows:

$$\hat{y}_t = \hat{c}_t + \alpha\gamma\hat{s}_t + \alpha(\eta - \frac{1}{\sigma})\hat{q}_t \tag{3.41}$$

Substitution of equation (3.37) into equation (3.41) yields;

$$\hat{y}_t = \hat{c}_t + \frac{\alpha\omega}{\sigma}\hat{s}_t \tag{3.42}$$

where

$$\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$$

Log-linearization of equation (3.13) is given by

$$\hat{y}^*{}_t = \hat{c}^*{}_t \tag{3.43}$$

The relation between domestic output, world output and the terms of trade is expressed as in the following equation using equations (3.40), (3.41) and (3.43):

$$\hat{y}_t = \hat{y}_t{}^* + \frac{1}{\sigma_\alpha}\hat{s}_t \tag{3.44}$$

where $\sigma_\alpha = \frac{\sigma}{1-\alpha+\alpha\omega}$.

Substituting equations (3.34) and (3.42) into the standard Euler equation, the Euler equation in terms of output can be expressed a

$$\hat{y}_t = \hat{y}_{t+1} - \frac{1}{\sigma}\left(\hat{\imath}_t - \hat{\pi}_{H,t+1}\right) - \frac{\alpha\Theta}{\sigma}E_t(\Delta\hat{s}_{t+1}) + d_t \tag{3.45}$$

where $\Theta = \omega - 1$.

Using the log-linearized $mc^r_{H,t}$ with $\hat{p}_t = \hat{p}_{H,t} + \alpha\hat{s}_t$ leads to the following expression.

$$\widehat{mc}^r_{H,t} = \widehat{w}^r_t + \alpha\hat{s}_t - \hat{a}_t$$

Using the definition of real marginal cost, equations (3.31), (3.39), (3.41-42) and (3.44), the following equation is obtained.

$$\widehat{mc}^r_{H,t} = \varphi\hat{z}_t + (\sigma - \sigma_\alpha)\hat{y}^*{}_t + (\varphi + \sigma_\alpha)\hat{y}_t - (1+\varphi)\hat{a}_t \qquad (3.46)$$

3.2.4. The Dynamics of the Model

3.2.4.1. Price-Resetting Firms

Following King and Wolman (1996)'s discussion, a positive trend inflation paves the way for two important consequences on the process of price-resetting at the steady state. Firstly, it makes intermediate goods producing firms become more forward-looking on resetting prices compared to zero-trend inflation. In other words, firms care more future variables rather than current variables on it. Secondly, when firms have opportunity to reset their nominal prices, they charge their prices higher than the average price level. The intuition is that firms may not reset their nominal prices in the future and so their nominal prices would be eroded relative to the average price level when they obtain price-resetting opportunity (Ascari & Ropele, 2009).

3.2.4.2. Trend Inflation

Ascari and Ropele (2009) discuss how the presence of trend inflation affects the dynamics of the NKPC for a closed economy. In the light of their discussions, it is evaluated how the presence of positive trend inflation affects the standard small open economy in Gali and Monacelli (2005)'s model. With positive trend inflation, the NKPC can be expressed as in equation (3.47).

$$\hat{\pi}_{H,t} = \kappa_1\widehat{mc}^r_{H,t} + \kappa_2\hat{\pi}_{H,t+1} + \kappa_3\hat{\psi}_{t+1} + u_t \qquad (3.47)$$

where

$\kappa_1 = \frac{(1-\beta\theta\pi^{\epsilon})(1-\theta\pi^{\epsilon-1})}{\theta\pi^{\epsilon-1}}$, $\kappa_2 = \beta[(1-\theta\pi^{\epsilon-1})(\pi - 1)\epsilon + 1]$, $\kappa_3 = \beta(1 - \theta\pi^{\epsilon-1})(\pi - 1)$, $\hat{\psi}_t = (1-\theta\beta\pi^{\epsilon})(\widehat{mc}^r_{H,t}) + \theta\beta\pi^{\epsilon}(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1})$, and $u_t = \rho_u u_{t-1} + e_{u,t}$ is the cost-push shock and $e_{u,t} \sim WN(0, \sigma^2)$.

Compared to the standard small-open economy model in Gali and Monacelli (2005), a positive trend inflation considerably changes the dynamics of the model. Three channels on the process of price-resetting can be identified at the background of changes in the dynamics of the model. Firstly, since positive trend inflation makes price setting firms more forward-looking, higher trend inflation makes the slope of the NKPC flatter. In other words, while the importance of current variables on the NKPC decreases, the importance of future variables on it increases. Secondly, trend inflation enables an extra variable, expected marginal cost, to enter into the NKPC. Thirdly, trend inflation makes price dispersion matter for the dynamics of the model. In addition, it provides an extra source of persistence to the model due to its backwardness. In turn, it yields more persistent dynamics of the NKPC. However, for zero-trend inflation, price dispersion loses its importance on the dynamics of the model.

It is next discussed whether openness affects the dynamics of the variables or not, and if so in what ways. There are two possible ways for openness to affect the dynamics of variables. Firstly, equation (3.46) is re-written for marginal cost below:

$$\widehat{mc}^r_{H,t} = \varphi\hat{z}_t + (\sigma - \sigma_\alpha)\hat{y}^*{}_t + (\varphi + \sigma_\alpha)\hat{y}_t - (1+\varphi)\hat{a}_t$$

As shown by Gali and Monacelli (2005), in the particular case of $\sigma\,\eta = 1$, σ_α equals σ. Thus, the slope of the NKPC does not depend on the degree of openness. In other words, the degree of openness does not change either the importance of current variables or forward-looking variables on the NKPC. Secondly, openness affects the dynamics of variables through the terms of trade variable. More specifically, the terms of trade affect the propagation mechanism of each shock, so that it affects the dynamics of variables. The second channel is more comprehensively discussed below. As indicated in equation (3.36), the terms of trade is a backward-looking variable and so yields more persistence for the dynamics of the model and variables.

3.2.4.3. The Interaction Between Trend Inflation and Openness

To show how the interaction between trend inflation and openness affects the dynamics of variables in response to shocks, the real exchange rate dynamics, which is a function of the terms of trade shown in equation (3.37), is used. For simplicity, calibration values for σ and φ as 1 and 0 are used, respectively. The world interest rate and world inflation rate are set to 0. Thus, the world consumption level $\hat{c}_t^*$ equals 0. Moreover, the Taylor rule is simplified as $i_t = \phi_\pi \pi_t + v_t$ where $\beta = \frac{1}{\phi_\pi}$. The exogenous shock m_t follows AR(1) with $\rho_m \in [0,1)$ where $m \in (v, d, u)$, and $E(m_{t+1}) = \rho_m\, m_t$.

The dynamics of the real exchange rate is summarised below:

$$\hat{q}_t = \frac{1}{\Lambda}[\frac{1}{1-\alpha}\hat{q}_{t-1} + \beta\hat{q}_{t+1} - \kappa_3\hat{\psi}_{t+1} + (\beta)\hat{\pi}_{t+1} - \kappa_2\hat{\pi}_{H,t+1} - u_t - \beta v_t + \beta d_t \qquad (3.48)$$

where $\Lambda = \frac{\kappa_1 + (1-\alpha)\beta + \alpha}{(1-\alpha)}$ and κ_1, κ_2 and κ_3 are as previously defined.

$$\hat{\psi}_t = (1 - \theta\beta\pi^{\epsilon})\left(\widehat{mc}^{r}_{H,t}\right) + \theta\beta\pi^{\epsilon}(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1})$$

The dynamics of the real exchange rate $\hat{q}_t$ depends on its past variable, its expected variable, other expected variables, domestic inflation, CPI inflation and auxiliary variable. The terms of trade is a backward-looking variable. The coefficients of dependent variables are affected by the rate of trend inflation and the degree of openness. To make further analysis on the effects of trend inflation rate and the degree of openness, the ceteris paribus condition is assumed. Thus, $\hat{\psi}_{t+1}$, $\hat{\pi}_{H,t+1}$ and $\hat{\pi}_{t+1}$ are dropped from equation (3.47) and the equation is expressed as follows:

$$\hat{q}_t = \frac{1}{\Lambda}\left[\frac{\alpha}{1-\alpha}\hat{q}_{t-1} + \beta\hat{q}_{t+1} - u_t - \beta v_t + \beta d_t\right]$$

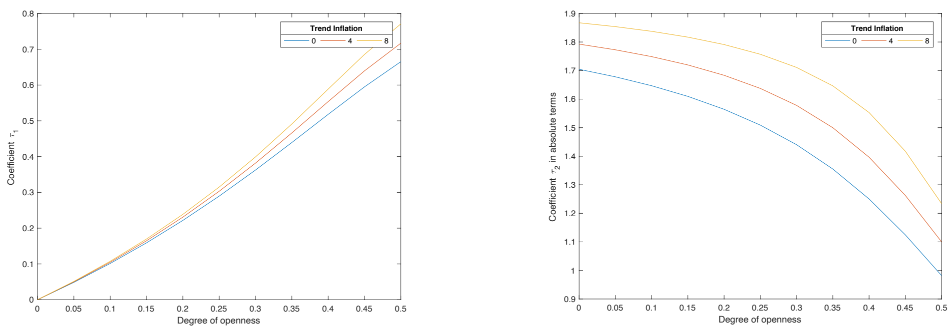
Since the coefficients for monetary policy shock $-\frac{\beta}{\Lambda}$, demand shock $\frac{\beta}{\Lambda}$ and cost-push shock $\frac{1}{\Lambda}$ are similar in absolute terms in this equation, the real exchange rate dynamics for the monetary policy shock suffice to obtain a general intuition about how the interaction between trend inflation and openness affects the dynamics of the real exchange rate. Applying the guess and verify method, the following real exchange rate dynamics with monetary policy shock is found:

$$\hat{q}_t = \tau_1\hat{q}_{t-1} + \tau_2 v_t$$

For a given level of trend inflation and degree of openness, the coefficients τ_1 and τ_2 are obtained as follows:

$$\tau_1 = \frac{1-\sqrt{1-\frac{4\beta\alpha}{\Lambda^2(1-\alpha)}}}{\frac{2\beta}{\Lambda}} \text{ and } \tau_2 = \frac{-\beta}{\Lambda(1-\frac{\beta}{\Lambda}\rho_v - -\frac{\beta}{\Lambda}\tau_1)} \tag{3.49}$$

As indicated in equation (3.49), both the trend inflation rate and the degree of openness affect the coefficients τ_1 and τ_2. To analyse the effect of trend inflation and openness on real exchange rate dynamics, τ_1 and τ_2 are plotted for different values of trend inflation and for degree of openness in Figure 3.1 for Canada. The figure for the UK is in Appendix II-B.1. When trend inflation is zero, the coefficient of the inertial variable increases as the economy becomes more open. For a given degree of openness, the coefficients of the inertial variable and the effect of monetary policy shock on the real exchange rate increase at higher trend inflation rates. With the increased trend rate, the real exchange rate becomes more persistent.



(a) Backward-looking variable

(b) Monetary Policy Shock v_t

Figure 3.1 Coefficients of the Backward-looking Variable and Monetary Policy Shock Variable

In short, openness affects the dynamics of variables through the real exchange rate dynamics. Since the terms of trade and the real exchange rate co-move according to equation (3.37), they similarly respond to changes in trend inflation.

3.2.5. Calibration

The model for Canada and the UK is calibrated in a fairly standard way. The reasons why Canada and the UK are chosen for the analysis are that both countries are good examples of small open economy, inflation targetters and exposed to ZLB circumstances. However, as indicated in Table 3.1, they have different openness rates and Calvo parameters. We set σ = 1, η = 1 and γ = 1 for both Canada and the UK. The discount factor β, is taken as 0.99. Labour is indivisible for both countries. The persistence for exogenous monetary policy shock is 0.50, it is 0.80 for exogenous demand shock and it is 0.80 for exogenous cost-push shock for both Canada and the UK. These are standard in the Business-Cycle literature. The rest of the structural parameters are shown in Table 3.1.

Table 3.1 Calibration Values of Parameters for Canada and the UK

Parameter	Value	Country	Source
ϵ	6	The UK and Canada	Britton et al. (2000), and Gali and Monacelli (2005)
α	0.33	Canada	Author's Calculation
α	0.31	The UK	Author's Calculation
θ	0.75	Canada	Gali and Monacelli (2005)
θ	0.70	The UK	Fragetta and Kirsanova (2010)

3.3. Impulse Response Analyses

Figures 3.2-4 present the impulse response functions (IRFs) of CPI inflation, the real interest rate, output, domestic inflation, the nominal interest rate, terms of trade, consumption and the real exchange rate for Canada in response to monetary policy, demand and cost-push shocks. First, it is discussed how each shock affects the dynamics of the model in case of zero-trend inflation and then how the presence of trend inflation affects the dynamics of each case. Since the results are similar, the results for Canada are only reported and the IRFs for the UK economy are shown in Appendix II-B.2.1-3. In sub-section 3.4, the comparisons of the results for closed economy and open economy are discussed in detail.

3.3.1. Monetary Policy Shock

Figure 3.2 shows the IRFs of the variables in response to a positive monetary policy shock at different rates of trend inflation ($i.e.$ 0, 4 and 8). For zero-trend inflation, monetary policy shock increases the nominal interest rate and real interest rate. The increase in the real interest rate leads to a fall in demand for home goods. Through the NKPC, domestic price level and domestic inflation decrease. Since the shock increases demand for domestic bonds, demand for domestic currency increases and thereby the nominal domestic currency appreciates. Thus, the terms of trade and the real exchange rate decrease. In other words, imported goods become relatively cheaper. Therefore, CPI inflation becomes lower than domestic inflation and aggregate domestic output decreases.

Since higher trend inflation makes the NKPC flatter, the relation between contemporaneous variable ($i.e.$ demand for home goods) and domestic inflation weakens. Thus, the initial decrease in demand for home goods by the shock causes domestic inflation to decrease less as trend inflation rises. On the other hand, the real interest rate is higher at higher trend inflation rates because of the decrease in domestic inflationary expectations. On the other hand, the increase in the real interest rate yields a significant decline in demand for home goods. Since the uncovered interest rate parity holds, the nominal domestic currency initially appreciates more. Sluggish dynamics of the domestic price level together with fast response of the domestic nominal currency lower the terms of trade and then real exchange rate. In other words, imported goods become relatively cheaper at higher trend inflation rates. The opposite dynamics of domestic inflation and the terms of trade in response to change in trend inflation cause the effect of trend inflation on CPI inflation to be limited. Moreover, aggregate domestic output decreases more, as trend inflation rises.

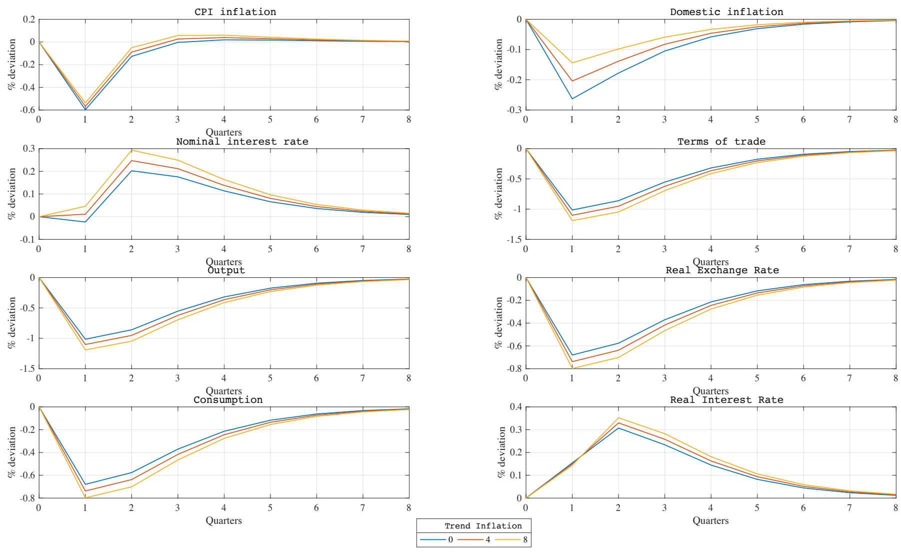


Figure 3.2 IRFs of 1 Percent Monetary Policy Shock

Note that all IRFs are percentage deviation from steady states in this section.

On the other hand, the effects of monetary policy shock on variables are short-lived. All the variables, except for real interest rate and nominal interest rate, reach their peaks (or bottoms) at quarter 1, but real interest and nominal interest rates reach at quarter 2. All the variables converge to their steady states at quarter 8. Prior to quarter 6, the effects of trend inflation on variables exist but weaken after quarter 6.

3.3.2. Demand Shock

Figure 3.3 presents the IRFs of the variables in response to a positive demand shock at specified rates of trend inflation. At the zero-trend inflation rate, the shock to demand initially leads to an increase in domestic demand. The increase in domestic demand leads to an increase in domestic price level and domestic inflation. According to the risk sharing condition in equation, the real exchange rate increases. This implies that imported goods become relatively more expensive. The higher domestic inflation and the relative price of imported goods cause CPI inflation to rise. Additionally, aggregate domestic output increases. According to the policy rule, the nominal interest rate increases.

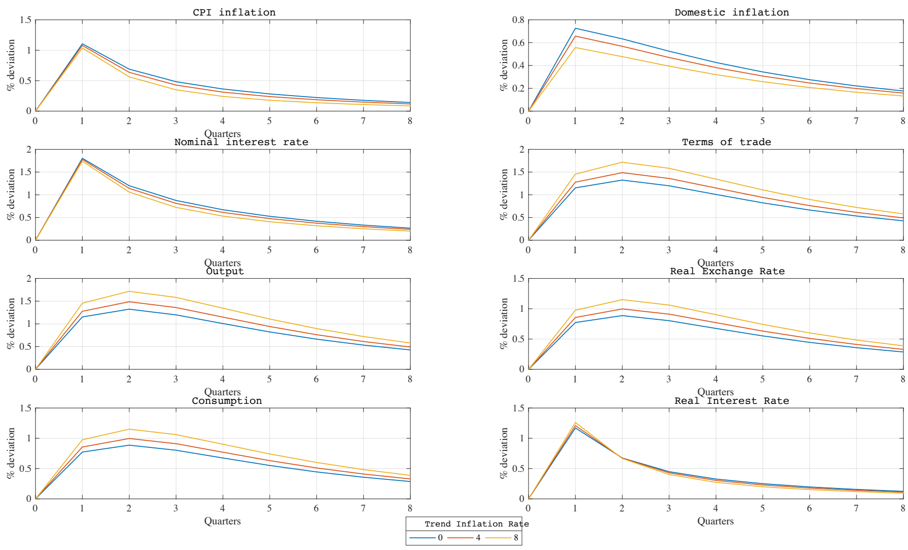


Figure 3.3 IRFs of 1 Percent Demand Shock

Due to the flatter slope of the NKPC, the increase in domestic demand causes domestic price level and domestic inflation to increase less, as trend inflation increases. The terms of trade and the real exchange rate increase more, and imported goods become relatively more expensive, as trend inflation increases. The opposite dynamics of domestic inflation and the real exchange rate in response to trend inflation limit the effect of trend inflation on CPI inflation. On the other hand, high domestic demand and relatively expensive imported goods induce increases in aggregate domestic output more, as trend inflation increases.

On the other hand, while consumption, output, terms of trade and real exchange rate reach their peaks at quarter 3, the rest of the variables reach their peaks at quarter 1. While CPI inflation, the real interest rate and the nominal interest rate converge to 0 around quarter 8, the rest of them have durations more than 2 years. The effects of trend inflation rate on output, consumption, domestic inflation, terms of trade and the real exchange rate exist more than 2 years, but the effects of trend inflation on the rest of the variables weaken earlier.

3.3.3. Cost-Push Shock

The IRFs of the variables in response to a positive cost-push shock for Canada at different rates of trend inflation are demonstrated in Figure 3.4. Cost-push shock initially increases the domestic price level and domestic inflation rate and decreases demand for home goods. The terms of trade and the real exchange rate decrease. Thus, imported goods become relatively cheaper. On the other hand, due to the relative cheapness of imported goods, increase in CPI inflation becomes less than the increase in domestic inflation. On the other hand, aggregate domestic output decreases. According to the policy rule, the nominal interest rate increases.

The implications of positive trend inflation are in effect through two channels. The first one is the importance of contemporaneous and future variables on the NKPC as discussed above. The second one works through the expectations channel. The second channel is so strong that it dominates the effect of the first channel on domestic inflation. Thus, higher trend inflation increases domestic price level and domestic inflation more. The terms of trade and the real exchange rate decreases more, as trend inflation increases. This implies that imported goods become relatively cheaper, and so increase in CPI inflation is less than the increase in domestic inflation. Further the decline in aggregate domestic output is significant.

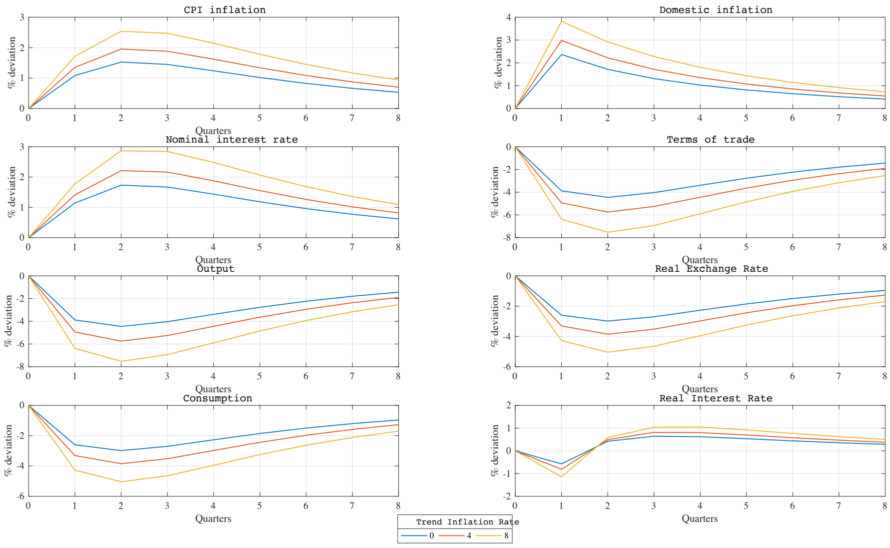
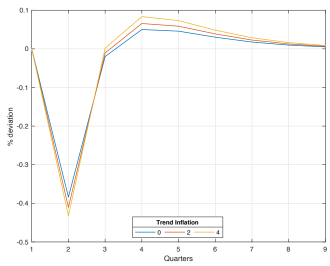


Figure 3.4 IRFs of 1 Percent Cost-Push Shock

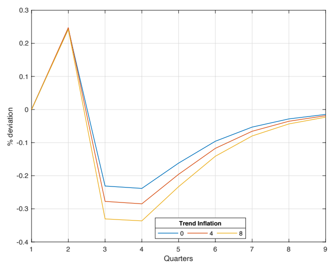
The effects of cost-push shock on variables are long-lived and last more than 2 years, except for the real interest rate. While CPI inflation, nominal interest rate, output, consumption, terms of trade and real exchange rate reach their peak at quarter 2, domestic inflation reaches at quarter 1 and real interest rate reaches at quarter 3. The effects of trend inflation rate on variables exist more than 2 years.

3.4 Open-Economy Case Versus Closed-Economy Case

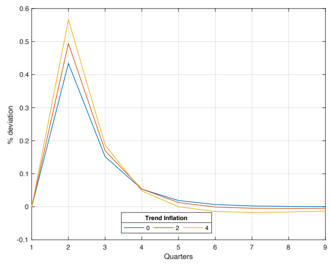
In this section, it is evaluated how openness dynamically affects variables and whether the rate of trend inflation amplifies the effect of openness on variables or not. For this reason, a new auxiliary variable, which composes of the difference between series for a variable in the open-economy case and in the closed-economy case, is generated at a given trend inflation level. Since the results are similar, the results of CPI inflation and output for Canada are only reported here and the IRFs for the UK economy are shown in Appendix II-B.3.



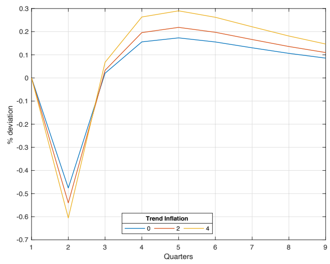
(a) CPI inflation-Monetary Policy Shock



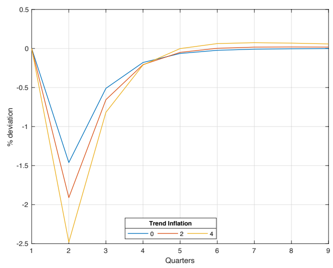
(b) Output- Monetary Policy Shock



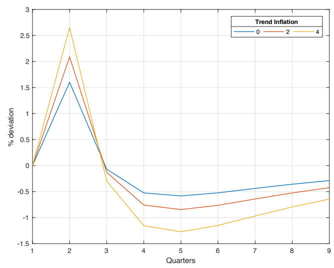
(c) CPI inflation-Demand Shock



(d) Output- Demand Shock



(e) CPI inflation-Cost-Push Shock



(f) Output- Cost-Push Shock

Figure 3.5 IRFs in Response to 1 Percent Shocks

Note that the IRFs are expressed as deviations from the closed-economy

3.4.1. Monetary Policy Shock

Figure 3.5-a and Figure 3.5-b represent differences in series between CPI inflation and output in the open economy case and closed economy case, respectively in response to the monetary policy shock at different levels of trend inflation. Openness affects the dynamics of variables through two channels. Firstly, it is through the real exchange rate channel. At zero-trend inflation, the real exchange rate aggravates the effect of shock on CPI inflation because imported goods are relatively cheaper. Secondly, it is through demand for the domestic bonds. Compared to the closed-economy case, in the open economy the nominal interest rate increases less because foreign demand for domestic bonds increases the bond prices. In other words, openness leads to a lesser increase in the interest rate. CPI inflation is lower in the open-economy case than in the closed-economy case and so the difference series for CPI inflation becomes negative over the initial periods. After period 3, CPI inflation is lower in the closed-economy than in the open-economy. Thus, the difference series for CPI inflation becomes positive. The output is lower in the open-economy case than in the closed-economy case and the difference series for output becomes positive. Due to the real exchange rate dynamics, output slowly returns to its steady state in the open-economy-case. Over the rest of the horizon, the difference series for output is lower in the open-economy than in the closed-economy. Thus, the difference series for output is negative over the rest of the period.

As trend inflation increases, the real exchange rate decreases more in response to the shock and its dynamics become more persistent. Thus, trend inflation amplifies the effect of openness on CPI inflation and the IRFs of the difference series for CPI inflation shifts outward. On the other hand, trend inflation has similar implications for the effect of openness on output as in the difference series for CPI inflation. The IRFs of the difference series for output shift outward also.

3.4.2. Demand Shock

Figure 3.5-c presents the difference series between CPI inflation in the open-economy case and one in the closed-economy case. Figure 3.5-d presents the difference series between output in the open-economy case and one in the closed-economy case in response to the demand shock at levels of trend inflation. At the zero-trend inflation rate, because of relatively expensive and highly persistent real exchange rate dynamics, CPI inflation is higher in the open-economy case than in the closed-economy case. In other words, the IRFs of the difference series for CPI inflation are positive over the horizon. On the other hand, output is lower in the open-economy case than in the closed-economy case in the initial periods. However due to dynamics of the real exchange rate, output becomes higher in open-economy case than in the closed-economy case over the rest of the horizon. Thus, while the IRFs of the difference series for output is initially negative, it turns out to be positive.

At higher trend inflation, the real exchange rate increases more in response to the demand shock and its dynamics become more persistent. Thus, the effect of openness on CPI inflation through the real exchange rate dynamics increases, as the trend inflation rate increases. The IRFs of the difference series for CPI inflation shift outward. Similarly, the IRFs of the difference series for output shift outward.

3.4.3. Cost-Push Shock

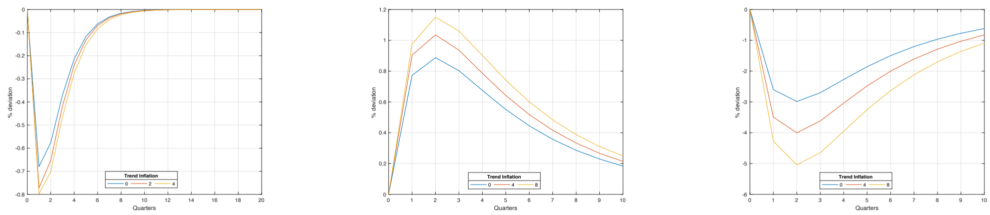
Figures 3.5-e shows that the IRF of CPI inflation to a cost push shock implied by the open economy case relative to the closed economy case. Figure 3.5-f represents the same response for output. At the zero-trend inflation rate, the real exchange rate alleviates the effect of the shock on CPI inflation because the shock makes imported goods relatively cheaper. This leads CPI inflation to increase less in the open-economy case. Because of the persistent shock, the IRFs of the difference series for CPI inflation is negative over the horizon. Output decreases less in open-economy case in the initial periods. Due to the hump-shaped dynamics of real exchange rate, the effect of the shock on output is long-lived in the open-economy. In the rest of period, the decrease in output in the open-economy surpass the one in closed-economy. Thus, the IRFs of the difference series for output is initially positive and then becomes negative. At higher trend inflation, the real exchange rate decreases more. Thus, the effect of openness on variables increases at higher trend inflation. In other words, the IRFs of the difference series for both CPI inflation and output shift outward.

3.5. Real Exchange Rate Puzzles

3.5.1. Delayed-Overshooting Puzzle

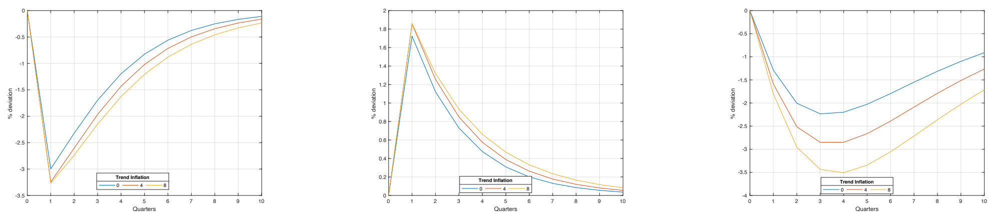
In this section, it is discussed how positive trend inflation contributes to the Delayed-Overshooting Puzzle in response to the types of shock under alternative sources of persistence or not. Figures 3.6-8 summarise the IRFs of the real exchange rate to the shocks at the levels of trend inflation under three alternative scenarios. three cases are considered: 1) shocks are persistent, 2) shocks are persistent and the policy rule has inertia, and 3) shocks are *i.i.d.* and the policy rule has inertia. Since the figures for Canada and the UK are similar, the figures only for Canada are shown and discussed. The figures for the UK are in Appendix II-B.4.

Figure 3.6 shows the IRFs of the real exchange rate in response to persistent monetary policy shock, persistent demand shock and persistent cost-push shock with the standard Taylor rule at different rates of trend inflation. Higher trend inflation rate increases the response of the real exchange rate to all the types of shocks, but it does not cause delayed-overshooting of the real exchange rate for all the types of shocks. Delayed-Overshooting occurs in the cases of demand and cost-push shocks



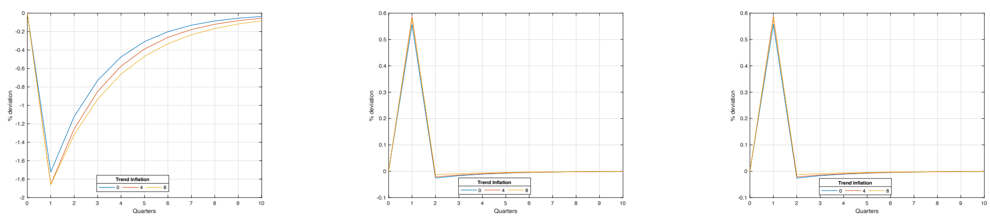
Monetary Policy Shock Demand Shock Cost-Push Shock

Figure 3.6 Standard Monetary Policy Rule with 1 Percent Persistent Shocks



Monetary Policy Shock Demand Shock Cost-Push Shock

Figure 3.7 Inertial Monetary Policy Rule with 1 Percent Persistent Shocks



Monetary Policy Shock Demand Shock Cost-Push Shock

Figure 3.8 Inertial Monetary Policy Rule with 1 Percent *i.i.d.* Shocks

Figure 3.7 presents the IRFs of the real exchange rate in response to persistent monetary policy shock, persistent demand shock and persistent cost-push shock with the inertial Taylor rule at different rates of trend inflation. Higher trend inflation rate increases the response of the real exchange rate to all the types of shocks. While it causes delayed-overshooting of the real exchange rate in the case of cost-push shock, it does not in the cases of monetary policy shock and demand shock. More specially, as can be observed in Figure 3.7-c, positive trend inflation plays an important role in the delayed overshooting of the real exchange rate. As trend inflation rises, the real exchange rate reaches its peak at a later quarter. In the other cases, the trend inflation rate does not play a significant role on the delayed-overshooting of the real exchange rate dynamics per se.

Figure 3.8 shows the IRFs of the real exchange rate in response to *i.i.d.* monetary policy shock, *i.i.d.* demand shock and *i.i.d.* cost-push shock with the inertial Taylor rule at different rates of trend inflation. Higher trend inflation rate increases the response of the real exchange rate to all the types of shock, but it does not cause delayed-overshooting of the real exchange rate for all the types of shock.

3.5.2. Purchasing Power Parity Puzzle

It is discussed whether the level of trend inflation plays any role to solve the Purchasing Power Parity Puzzle under the alternative scenarios or not. Tables 3.2, 3.3 and 3.4 summarise the persistence and volatility results, which are the half-life (HL), the quarter-life (QL), the up-life (UL)15, the first order autocorrelation coefficient < and the standard deviations, under the alternative scenarios for Canada. Since the results for Canada and the UK are similar, the results for Canada are only reported here and the ones for the UK are shown in Appendix II-B.5. It is found that the persistence of the real exchange rate rises in response to the shocks under all alternative scenarios with the exemption of persistent demand shock with inertial policy rule. On other hand, the real exchange rate becomes more volatile, as the level of trend inflation rises.

Table 3.2: Real Exchange Rate Properties under different Monetary Policy Shock Specifications and Policy Rules

	$\rho_i = 0$ and $\rho_v = 0.50$					$\rho_i = 0.80$ and $\rho_v = 0.50$					$\rho_i = 0.80$ and $\rho_v = 0$				
π	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.
0	2.13	4.26	1	0.72	1.00	2.30	4.61	1	0.74	4.46	1.61	3.22	1	0.65	2.27
4	2.21	4.42	1	0.73	1.10	2.59	5.17	1	0.76	4.87	1.79	3.58	1	0.68	2.44
8	2.29	4.58	1	0.74	1.21	2.94	5.87	1	0.79	5.34	2.01	4.02	1	0.71	2.64

Table 3.3: Real Exchange Rate Properties under different Demand Shock Specifications and Policy Rules

	$\rho_i = 0$ and $\rho_d = 0.80$					$\rho_i = 0.80$ and $\rho_d = 0.80$					$\rho_i = 0.80$ and $\rho_d = 0$				
π	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.
0	6.44	12.89	2	0.90	1.83	1.61	3.22	1	0.65	2.27	0.50	0.25	1	-0.04	0.56
4	6.68	13.37	2	0.90	2.07	1.79	3.58	1	0.68	2.44	0.50	0.25	1	-0.03	0.57
8	6.92	13.84	2	0.90	2.40	2.01	4.02	1	0.71	2.64	0.50	0.25	1	-0.02	0.58

Table 3.4: Real Exchange Rate Properties under different Cost-Push Shock Specifications and Policy Rules

	$\rho_i = 0$ and $\rho_u = 0.80$					$\rho_i = 0.80$ and $\rho_u = 0.80$					$\rho_i = 0.80$ and $\rho_u = 0$				
π	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.	HL	QL	UL	ρ	St. Dev.
0	6.44	12.89	2	0.90	6.15	16.04	32.07	3	0.95	5.54	1.61	3.22	1	0.65	0.68
4	6.68	13.37	2	0.90	7.99	17.84	35.69	3	0.96	7.02	1.79	3.59	1	0.68	0.73
8	6.92	13.84	2	0.90	10.53	20.04	40.08	4	0.97	9.12	2.01	4.02	1	0.71	0.79

Table 3.5 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation in Monetary Policy Shock

	CPI Inflation				Output			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	0.61	0.60	0.21	0.24	1.49	1.43	0.72	0.69
4	0.58	0.57	0.15	0.19	1.64	1.55	0.73	0.71
8	0.55	0.55	0.11	0.14	1.80	1.68	0.74	0.72

Table 3.6 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation in Demand Shock

	CPI Inflation				Output			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	1.51	1.52	0.68	0.72	2.73	2.51	0.90	0.87
4	1.42	1.46	0.64	0.70	3.09	2.72	0.90	0.88
8	1.29	1.39	0.59	0.68	3.59	3.00	0.90	0.88

Table 3.7 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation in Cost-Push Shock

	CPI Inflation				Output			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	3.18	4.06	0.92	0.93	9.18	11.84	0.90	0.91
4	4.11	5.09	0.93	0.94	11.93	14.87	0.90	0.92
8	5.40	6.47	0.93	0.94	15.72	18.97	0.90	0.92

3.6. Robustness Analysis

3.6.1. Domestic Inflation Indexation[15]

In this section, robustness analysis by introducing domestic inflation indexation into the benchmark model for both Canada and the UK is performed. This model is called as domestic inflation-indexed model. Since the results are similar for both countries, the results only for Canada are reported and are in appendix II-B.6 for the UK. Tables 3.5, 3.6 and 3.7 below display standard deviation and first order autocorrelation of the benchmark model and the model with partial domestic inflation indexation with degree of 0.20 in response to monetary policy shock, demand shock and cost-push shock.

Table 3.5 compares the specification results of CPI inflation and output generated by monetary policy shock in the benchmark model with the domestic inflation-indexed model. The standard deviations of both CPI inflation and output are higher in the

[15] All derivations related to this part are presented in Appendix II-A.3.

benchmark model compared to the other at different rates of trend inflation. While the indexation decreases the autocorrelation of output, it increases the autocorrelation of CPI inflation at different rates of trend inflation.

Table 3.6 compares the specification results of CPI inflation and output generated by demand shock in the benchmark model with the domestic inflation-indexed model. While the indexation increases the autocorrelation and standard deviation of CPI inflation, it decreases the autocorrelation and standard deviation of output at different rates of trend inflation.

Table 3.7 compares the specification results of CPI inflation and output generated by cost-push shock in the benchmark model with the domestic inflation-indexed model. The indexation increases both standard deviation and autocorrelation of CPI inflation and output at different rates of trend inflation.

More specifically, for the monetary policy shock and demand shock, all the specialisations (the standard deviation and first order autocorrelation) for both models are close to each other at the levels of trend inflation. On the other hand, while the autocorrelations are close each other for output, the standard deviations are different in the type of cost-push shock.

3.6.2. Independent and Identically Distributed Shocks *(i.i.d.)*

Figures 3.9-11 present the IRFs for Canada with an alternative shock persistence, (*i.i.d*). at different levels of trend inflation. The figures for the UK are in Appendix B-VII. Compared to the benchmark model, the effect of trend inflation on the variables with the exception of domestic inflation rate weakens for monetary policy shock and demand shock. The effect of trend inflation on domestic inflation is clear. It's effect on all variables weaken for cost-push shock.

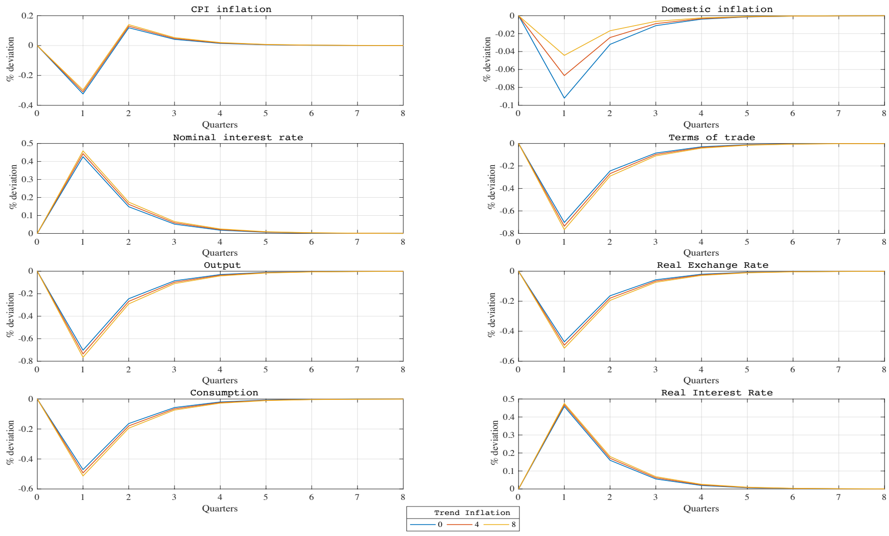


Figure 3.9 IRFs of the 1 Percent *i.i.d.* Monetary Policy Shock

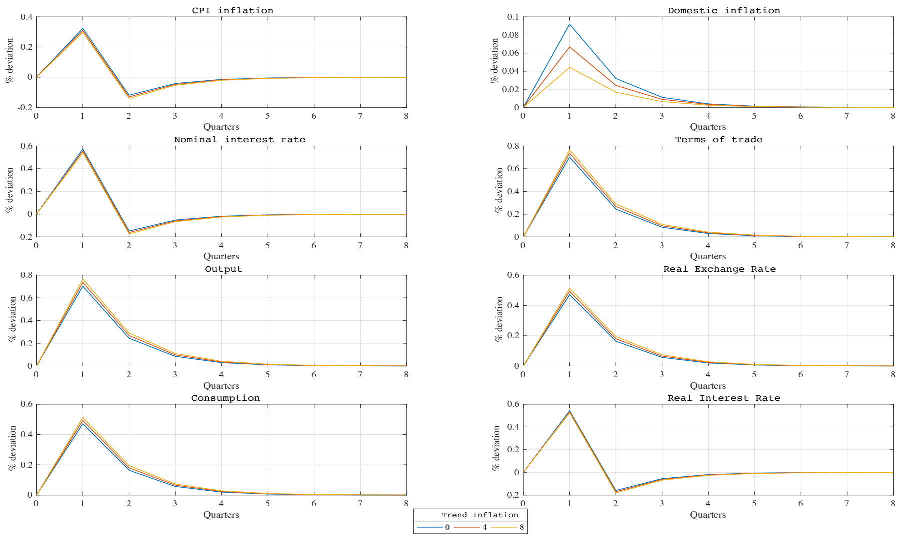


Figure 3.10 IRFs of the 1 Percent *i.i.d.* Demand Shock

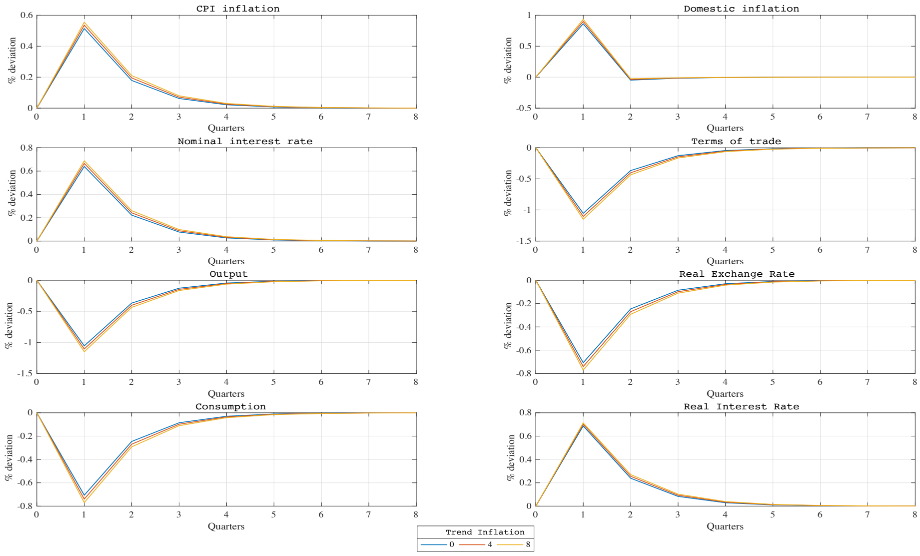


Figure 3.11 IRFs of 1 Percent *i.i.d.* Cost-Push Shock

3.7. Comparison of the Results with Relevant Studies

The issue of inflation targeting announced by Central Banks has been studied mainly in closed-economy models. In the context of New Keynesian framework, specifically Ascari (2004), Ascari and Ropele (2009), and Ascari and Sbordone (2014) analyse how the level of trend inflation affects the slope of NKPC in the closed-economy models. They conclude that positive trend inflation makes NKPC flatter. In other words, while future variables gain importance on NKPC, contemporaneous variables lose importance on it. Regarding this analysis, the model constructed in this study shows a similar pattern. As trend inflation increases, NKPC flattens. On the other hand, the degree of openness does not change the slope of NKPC.

Ascari and Ropele (2009) analyse the effects of cost-push shock on variables at different rates of trend inflation in the case of discretionary monetary policy rule in a closed economy. They find that trend inflation amplifies the effect of cost-push shock on inflation and output. In this paper, the effects of cost-push shock on the economy in the case of Taylor rule are analysed. Similar results with Ascari and Ropele (2009) are reached. Ascari and Sbordone (2014) analyse the effect of monetary policy shock on output and inflation at different rates of trend inflation. They find that trend inflation decreases the effect of monetary policy shock on inflation and increases the effect of the shock on output. In this paper, similar results are obtained and it is found that trend inflation decreases the effect of monetary policy shock on CPI inflation and domestic inflation and increases the effect of the shock on output.

Gali and Monacelli (2005) and Cooke (2011) discuss whether the degree of openness has an effect on the slope of NKPC or not. While Gali and Monacelli (2005) finds that the degree of openness has no effect on the slope of NKPC, Cooke (2011) finds the opposite result. In this regard, it is shown that the degree of openness has no impact on the slope of NKPC at the levels of trend inflation in our model. Similar to Gali and Monacelli (2005), the effect of openness on this model only works through real exchange rate dynamics. These dynamics alleviate the effects of trend inflation on CPI inflation and aggravate the effects of trend inflation on output. In addition to this channel, Cooke (2011) indicates that there is another channel, through which the degree of openness affects the slope of NKPC. In this model, since $\sigma = \eta = \gamma = 1$, the effect of openness working through NKPC does not affect the model.

Considering the effect of real exchange rate on the model, Cooke and Kara (2018) analyse that the effect of trend inflation on the dynamics of real exchange rate in both heterogenous and homogenous price stickiness in response to monetary policy shock. They find that while positive trend inflation leads more-muted dynamics for real exchange rate in response to monetary policy shock in the case of homogenous-price stickiness, it leads to stronger dynamics for real exchange rate in heterogeneous price-stickiness. In this paper, it is found that the dynamics of real exchange rate depends on the type of shock and the source of persistence in response to change in the level of trend inflation. In contrast to Cooke and Kara (2018), positive trend inflation leads to more persistent dynamics of real exchange rate in response to monetary policy shock in homogenous price stickiness. More specifically, higher trend inflation decreases the persistence of real exchange rate in Cooke and Kara (2018), but it increases the persistency of real exchange rate in this model.

3.8. Conclusion

An alternative version of *Small Open Economy* model based on Gali and Monacelli (2005) with positive trend inflation is developed Gali and Monacelli (2005)'s model assume that trend inflation is zero. It is a counterfactual assumption because of two reasons. First, the average inflation rates for developed countries are well above zero. Second, the Central Banks do not target zero inflation rate. This model is calibrated for both Canada and the UK. Initially, it is analysed how positive trend inflation affects the price-resetting behaviour of firms. Positive trend inflation has two-fold effects on their behaviour. First, the increased trend inflation makes intermediate goods producing firms more forward-looking. Second, intermediate firms increase their nominal prices more than the average nominal prices when they reset their prices. On the other hand, the effects of the increased trend inflation on the importance of both current and forward-looking variables in the NKPC are discussed. It is found that the importance of current variables on domestic inflation decreases while the effect of forward-looking variables on domestic inflation increases at higher trend inflation rates. The implications of trend inflation on the slope of NKPC for open-economy is similar to the ones for closed-economy modelled by Ascari (2004), Ascari and Ropele (2007), and Ascari and Sbordone (2014)' studies. Openness does not affect the slope of the NKPC, but only it affects the model through the foreign trade channel. For a given degree of openness, trend inflation aggravates the persistence of the real exchange rate. Thus, it affects the dynamics of the NKPC.

The IRFs are plotted to analyse the role of trend inflation on the dynamics of variables and it is found that the trend inflation rate plays a key role on the macroeconomic dynamics of variables in response to different types of shocks. For monetary policy shock, the increased trend inflation decreases the effect of shock on CPI inflation and domestic inflation, but it increases the effect of shock on the rest of the variables. At higher trend inflation, the Central Bank increases the nominal interest rate more to stabilise changes in CPI inflation and output, and households and firms face higher domestic inflation and CPI. For demand shock, the increased trend inflation decreases the effects of the shock on CPI inflation, domestic inflation and nominal interest rate while it increases the effects of the shock on the rest of the variables. The CB increases nominal interest rate less to stabilise change in CPI inflation and output in response to demand shock. The increased trend inflation increases the effects of shock on the variables in the case of cost-push shock. At higher trend inflation, the Central Bank increases nominal interest rate more to stabilise changes in CPI inflation and output, and households and firms face higher domestic inflation rate and CPI inflation rate in response to cost-push shock. Then, to analyse the effect of openness at the levels of trend inflation, the IRFs, expressed as deviations from the closed economy, for CPI inflation and output are presented for each type of shock. It is shown that openness affects the dynamics of variables mainly because of the real exchange rate dynamics regardless of trend inflation rate. The increased trend inflation aggravates the effect of openness on both CPI inflation and output for all types of shock.

It is finally discussed whether trend inflation and the sources of persistence lead to the delayed-overshooting of the real exchange rate under alternative scenarios or not. Higher trend inflation rate increases the effects of each shock on the real exchange rate, it only matters for the delayed-overshooting of the real exchange rate in response to the persistent cost-push shock with inertial policy rule. On the other hand, the source of persistence leads to the delayed overshooting of the real exchange rate in response to persistent demand and cost-push shocks with the standard Taylor rule and the persistent shock with the inertial Taylor rule regardless of trend inflation rate. Then, it is analysed the effect of positive trend inflation on both persistence and volatility of the real exchange rate in the context of PPP puzzle. It is found that trend inflation increases the persistence of the real exchange rate under all scenarios with an exemption of persistent demand shock with the inertial policy rule and increases the volatility of the real exchange rate.

There are several policy implications for the central banks that are implied by this study. Higher inflation targeting policy, followed by central banks, has both benefits and costs for the policy-makers. Those benefits and costs depend on the types of shock. In the cases of monetary policy shock and cost-push shock, higher trend inflation unanchors inflation expectations. The central banks could increase nominal interest rate substantially to combat the fluctuations of inflation rate and output. For this reason, the central banks should adopt long-run trend inflation rate as target level. However, in the case of demand shock, central bank does not need to respond to higher trend inflation by increasing nominal interest rate, due to the fact that effect of higher trend inflation on nominal interest rate is limited. Thus, central banks could target higher inflation rate in case of demand shock.

CHAPTER 4

TRADE OPENNESS, TREND INFLATION AND AGGREGATE INSTABILITY

4.1 Introduction

Prior to the 1980s, the US economy had been exposed to macroeconomic instability (volatile GDP, high inflation and unemployment rate) and trend inflation reached its peak of 5 percent. Starting from the mid-1980s, the inflation rate was significantly stabilised. This period is called the Great Moderation in economics literature. According to Bernanke (2004), strong monetary policy was the reason behind the Great Moderation. Clarida, Gali and Gerther (CGG) (2000) argue that the implemented monetary policy in the US economy is tighter in Volcker's tenure compared to the pre-Volcker period. The self-fulfilling fluctuations have occurred in the economy during the pre-Volcker period. Lubik and Schorfheide (LS) (2004) discuss the role of monetary policy on macroeconomic instability before 1979 and how changes in the policy contribute to macroeconomic stability after 1979. Boivin and Giannoni (2006), and Mavroeidis (2010) study this issue and their findings are in the line with CGG (2000) and LS (2004) findings. Therefore, the empirical evidence in the respective studies support Bernanke's explanation.

After the Credit Crunch in 2007, most of the central banks (CBs) abandoned symmetric response to macroeconomic variables through Taylor Rule and lowered nominal interest rate to zero lower bound. This phenomenon is known as Zero-Lower

Bound (ZLB). Some economists - like Blanchard et al. (2010), Williams (2009) and Ball (2013))- suggest to increase the target inflation rate. The reason behind this suggestion is that the increased trend inflation would pave the way for inflationary economic environment, leading to higher nominal interest rate through Taylor rule. Bernanke (2010) opposes to this suggestion and notes that cons of higher inflation targeting would overwhelm its pros. This policy would increase inflation expectations and self-fulfilling fluctuations in inflation could occur. Bernanke's concerns are empirically supported by Coibion and Gorodnichenko (2011). They show that a higher level of trend inflation contributes to indeterminacy in the pre-Volcker period.

The effect of positive trend inflation is already discussed by several authors. Woodford (2003) shows that determinacy region depends on how output responds to increase in inflation in the long-run. According to this finding, the central bank should increase nominal interest rate more than increase in inflation expectations. Ascari and Ropele (AR) (2009) indicate that the increased trend inflation shrinks determinacy region and the CB aggressively responds to fluctuations of inflation rate to achieve equilibrium determinacy[16]. Kara and Yates (KY) (forthcoming) reach similar results with AR (2009). Kara and Yates (KY) (forthcoming) find that the determinacy region is smaller in the model with heterogeneity-in-price stickiness compared to the one with homogenous price stickiness.

In this paper, this issue is re-visited, but unlike the papers cited above, the implications of positive trend inflation in an open economy model are studied. In particular, two-open and identical economy model of Gali and Monacelli (2005) is extended to account for positive trend inflation and heterogeneity-in-price stickiness as in KY (forthcoming).

[16] See Ascari and Sbordone (AS) (2014) for a survey.

The research question is as follows: *Does trade openness strengthen (or weaken) the effect of positive trend inflation on equilibrium determinacy?* To answer this question, we analytically discuss the effects of positive trend inflation on different models, especially on the New-Keynesian Philips Curves (NKPCs), which are standard-Calvo model, Multiple Calvo (MC) model and Open-Economy Multiple Calvo (OMC) model. This enables us to compare the models with each other and to understand how the individual features (*i.e.* heterogeneity in price stickiness and openness) of the MC and OMC models amplify (lessen) the effects of positive trend inflation on the models. In the case of the standard model, positive trend inflation induces more forward-looking and less contemporaneous dynamics of the New-Keynesian Philips Curve (NKPC) and a more persistent model through price dispersion. The findings are in parallel with AR (2009) and AS (2014). Moreover, the effects of trend inflation on the MC model are analysed. Depending on the degree of price stickiness, the implications of trend inflation on the MC model are heterogeneous. Higher (Lower) degrees of price-stickiness amplify (lessen) the effects of trend inflation on both contemporaneous and expected variables in the MC-NKPC. The NKPC depends on the expected variables more and on contemporaneous less in sectors with relatively sticky price behaviour. The reverse is valid for relatively flexible price behaviour sectors. Furthermore, it is shown that openness weakens the effect of positive trend inflation on the contemporaneous relation between MC-NKPC and output. In the long-run, openness plays multiplier role for the slope of the NKPC at different trend inflation rates. As economy becomes more open, the slope of NKPC becomes steeper and it becomes even steeper with the increased trend inflation.

It is found that openness and MC are important features for the effects of trend inflation on the dynamics of the model. Then, it is discussed how these features affect determinacy, using the standard Taylor rule. When the economy is closed, higher trend inflation leads to a narrower determinacy region in both MC and standard-Calvo models. The results are supported by Kara and Yates (forthcoming) for the MC model and are in line with AR (2009) and AS (2014) for the standard Calvo model. Openness multiplies the effects of trend inflation on the model. Accordingly, higher openness leads to higher effect of trend inflation on the determinacy region. At positive trend inflation rates, determinacy region becomes even narrower with the increased degree of openness. In the MC model, the region is even smaller than the Calvo model. In more open economy, the central bank should strongly respond to inflation rate fluctuations and weakly respond to output fluctuations to guarantee the equilibrium determinacy.

There are two main differences in the monetary policy transmission mechanisms in an open-economy and a closed-economy. The first channel is that increased trade openness flattens the slope of OMC-NKPC, and the second-channel is that the elasticity of output with respect to nominal interest rate is higher in the open-economy. With the increased openness, terms of trade affects the Euler Equation. More specifically, openness strengthens the effect of nominal interest rate on output through the dynamics of terms of trade. Thus, output responds more to monetary policy shock in the open economy compared to the closed-economy. Compared to the closed-economy, CPI inflation and nominal interest rate are higher and output is lower in the open-economy.

The organisation of the study is as follows: Section 4.2 introduces the model. Section 4.3 discusses how trend inflation, heterogeneity and openness contribute to the standard model. While Section 4.4 covers determinacy region discussion, Section 4.5 performs Robustness analysis. Section 4.6 discusses the effect of openness on the dynamics of the model. The last section, Section 4.7, concludes the paper.

4.2 Model[17]

In this paper, the model in Kara and Yates (forthcoming) is extended with an open economy setting[18]. There are two important features of this model. The first feature is heterogeneity in price stickiness (Carvalho (2006) and Kara (2015)). There are multiple sectors and there is individual Calvo-price setting mechanism with corresponding probability of price change. This is referred to a Multiple Calvo (MC) model. The second feature is positive trend inflation as in AS (2014). In each economy, there is continuum of intermediate firms indexed by $i \in [0,1]$ and firms are segmented into sectors indexed by $k \in [1, n]$ according to the degree of their price stickiness θ_k. There are two identical economies which are home economy and foreign economy indicated by H and F, respectively. The equations re-written for foreign economy below are shown with a star superscript.

4.2.1. Household

There is a representative and infinitely lived household in both home and foreign countries. The domestic household maximises the following utility function:

$$E_t \sum_{j=0}^{\infty} \beta^j \left[\frac{C_{t+j}^{1-\sigma}}{1-\sigma} - \frac{N_{t+j}^{1+\varphi}}{1+\varphi}\right] \tag{4.1}$$

[17] All derivations related to the model are shown in Appendices III-A.1 and III-A.2.

[18] Cooke and Kara (2018) develop two-identical and open economy model with positive trend inflation and heterogeneity in price stickiness to discuss the effect of trend inflation on Purchasing Power Parity puzzle.

subject to the period by period budget constraint:

$$P_t C_t + E_t\{(1+i_t)^{-1} B_{t+1}\} = B_t + W_t N_t + \Pi_t \tag{4.2}$$

where C_t is the aggregate composite consumption, N_t is labour supply, B_{t+1} is the nominal payoff in period *t + 1* of the portfolio held at the end of period *t*. W_t is nominal wage and Π_t is profit from firms' dividends. i_t is the nominal interest rate, $\sigma$is the inverse inter-temporal elasticity of substitution in consumption, φ is the inverse Frisch elasticity of labour supply, β is the intertemporal discount factor and E_t is the expectation operator at time *t*.

The optimisation of the household problem provides the Euler equation and the labour supply equation:

$$E_t\{\left(\frac{C_{t+1}}{C_t}\right)^{\sigma} P_{t+1}\} = \beta(1+i_t)P_t \tag{4.3}$$

$$\frac{W_t}{P_t} = C_t^{\sigma}\ N_t^{\varphi} \tag{4.4}$$

The composite consumption index C_t and sub-composite consumption indices $C_{H,t}$, $C_{F,t}$, $C_{H,k,t}$ and $C_{F,k,t}$ for home economy are defined as:

$$C_{H,k,t} = [f_k^{\frac{\epsilon-1}{\epsilon}} \int_0^1 \left(C_{H,k,i.t}\right)^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}} \tag{4.5}$$

and

$$C_{H,t} = [f_k^{\frac{1}{\zeta}} \sum_{k=1}^{n} (C_{H,k,t})^{\frac{\zeta-1}{\zeta}}]^{\frac{\zeta}{\zeta-1}}$$

$$C_{F,k,t} = [f_k^{\frac{\epsilon-1}{\epsilon}} \int_0^1 (C_{F,k,i.t})^{\frac{\epsilon-1}{\epsilon}} di]^{\frac{\epsilon}{\epsilon-1}}$$

and (4.6)

$$C_{F,t} = [f_k^{\frac{1}{\zeta}} \sum_{k=1}^{n} (C_{F,k,t})^{\frac{\zeta-1}{\zeta}}]^{\frac{\zeta}{\zeta-1}}$$

$$C_t = [(1-\alpha)^{\frac{1}{\nu}}(C_{H,t})^{\frac{\nu-1}{\nu}} + (\alpha)^{\frac{1}{\nu}}(C_{F,t})^{\frac{\nu-1}{\nu}}]^{\frac{\nu}{\nu-1}} \tag{4.7}$$

where $C_{H,k,i,t}$ is domestic demand for domestically-produced good i in sector k in home economy, $C_{F,k,i,t}$ is imported consumption good i in sector k to home economy, $C_{H,k,t}$ is the index of domestically-produced goods in sector k in home economy, $C_{F,k,t}$ is the index of imported consumption goods in sector k home economy, f_k is the weight of consumption goods in sector k across sectors where $\sum_{k=1}^{n} f_k = 1$, α is the degree of openness, ν is the elasticity of substitution between domestic and foreign goods, ϵ is the elasticity of substitution among differentiated goods in sector k and ζ is the elasticity of substitution among sectors.

Using cost-minimisation, domestic demand function for domestically-produced (imported) good i in sector k, domestic demand function for domestically-produced (imported) goods in sector k and aggregate domestic demand function for domestically-produced (imported) goods are:

$$C_{H,k,i,t} = f_k^{-1}\left(\frac{P_{H,k,i,t}}{P_{H,k,t}}\right)^{-\epsilon} C_{H,k,t};\ C_{H,k,t} = f_k\left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} C_{H,t};$$
$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t \tag{4.8}$$

$$C_{F,k,i,t} = f_k^{-1}\left(\frac{P_{F,k,i,t}}{P_{F,k,t}}\right)^{-\epsilon} C_{F,k,t};\ C_{F,k,t} = f_k\left(\frac{P_{F,k,t}}{P_{F,t}}\right)^{-\zeta} C_{F,t};$$
$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\nu} C_t \tag{4.9}$$

Consumer Price Index P_t and the other price indices $P_{H,t}$, $P_{H,k,t}$, $P_{F,t}$ and $P_{F,k,t}$ for home economy are:

$$P_{H,k,t} = [\int_0^1 (P_{H,k,i,t})^{1-\epsilon} di]^{\frac{1}{1-\epsilon}};$$
$$P_{H,t} = [\sum_{k=1}^{n} f_k (P_{H,k,t})^{1-\zeta}]^{\frac{1}{1-\zeta}} \tag{4.10}$$

$$P_t = [(1-\alpha)(P_{H,t})^{1-\nu} + \alpha(P_{F,t})^{1-\nu}]^{\frac{1}{1-\nu}} \tag{4.11}$$

$$P_{F,k,t} = [\int_0^1 (P_{F,k,i,t})^{1-\epsilon} di]^{\frac{1}{1-\epsilon}};$$
$$P_{F,t} = [\sum_{k=1}^{n} f_k (P_{F,k,t})^{1-\zeta}]^{\frac{1}{1-\zeta}} \tag{4.12}$$

where $P_{H,k,i,t}$ is the price of domestically-produced good *i* in sector *k* in home economy, $P_{H,k,t}$ is the price index of domestically-produced goods for sector *k* in home economy, $P_{H,t}$ is the aggregate price index for domestically-produced goods in home economy, $P_{F,k,i,t}$ is the price of imported good *i* in sector *k* in home economy, $P_{F,k,t}$ is the price index of imported goods for sector *k* in home economy, $P_{F,t}$ is the aggregate price index for imported goods in home economy and P_t is the aggregate price index in home economy.

4.2.2. Firms

In both home and foreign economies, a firm in sector k re-optimises its nominal price with the probability of $1-\theta_k$ and keeps its nominal price constant at time *t-1* with the probability of θ_k. Firm i in sector k maximises the following profit function in home economy to obtain the optimisation price $P^*_{H,k,i,t}$:

$$\max_{P^*_{H,k,i,t}} E_t \sum_{j=0}^{\infty} D_{t,t+j}\, \theta_k^j [P^*_{H,k,i,t} Y_{H,k,i,t+j} - W_{t+j} \frac{Y_{H,k,i,t+j}}{A_{t+k}}] \tag{4.13}$$

subject to the following demand function which the firm faces:

$$Y_{H,k,i,t+j} \equiv \left(\frac{P^*_{H,k,i,t}}{P_{H,k,t+j}}\right)^{-\epsilon} \left(\frac{P_{H,k,t+j}}{P_{H,t+j}}\right)^{-\zeta} Y_{t+j} \tag{4.14}$$

where $D_{t,t+j} = \beta^j \left(\frac{C_{t+j}}{C_t}\right)^{-\sigma} \left(\frac{P_t}{P_{t+j}}\right)$ is the Stochastic Discount Factor for home economy.

$$P^*_{H,k,i,t} = \frac{\epsilon}{\epsilon-1}\frac{\sum_{j=0}^{\infty}(\theta_k\beta)^j\left(C_{t+j}\right)^{-\sigma} w^r_{t+j}\, A^{-1}_{t+j}Y_{t+j}\left(P_{H,k,k+j}\right)^{\epsilon-\zeta} P^{\zeta}_{H,t+j}}{\sum_{j=0}^{\infty}(\theta_k\beta)^j\left(C_{t+j}\right)^{-\sigma}\, P^{-1}_{t+j}Y_{t+j}\left(P_{H,k,k+j}\right)^{\epsilon-\zeta} P^{\zeta}_{H,t+j}} \quad (4.15)$$

where $w^r_t = \frac{W_t}{P_t}$ is the real wage at time t in home economy.

$$p^*_{H,k,i,t} = \frac{\epsilon}{\epsilon-1}\frac{\sum_{j=0}^{\infty}(\theta_k\beta)^j\left(C_{t+j}\right)^{-\sigma} w^r_{t+j}\, A^{-1}_{t+j}Y_{t+j}\left(\Pi_{H,k,t,t+j}\right)^{\epsilon-\zeta}\Pi^{\zeta}_{H,t,t+j}}{\sum_{j=0}^{\infty}(\theta_k\beta)^j\left(C_{t+j}\right)^{-\sigma}\,\Pi^{-1}_{t,t+j}Y_{t+j}\left(\Pi_{H,k,t,t+j}\right)^{\epsilon-\zeta}\Pi^{\zeta}_{H,t,t+j}} \quad (4.16)$$

where $p^*_{H,k,i,t} = \frac{P^*_{H,k,i,t}}{P_t}$ is the relative reset price of firm *i* in sector *k* in the home economy, $\Pi_{t,t+j}$ is cumulative CPI inflation, $\Pi_{H,t,t+j}$ is cumulative domestic inflation and $\Pi_{H,k\ t,t+j}$ is cumulative domestic sectoral inflation in home economy between periods *t* and *t+j*. Note that since the mark-up is constant and the marginal cost is the same across intermediate firms, the relative reset prices are the same across firms (*i.e.* $p^*_{H,k,i,t} = p^*_{H,k,t}$). Both variables in the brackets are interchangeably used in the rest of the paper.

$$p^*_{H,k,t} = \frac{\epsilon}{\epsilon-1}\frac{\psi_{k,t}}{\phi_{k,t}} \quad (4.17)$$

$\psi_{k,t}$ and $\phi_{k,t}$ are recursively rewritten as follows:

$$\psi_{k,t} = w_t^r A_t^{-1} C_t^{-\sigma} Y_t + \beta\theta_k E_t(\pi_{H,k,t+1}^{\epsilon-\zeta} \pi_{H,t+1}^{\zeta} \psi_{k,t+1}) \quad (4.18)$$

and

$$\phi_{k,t} = C_t^{-\sigma} Y_t + \beta\theta_k E_t(\pi_{H,k,t+1}^{\epsilon-\zeta} \pi_{H,t+1}^{\zeta} \pi_{t+1}^{-1} \phi_{k,t+1}) \quad (4.19)$$

Equations (4.18) and (4.19) imply the present value of discounted marginal cost and the present value of discounted marginal revenue, respectively.

4.2.2.1. Price Dispersion

Labour demand is aggregated over *k* as follows:

$$N_t = \sum_{k=1}^{n} f(k) \frac{Y_{k,t}}{A_t} = \sum_{k=1}^{n} f(k) \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \frac{Y_t}{A_t} \quad (4.20)$$

The measure of price dispersion is $z_t = \sum_{k=1}^{n} f(k) \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta}$ and the measure of sectoral price dispersion is $z_{k,t} = \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta}$. The measure of price dispersion is expressed as follows: $z_t = \sum_{k=1}^{n} f(k) z_{k,t}$. It is the weighted average of sectoral price dispersions.

The aggregate production function is re-written as follows:

$$N_t = z_t \frac{Y_t}{A_t} \tag{4.21}$$

Following Schmitt-Grohé and Uribe (2007), sectoral price dispersion is expressed as

$$z_{k,t} = (1-\theta_k)\left(p^*_{H,k,t}\frac{P_t}{P_{H,t}}\right)^{-\zeta} + \theta_k \pi^{\zeta}_{H,t} z_{k,t-1} \tag{4.22}$$

4.2.2.2. Sectoral Calvo Pricing

In sector *k*, the average sectoral price level is expressed as follows:

$$P_{H,k,t} = \left[(1-\theta_k)\left(P^*_{H,k,t}\right)^{1-\epsilon} + \theta_k\left(P_{H,k,t-1}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \tag{4.23}$$

4.2.3. Monetary Policy Rule

The central bank follows the following policy rule:

$$\left(\frac{1+i_t}{1+\bar{\imath}}\right) = \left(\frac{\pi_t}{\pi}\right)^{\phi_\pi}\left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} \exp(v_t) \tag{4.24}$$

where i_t is the nominal interest rate and v_t, exogenous domestic monetary shock, follows AR(1). $\bar{\imath}, \bar{Y}$ and π are the steady state values of the nominal interest rate, output and CPI inflation. ϕ_π and ϕ_y are the coefficients of CPI inflation and output in monetary policy rule, respectively.

4.2.4. Some Definitions

Real Exchange Rate Q_t is the ratio of the foreign aggregate price level to the domestic aggregate price level in terms of the domestic currency.

$$Q_t = \frac{e_t P_t^*}{P_t} \tag{4.25}$$

where e_t is the nominal exchange rate and P_t^* is the aggregate price level in country *F* in terms of the foreign currency.

International Risk-Sharing condition defines that state-contingent bonds are internationally traded with no transaction cost. Using domestic and foreign Euler equations, the following relation is obtained:

$$Q_t = \left(\frac{C_t}{C_t^*}\right)^{\sigma} \tag{4.26}$$

Terms of Trade S_t is the ratio of the price index of imported goods in terms of domestic currency to the price index of domestic goods.

$$S_t = \frac{P_{F,t}}{P_{H,t}} \tag{4.27}$$

4.2.5. Market Clearing

The amount of domestically-produced good j in sector k equals the sum of domestic demand and foreign demand for this good.

$$Y_{H,k,i,t} = C_{H,k,i,t} + C_{H,k,i,t}^{F} \tag{4.28}$$

Substituting equations (4.8-9) and analogous of equations (4.8-9) for foreign economy into equation (4.28):

$$\begin{aligned} Y_{H,k,i,t} = \left(\frac{P_{H,k,i,t}}{P_{H,k,t}}\right)^{-\epsilon} \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} ((1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t \\ + \alpha^* \left(\frac{P_{H,t}}{e_t P_t^*}\right)^{-\nu} C_t^*) \end{aligned} \tag{4.29}$$

$$\begin{aligned} Y_{H,k,i,t} = (1-\alpha)\left(\frac{P_{H,k,i,t}}{P_{H,k,t}}\right)^{-\epsilon} \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t \\ + \alpha^* \left(\frac{P_{H,k,i,t}}{P_{H,k,t}}\right)^{-\epsilon} \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \left(\frac{P_{H,t}}{e_t P_t^*}\right)^{-\nu} C_t^* \end{aligned} \tag{4.30}$$

Using aggregate domestic output $Y_{H,k,i,t} = \left(\frac{P_{H,k,i,t}}{P_{H,k,t}}\right)^{-\epsilon} \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} Y_t$,

$$Y_t = ((1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t + \alpha^* \left(\frac{P_{H,t}}{e_t P_t^*}\right)^{-\nu} C_t^* \tag{4.31}$$

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t((1-\alpha) + \alpha^* \left(\frac{e_t P_t^*}{P_t}\right)^{\nu} \frac{C_t^*}{C_t}) \tag{4.32}$$

Using the risk-sharing condition $Q_t = \left(\frac{C_t}{C_t^*}\right)^{\sigma}$ and real exchange rate $Q_t = (\frac{e_t P_t^*}{P_t})$, the market clearing condition is

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\nu} C_t((1-\alpha) + \alpha^* Q_t^{\nu-\frac{1}{\sigma}}) \tag{4.33}$$

Note that the equations above which belong to home economy analogously hold for foreign economy.

4.2.6. Log-linearization

In this section, the equations are log-linearized around deterministic steady state. The Euler equation and labour supply in equations (4.3) and (4.4) are log-linearized as:

$$\hat{c}_t = \hat{c}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1});\ \widehat{w}^r{}_t = \sigma\hat{c}_t + \varphi\hat{n}_t \tag{4.34}$$

The pricing rule in equation (4.17):

$$\hat{p}^*{}_{H,k,t} = \hat{\psi}_{k,t} - \hat{\phi}_{k,t} \tag{4.35}$$

where

$$\hat{\psi}_{k,t} = (1 - \beta\theta_k\pi^{\epsilon})(\hat{w}^r{}_t - \hat{a}_t + \hat{y}_t - \sigma\hat{c}_t) + \beta\theta_k\pi^{\epsilon}((\epsilon - \zeta)\hat{\pi}_{H,k,t+1} + \zeta\hat{\pi}_{H,t+1} + \hat{\psi}_{k,t+1})$$

and

$$\hat{\phi}_{k,t} = (1 - \beta\theta_k\pi^{\epsilon-1})(\hat{y}_t - \sigma\hat{c}_t) + \beta\theta_k\pi^{\epsilon-1}((\epsilon - \zeta)\hat{\pi}_{H,k,t+1} + \zeta\hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{\phi}_{k,t+1})$$

The log-linearized Market Clearing Condition is as follows

$$\hat{y}_t = -\nu\hat{p}_{H,t} + \hat{c}_t + \alpha^*\left(\nu - \frac{1}{\sigma}\right)\hat{q}_t \tag{4.36}$$

Log-linearization of the sectoral average Calvo rule is:

$$\hat{p}^*{}_{H,k,t} = \hat{p}_{H,k,t} + \frac{\theta_k\pi^{\epsilon-1}}{1 - \theta_k\pi^{\epsilon-1}}\hat{\pi}_{H,k,t} \tag{4.37}$$

Log-linearization of sectoral price dispersion:

$$\hat{z}_{k,t} = \left(1 - \theta_k \pi^{\zeta}\right)\left(-\zeta \hat{p}^*{}_{H,k,t} + \zeta \hat{p}_{H,t}\right) + \theta_k \pi^{\zeta}(\zeta \hat{\pi}_{H,k,t} + \hat{z}_{k,t-1}) \tag{4.38}$$

$$\hat{z}_t = \sum_{k=1}^{n} f_k \hat{z}_{k,t} \tag{4.39}$$

The aggregate domestic production function in equation (4.21) is log-linearized as:

$$\hat{n}_t = \hat{z}_t + \hat{y}_t - \hat{a}_t \tag{4.40}$$

The weighted average of the domestic sectoral real prices is 0.

$$\sum_{k=1}^{n} f_k \hat{p}_{H,k,t} = 0 \tag{4.41}$$

The relation between the sectoral real domestic price in sector *k*, domestic inflation in sector *k* and CPI inflation is as follows:

$$\hat{p}_{H,k,t} = \hat{p}_{H,k,t-1} + \hat{\pi}_{H,k,t} - \hat{\pi}_t \tag{4.42}$$

The relation between the sectoral real price of imported goods at sector k, sectoral inflation of imported goods in sector k and CPI inflation is as follows:

$$\hat{p}_{F,k,t} = \hat{p}_{F,k,t-1} + \hat{\pi}_{F,k,t} - \hat{\pi}_t \tag{4.43}$$

Equation (4.12) is log-linearized as:

$$0 = (1-\alpha)\hat{p}_{H,t} + \alpha\hat{p}_{F,t} \tag{4.44}$$

When equation (4.26) is log-linearized as:

$$\hat{q}_t = \sigma(\hat{c}_t - \hat{c}_t^*) \tag{4.45}$$

The relation between sectoral inflation and aggregate domestic inflation is

$$\hat{\pi}_{H,t} = \sum_{k=1}^{n} f(k)\hat{\pi}_{H,k,t} \tag{4.46}$$

The Monetary Policy Rule:

$$\hat{\imath}_t = \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + v_t \tag{4.47}$$

Exogenous shocks for both economies are as follows:

$$Technology\ shock\ for\ home\ economy: \hat{a}_t = \rho_{\hat{a}}\hat{a}_{t-1} + e_{\hat{a},t} \qquad (4.48)$$

$$Monetary\ policy\ shock\ for\ home\ economy: \qquad (4.49)$$

$$v_t = \rho_v v_{t-1} + e_{v,t}$$

where ρ_v and $\rho_{\hat{a},t}$ are the persistence of monetary policy shock and technology shock, respectively.

4.2.7. Calibration

Table 4.1 Calibration Values of Parameters

Parameter	Value	Source
ϵ	10	Ascari and Sbordone (2014)
ζ	1	Carvalho and Nechio (2011 and 2016)
ν	1.5	Carvalho and Nechio (2011)
σ	3	Carvalho and Nechio (2011)

The stochastic discount factor β is 0.99, a common value in the business cycle literature. The persistence of exogenous monetary policy shock ρ_v is 0.85. For simplicity, the inverse Frisch elasticity of labour supply is assumed to be 0. Following Bils and Klenow (BK) (2004), the weight of each frequency (or sector) is calibrated according to BK (2004). They report the frequency of price changes for around 300 categories. Following Kara (2015), all the sectors are aggregated and divided into 10 segments according to their reset probabilities (0.1, 0.2 ... 1) by rounding reset probabilities to 0.10 percentage points. The sectors are scaled in the weight in expenditure share and distributed into each probability interval.

4.3. Trend Inflation, Heterogeneity and Openness

In this section, it is discussed how trend inflation affects the model, more specially the NKPC. For this reason, Open Economy Multiple-Calvo New Keynesian Phillips Curve (OMC-NKPC) is derived below in equation (4.50) using equations (4.35) and (4.37).

$$\begin{aligned} \hat{\pi}_{H,k,t} = {} & \kappa_{1,k}\left(\hat{w}^r{}_t - \hat{a}_t - \hat{p}_{H,k,t}\right) - \kappa_{2,k}(\hat{y}_t - \sigma\hat{c}_t) \\ & + \kappa_{2,k}\left(\zeta\hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{\phi}_{k,t+1}\right) \\ & + \kappa_{3,k,o}(\hat{\pi}_{H,k,t+1}) \end{aligned} \tag{4.50}$$

where $\kappa_{1,k} = (1 - \beta\theta_k\pi^{\epsilon})\frac{1-\theta_k\pi^{\epsilon-1}}{\theta_k\pi^{\epsilon-1}}$, $\kappa_{2,k} = \beta(\pi - 1)(1 - \theta_k\pi^{\epsilon-1})$,

$\kappa_{3,k,o} = \beta(\pi + (\epsilon - \zeta)(\pi - 1)(1 - \theta_k\pi^{\epsilon-1}))$ and

$$\hat{\phi}_{k,t} = (1 - \beta\theta_k\pi^{\epsilon-1})(\hat{y}_t - \sigma\hat{c}_t) + (\beta\theta_k\pi^{\epsilon-1})((\epsilon - \zeta)\hat{\pi}_{H,k,t+1} + \zeta\hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{\phi}_{k,t+1})$$

For better understanding how positive trend inflation affects the model, heterogeneity-in price stickiness and openness features of the model are considered. To shed light on how these features change the effect of trend inflation on the model, the standard model, Multiple Calvo (MC) model, and two-open and identical economy model are returned. It is discussed how incorporating positive trend inflation into the models change their dynamics and then compare the models with each other to capture the differences which arise from heterogeneity-in price stickiness and openness. To do so, the approaches in AR (2009) and AS (2014) are followed.

Dropping heterogeneity and openness features from the model reduces it to the ones in the papers mentioned above. In other words, the OMC-NKPC with trend inflation collapses to the standard NKPC with trend inflation in equation (4.51). The effect of the increased trend inflation on the standard model is previously discussed in AR (2009) and AS (2014). Recapitulating the discussion, it can be claimed that with positive trend inflation, the dynamics of the standard model change in three ways. First, the importance of the current variables decreases while the importance of the future variables increases on the NKPC with increased trend inflation. The reasons behind this change is based on the price-setting part of the model. The increase in trend inflation yields more forward-looking behaviour for price-resetting firms. In other words, firms care future variables more than current variables on resetting prices. Firms are aware that they can reset their prices in the future with a given probability. The relative prices and mark-ups would decrease if they do not reset. Therefore, they set their reset prices well above the average price level to protect the erosion of their relative prices and mark-ups at higher trend inflation rates. These two effects yield changes in the dynamics of NKPC. Second, positive trend inflation yields more persistent dynamics for price dispersion and so more persistent dynamics for the model. Third, an extra variable expected sectoral marginal revenue, $\hat{\phi}_{k,t+1}$ enters into to the dynamics of the NKPC.

$$\hat{\pi}_t = \kappa_1(\hat{w}^r{}_t - \hat{a}_t) - \kappa_2(1-\sigma)\hat{y}_t + \kappa_2(\hat{\phi}_{t+1}) + \kappa_3(\hat{\pi}_{t+1}) \qquad (4.51)$$

where $\kappa_1 = (1-\beta\theta\pi^{\epsilon})\frac{1-\theta\pi^{\epsilon-1}}{\theta_k\pi^{\epsilon-1}}$, $\kappa_2 = \beta(\pi-1)(1-\theta\pi^{\epsilon-1}), \kappa_3 = \beta\big(\pi + (\epsilon-1)(\pi-1)(1-\theta\pi^{\epsilon-1})\big)$

and

$$\hat{\phi}_t = (1-\beta\theta\pi^{\epsilon-1})(1-\sigma)\hat{y}_t + (\beta\theta\pi^{\epsilon-1})((\epsilon-1)\hat{\pi}_{t+1} + \hat{\phi}_{t+1})$$

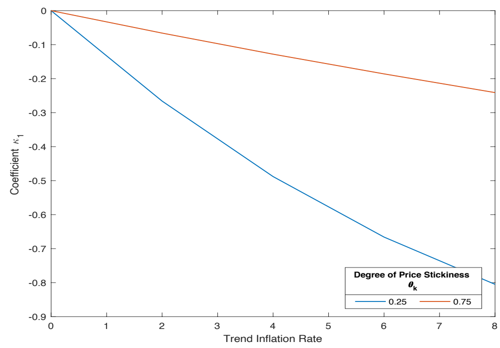
Having indicated the effects of positive trend inflation in the standard model, It is now turned to analyse the effects of positive trend inflation in the MC model. If a closed economy is assumed, the model reduces to the MC model with trend inflation as in Kara and Yates (forthcoming). Accordingly, the OMC-NKPC collapses to the MC-NKPC in equation (4.52). The implications of the increased trend inflation on the MC model is previously discussed in Kara and Yates (forthcoming) and the discussion mainly to understand whether the degree of heterogeneity-in price stickiness has effect(s) on the implications of positive trend inflation or not are re-visited. With positive trend inflation, the MC model changes in three ways. First, the weight of contemporaneous variables on sectoral NKPC decreases while the future variables' increases, with the increased trend inflation. To capture the role of heterogeneity in price stickiness on the effect of trend inflation on the contemporaneous and future variables through coefficients $\kappa_{1,k}$ and $\kappa_{2,k}$, two graphs are drawn in Figure 4-1. The red line belongs to relatively flexible sector and the blue line belongs to relatively sticky sector. The degrees of heterogeneity in price stickiness are set to 0.25 and 0.75, respectively. It is assumed that σ is 1 only for this analysis.

$$\hat{\pi}_{k,t} = \kappa_{1,k}\left(\hat{w}^r{}_t - \hat{a}_t - \hat{p}_{k,t}\right) - \kappa_{2,k}(1-\sigma)\hat{y}_t + \kappa_{2,k}\left(\hat{\phi}_{k,t+1} - \hat{\pi}_{t+1}\right) + \kappa_{3,k}(\hat{\pi}_{k,t+1}) \tag{4.52}$$

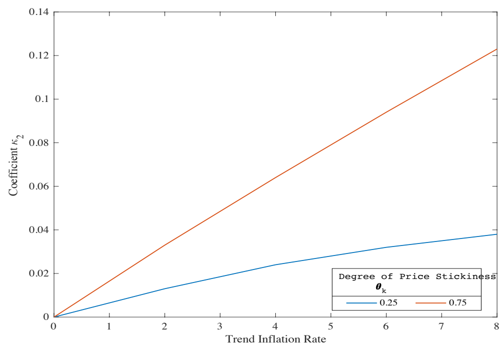
where $\kappa_{1,k} = (1-\beta\theta_k\pi^{\epsilon})\frac{1-\theta_k\pi^{\epsilon-1}}{\theta_k\pi^{\epsilon-1}}$, $\kappa_2 = \beta(\pi-1)(1-\theta_k\pi^{\epsilon-1})$,
$\kappa_{3,k} = \beta(\pi + (\epsilon)(\pi-1)(1-\theta_k\pi^{\epsilon-1}))$

and

$$\hat{\phi}_{k,t} = (1-\beta\theta_k\pi^{\epsilon-1})(1-\sigma)\hat{y}_t + (\beta\theta_k\pi^{\epsilon-1})((\epsilon-\zeta)\hat{\pi}_{k,t+1} + (\zeta-1)\hat{\pi}_{t+1} + \hat{\phi}_{k,t+1})$$



(a) Coefficient $\kappa_{1,k}$: Percentage deviation from zero trend inflation rate



(b) Coefficient $\kappa_{2,k}$: Percentage deviation from zero trend inflation rate

Figure 4.1 Comparative Analysis $\kappa_{1,k}$ and $\kappa_{2,k}$ in Relatively Flexible and Sticky Sectors

Figure 4.1 compares how coefficients $\kappa_{1,k}$ and $\kappa_{2,k}$ in terms of percentage deviation from their values at zero-trend inflation rate respond to increase in trend inflation in relatively flexible sector and relatively sticky sector. Figure 4.1-a shows that the sensitivity of the coefficient $\kappa_{1,k}$ to increase in trend inflation is higher in relatively flexible sector than in relatively sticky sector while the responsiveness of the coefficient $\kappa_{2,k}$ to increase in trend inflation is higher in relatively sticky sector than in relatively flexible sector. As trend inflation rate increases, inflation rate becomes less (more) sensitive to change in contemporaneous (expected) variables in relatively sticky sector while it becomes more (less) sensitive to change in contemporaneous (expected) variables in relatively flexible sector. Firms in relatively sticky sector know that they can reset their nominal prices with a lower probability than those in relatively flexible sector. When firms in sticky sector have opportunity to reset their nominal prices, they reset their nominal prices more aggressively than those in relatively flexible sector. Therefore, their nominal prices become well above the average price level. In this way, it is explained how the degree of heterogeneity in price stickiness alters the effect of trend inflation on the NK model.

Second, some extra variables $\hat{\phi}_{k,t+1}$ and $\hat{\pi}_{t+1}$which are expected sectoral marginal cost and CPI inflation enters into the model. Since sectoral inflation $\hat{\pi}_{H,k,t}$ is influenced by CPI inflation, Kara and Yates (forthcoming) note that the sectoral inflations affect each other. In other words, the sectoral inflation of any sector is determined by other sectors' through CPI inflation rate channel. Later, sectoral price dispersion enters into the model, and due to inertial dynamics of price dispersion, price dispersion yields more persistent dynamics for the model.

4.3.1. Multiple Calvo with Trade Openness

So far, the effects of positive trend inflation on the dynamics of the models have been discussed above. Bearing the effects of trend inflation on the models in mind, it is now turned to discussions on the effect of positive trend inflation on the OMC model. In particular, it is analysed how *trade openness* alters the effects of positive trend inflation in the OMC model. To address this issue, the OMC-NKPC in equation (4.50) is written in the terms of output. For this purpose, the following steps are pursued: The MC model is reduced to two-sector model, which composes of one sticky, sector 1, and one flexible sector, sector 2, as in KY (forthcoming). The weights of each sector are assumed to be ω_1 and ω_2. The consumption of foreign country is kept constant and φ is assumed to be 0. Using the following relation $-\hat{p}_{H,1,t} = \frac{\omega_2}{\omega_1}\hat{p}_{H,2,t} = \frac{\omega_2}{\omega_1}\sigma\hat{c}_t$ the NKPC in terms of output for the sticky sector is written as follows

$$\hat{\pi}_{H,1,t} = \left(\frac{\kappa_{1,1}}{\Lambda}\left(\sigma\frac{\omega_2}{\omega_1} + \sigma\right) - \kappa_{2,1}\left(1 - \frac{\sigma}{\Lambda}\right)\right)\hat{y_t} + \kappa_{2,1}\left(\zeta\hat{\pi}_{H,t+1} - \hat{\pi}_{t+1} + \hat{\phi}_{1,t+1}\right) + \kappa_{3,1,o}\left(\hat{\pi}_{H,1,t+1}\right) \quad (4.53)$$

where

$$\Lambda = \frac{\nu\sigma\alpha}{1-\alpha} + 1 + \alpha^*(\nu\sigma - 1)$$

Equation (4.53) shows that openness has an effect on the importance of the current variables in the sectoral NKPC, but it does not affect the importance of the future variables. In other words, the degree of openness changes the contemporaneous relation between sectoral domestic inflation and output. To demonstrate this contemporaneous relation (*i.e.* the slope of short-run sectoral NKPC) for the range of $\alpha \in [0{,}50]$ at different trend inflation rates, the weight of each sector is assumed to be 0.50 and price rigidity of sector 1 (θ_1) is set to 0.75. The other parameter values are the same as before.

Figure 4.2 elaborates the effect of trend inflation rates on the contemporaneous coefficient of the OMC-NKPC across the different degrees of openness. it is found that the more open the economy, the flatter the OMC-NKPC at zero-trend inflation rate. Razin and Yuen (2002) analyse the effect of openness on the slope of NKPC in the standard model and indicate that higher trade openness decreases the slope of NKPC. At positive trend inflation rates, the short-run OMC-NKPC's slope becomes even more flatter. It is concluded that openness decreases the effect of positive trend inflation only on the contemporaneous relation. The intuition behind this dynamics is that price-resetting firms re-set their prices in open-economy with the increased trend inflation, accounting for import-export channel. Otherwise, keeping prices at the level in closed-economy would induce lower demand for price-resetting firms in the domestic economy. Thus, they put lower prices compared to the closed-economy.

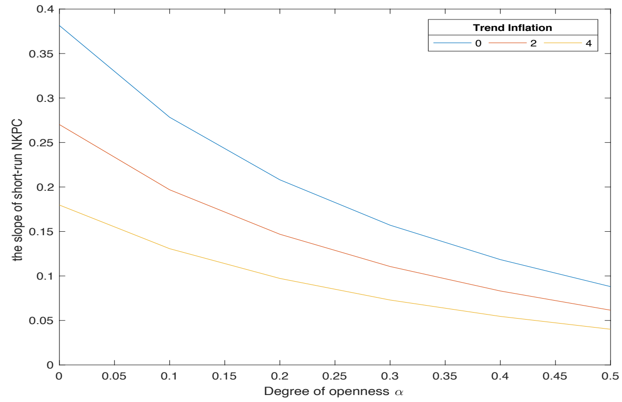
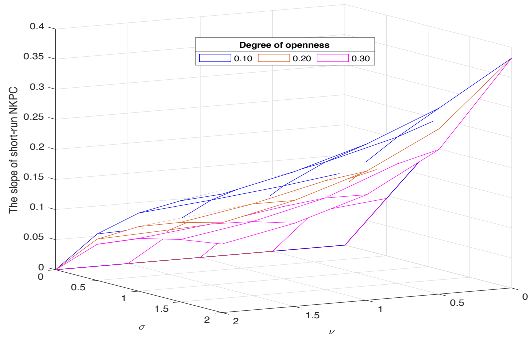


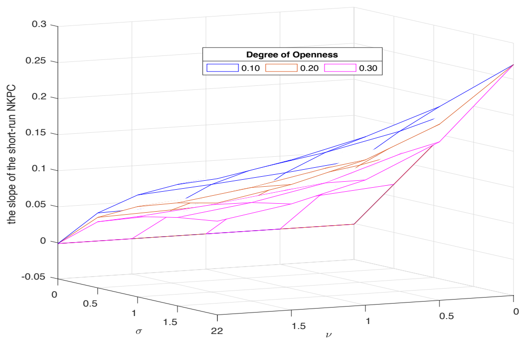
Figure 4.2 the Slope of the NKPC in terms of Output

Furthermore, allowing positive trend inflation enriches the dynamics of the NKPC. In addition to output and expected sectoral domestic inflation, the sectoral domestic inflation depends on the expected CPI inflation, domestic inflation and auxiliary variable $\hat{\phi}_{H,k,t+1}$. In other words, it is also affected by inflation rates of other sectors through domestic inflation and foreign price level through CPI inflation. Sectoral price dispersion becomes more persistent and the model so at positive trend inflation rates. Finally, it is controlled whether the relation between the inverse elasticity of intra-temporal substitution σ and the elasticity of substitution between domestic and foreign goods ν matters for short-run slope or not.

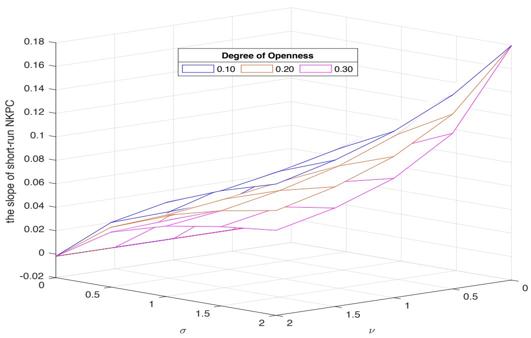
As shown in Figure 4.3, it is found that the degree of openness affects the slope of OMC-NKPC, regardless of the magnitude of $\sigma\nu$. At all the values of $\sigma\nu$, an increase in degree of openness lowers the slope of OMC-NKPC. However, for higher values of them, the decrease in the slope becomes higher. This conclusion is independent of trend inflation rates. Ceteris paribus, increase in trend inflation rate flattens the slope of OMC-NKPC.



(a) 0 % Trend Inflation



(b) 2 % Trend Inflation



(c) 4 % Trend Inflation

Figure 4.3 the Slope of Short-run NKPC

4.3.2. The Long-run Sectoral NKPC

Woodford (2003) argues that determinacy region is affected by the elasticity of output with respect to inflation rate in the long-run (*i.e.* the slope of the long-run OMC-NKPC). To analyse the effect of trend inflation on the determinacy region, it is shown how output responds to inflation rate with the increased openness at higher trend inflation rates in the long-run. $\hat{\pi}_{H,k,t}$, $\hat{\pi}_{H,t}$ and $\hat{\pi}_t$ equal $\hat{\pi}$ and $\hat{y}_t$ equals $\hat{y}$ in the long-run. Therefore, the long-run OMC-NKPC can be written as follows:

$$\hat{\pi} = \left(\frac{\kappa_{1,1}}{\Lambda}\left(\sigma\frac{\omega_2}{\omega_1}+\sigma\right)-\kappa_{2,1}\left(1-\frac{\sigma}{\Lambda}\right)\right)\hat{y}+(\kappa_{2,1}(\epsilon-1)+\beta\pi)\hat{\pi} + \kappa_{2,1}\hat{\phi}_1 \tag{4.54}$$

After some manipulations, the present value of discounted marginal cost equation in the long-run becomes is as follows:

$$\hat{\phi}_1 = (1-\beta\theta_1\pi^{\epsilon-1})\left(1-\frac{\sigma}{\Lambda}\right)\hat{y}+(\beta\theta_1\pi^{\epsilon-1})((\epsilon-1)\hat{\pi}+\hat{\phi}_1)$$

The slope of the long-run NKPC is

$$\frac{\partial\hat{y}}{\partial\hat{\pi}} = \Lambda\frac{(1-\kappa_{2,1}\left(\epsilon-1+\dfrac{\beta\theta_1\pi^{\epsilon-1}(\epsilon-1)}{1-\beta\theta_1\pi^{\epsilon-1}}\right)-\beta\pi)}{\kappa_{1,1}\left(\sigma\dfrac{\omega_2}{\omega_1}+\sigma\right)} \tag{4.55}$$

where $\Lambda = \frac{\nu\sigma\alpha}{1-\alpha}+1+\alpha^*(\nu\sigma-1)$

Equation (4.55) indicates that the slope of OMC-NKPC depends on the trend inflation rate π, the degree of openness α, the weight of sticky sector, the inverse elasticity of inter-temporal substitution σ, and the elasticity of substitution between domestic and foreign goods ν in the long-run. When positive trend inflation, heterogeneity and openness assumptions, and related parameters are dropped, the equation collapses to $\frac{\partial \hat{y}}{\partial \hat{\pi}} = \frac{1-\beta}{\kappa_1}$ which is the same as in Woodford (2003). Accounting only for positive trend inflation, the equation changes to the one in AR (2009) as follows:

$$\frac{\partial \hat{y}}{\partial \hat{\pi}} = \frac{(1 - \kappa_{2,1}\left(\epsilon - 1 + \frac{\beta\theta\pi^{\epsilon-1}(\epsilon - 1)}{1 - \beta\theta\pi^{\epsilon-1}}\right) - \beta\pi)}{\kappa_{1,1}(\sigma)} \tag{4.56}$$

By setting σ and ν to 3 and 1.5 respectively, equal sectoral weights (*i.e.* $\omega_1 = \omega_2 = 0.50$) and $\theta_1 = 0.75$ for sticky sector and $\theta_2 = 0$ for flexible sector, Figure 4.4 plots the long-run relation between output and sectoral inflation for openness $\alpha \in [0, 0.50]$ at different trend inflation rates.

At zero trend inflation rate, the slope of the long-run OMC-NKPC is positive. In other words, decrease in output goes along with decrease in sectoral inflation. Higher trend inflation yields higher inflation expectation and this dominates decrease in output, so the slope becomes negative. There occurs an inverse relation between output and OMC-NKPC. Openness plays a multiplier role for the long-run relation between output and inflation. In other words, the degree of openness makes the slope of the OMC-NKPC flatter at a given rate trend inflation. At higher trend inflation rates, openness makes the OMC-NKPC even flatter. Higher trend inflation yields more persistent dynamics of terms of trade and a significant decline in terms of trade. In other words, domestic goods become comparatively expensive. Higher degree of openness provides opportunity to trade with foreign countries. In a more open economy, imported goods are preferred more due to relative cheapness with the increased trend inflation. Thus, decrease in domestic production is greater. This mechanism summarises the intuition behind why higher openness leads to steeper OMC-NKPC in higher trend inflation rates in the long-run.

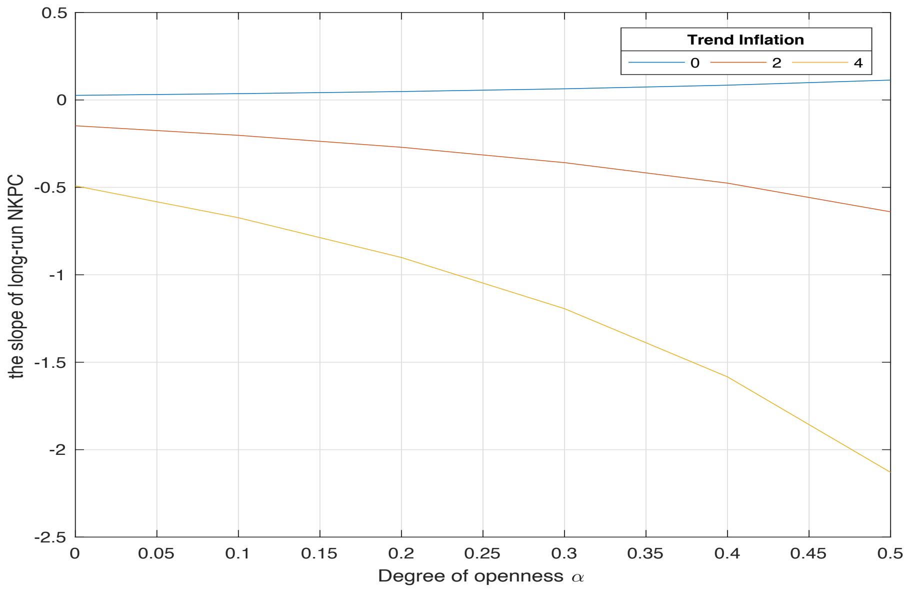


Figure 4.4 the Slope of Long-run NKPC

4.4. Determinacy

Having analytically discussed how openness and MC affect the importance of trend inflation on the short-run and long-run dynamics of the model, it is now turned to analyse how these features shape determinacy region. Determinacy region is a set of pairs of alternative Taylor Rule parameters where determinacy equilibrium is achieved for each pair. Following Woodford (2003), a necessary and sufficient condition for determinacy at zero-trend inflation rate in a closed-economy is

$$\frac{\partial \hat{\imath}}{\partial \hat{\pi}} = \phi_\pi + \phi_y \frac{1-\beta}{\kappa_1} > 1 \qquad (4.57)$$

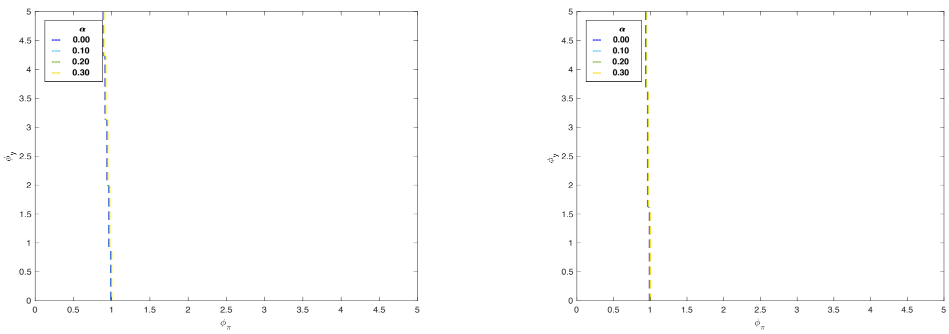
This condition implies that one percent sunspot increase in inflation expectations requires that the Central Bank should increase nominal interest rate by more than one percent to achieve equilibrium determinacy. A sun-spot increase in inflation decreases the real interest rate. This increase in real interest rate leads to increase output and then contemporaneous inflation rate through the NKPC. Using the standard NKPC $\hat{\pi}_t = \frac{(1-\theta)(1-\beta\theta)}{\theta}\hat{y}_t + \beta\hat{\pi}_{t+1}$, contemporaneous inflation rate is higher than sun-spot increase in inflation expectation. Unless the central bank sufficiently responds to these increases by increasing nominal interest rate, economy is exposed to self-fulling driven fluctuations. Thus, the CB sticks to the condition above to prevent the self-fulling fluctuations. Having given the standard condition for equilibrium determinacy, the generalised condition for equilibrium determinacy is as follows:

$$\frac{\partial\hat{\imath}}{\partial\hat{\pi}} = \phi_\pi + \phi_y\frac{\partial\hat{y}}{\partial\hat{\pi}} > 1 \qquad (4.58)$$

Besides Taylor rule parameters ϕ_π and ϕ_y , the condition depends on the long-run slope of NKPC, $\frac{\partial\hat{y}}{\partial\hat{\pi}}$.

Figure 4.5 presents how determinacy regions respond to increase in the degree of openness at different trend inflation rates and then compares the results with the ones in the standard model. The degree of openness does not affect the determinacy region at zero-trend inflation rate. The result is consistent with the finding in Figure 4.4. In the other words, the long-run slope of NKPC is nearly flat over different degrees of openness at zero-trend inflation rate. This is the reason why openness does not affect the region at this level of trend inflation. It would be sufficient for the central bank to react only to fluctuations in inflation rate. At zero trend inflation rate, determinacy region is not affected by trade openness in both the standard model and MC model. De Fiore and Liu (2005) confirm the result for the standard model. Raising trend inflation from 0 to positive rate(s) makes openness matter for determinacy region. At

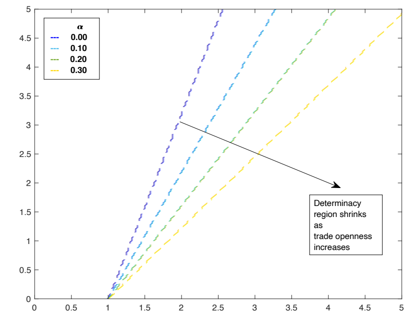
2 percent trend inflation, higher degree of openness rapidly shrinks the determinacy region. This means that openness magnifies the effect of positive trend inflation over the region. In openness of economies increases, the central banks should react strongly to inflation, but weakly to output to guarantee determinacy. Reacting strongly to output fluctuations may lead to equilibrium indeterminacy. At 4 percent trend inflation rate, rising the degree of openness rapidly shrinks determinacy region more. In other words, it gets even narrower as the degree of openness increases. Comparing the result with the standard model, at positive trend inflation rates, determinacy regions are even smaller for each degree of openness. The intuition depends on the relation between sectoral price stickiness and trend inflation rate. In relatively more rigid sectors, the effects of trend inflation on the dynamics of OMC-NKPC are larger, regardless of the degree of openness. Thus, the effects of trend inflation on determinacy region become higher in the OMC model compared to the standard model. On the other hand, increase in the degree of openness shrinks the determinacy region in the standard-Calvo model at positive trend inflation rates.



(a) 0 % Trend Inflation
Multiple Sector

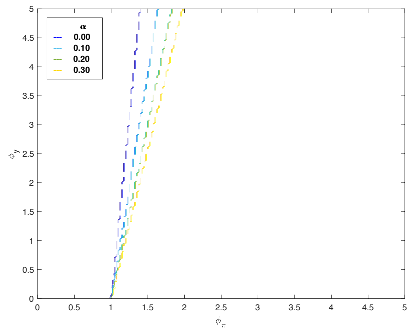
(b) 0 % Trend Inflation
One Sector

Figure 4.5 Determinacy Region-Multiple Sector versus One Sector



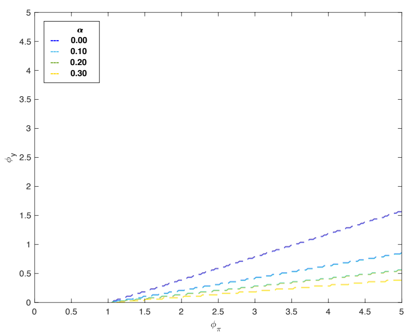
(c) 2 % Trend Inflation

Multiple Sector



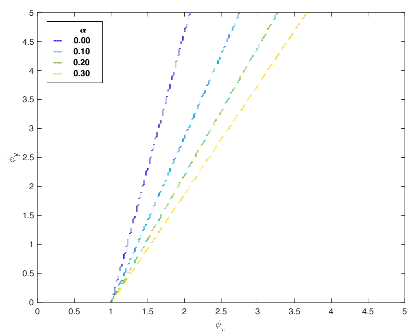
(d) 2 % Trend Inflation

One Sector



(c) 4 % Trend Inflation

Multiple Sector



(d) 4 % Trend Inflation

One Sector

Figure 4.5 (Con't) Determinacy Region-Multiple Sector versus One Sector

4.5. Robustness

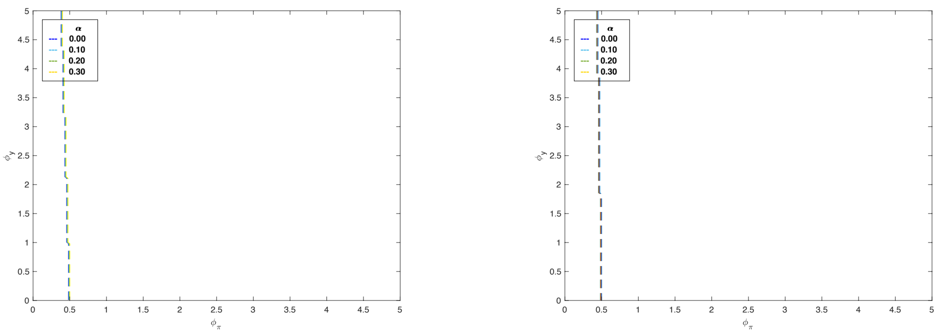
In this section, it is analysed whether the results found in the previous section are robust with respect to the inertial Taylor rule or not and compare the findings in this section with the previous one. The inertial Taylor rule is expressed as follows: $\hat{\imath}_t = \rho_i \hat{\imath}_{t-1} + \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t + v_t$. A necessary and sufficient condition for equilibrium determinacy in the case of inertial Taylor rule is:

$$\frac{\partial \hat{\imath}}{\partial \hat{\pi}} = \phi_\pi + \phi_y \frac{\partial \hat{y}}{\partial \hat{\pi}} > 1 - \rho_i \tag{4.59}$$

With ρ_i = 0.50, this condition becomes:

$$\frac{\partial \hat{\imath}}{\partial \hat{\pi}} = \phi_\pi + \phi_y \frac{\partial \hat{y}}{\partial \hat{\pi}} > 0.50 \tag{4.60}$$

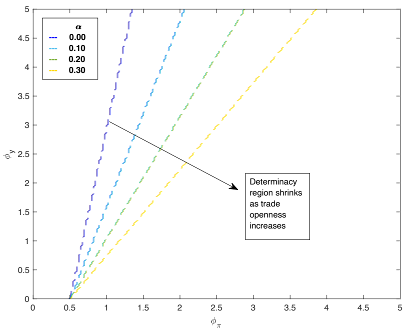
Equation (4.60) implies that one percent sunspot increase in inflation expectations should require more than half percent increase in nominal interest rate to achieve equilibrium determinacy. Figures 4.6 shows the effect of openness on determinacy region at different trend inflation rates in the inertial Taylor rule. The degree of openness has the similar implications with the standard Taylor rule on determinacy region at the different interest rate. However, determinacy region is comparatively larger in the case of the inertial Taylor rule. The reason behind this result is that monetary policy parameters, ϕ_π and ϕ_y comparatively lose their importance on stabilising inflation. Thus, the Central Bank does not need to respond to both inflation and output fluctuations in the inertial Taylor rule as strongly as in the standard Taylor rule.



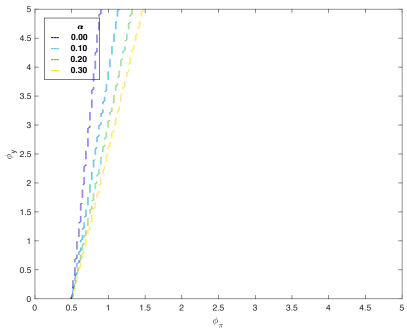
(a) 0 % Trend Inflation Multiple Sector

(b) 0 % Trend Inflation One Sector

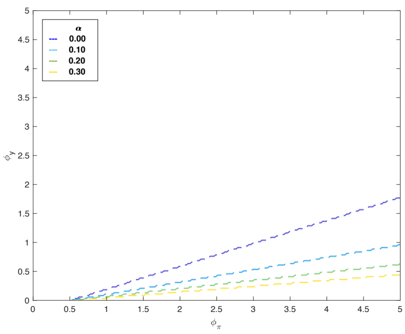
Figure 4.6 Determinacy Region-Multiple Sectors versus One Sector



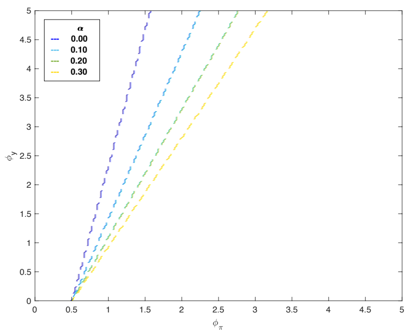
(c) 2 % Trend Inflation
Multiple Sector



(d) 2 % Trend Inflation
One Sector



(e) 4 % Trend Inflation
Multiple Sector



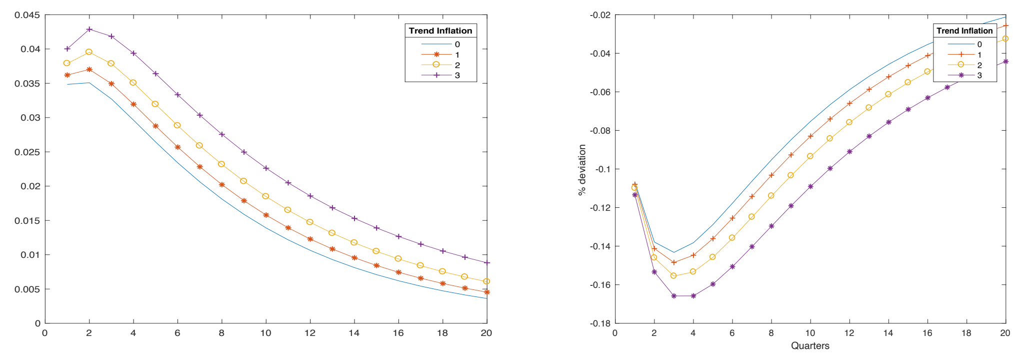
(f) 4 % Trend Inflation
One Sector

Figure 4.6 (Con't) Determinacy Region-Multiple Sectors versus One Sector

4.6. Dynamic Analysis

In this section, the differences of monetary transmission mechanism of the model with the closed-economy is firstly revealed. There are two channels, with regards to the monetary policy transmission mechanism of the open-economy, which are not present in closed-economy models. The first channel is that openness flattens the slope of sectoral NKPC. It means that sectoral inflation weakly responds to change in contemporaneous variables. The latter channel is terms of trade and discussed through Euler Equation for output. Moreover, positive trend inflation has effects on these channels. Higher trend inflation rates flatten the slope of sectoral NKPC and yields more persistent dynamics of terms of trade for a given degree of openness.

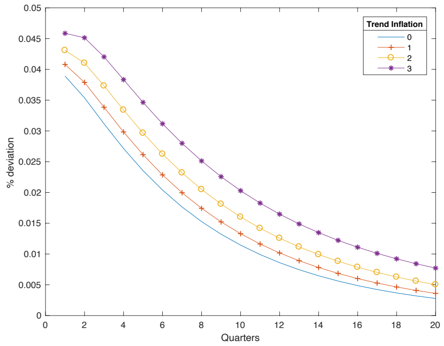
In the light of these differences, the effect of one percent monetary policy shock on CPI inflation, nominal interest rate, output and terms of trade are evaluated at different trend inflation rates. The impulse response functions (IRFs) of these variables are expressed in the form of deviation from the closed-economy are shown in Figure 4.7. Solving the Euler Equation in the terms of output for open and closed-economies leads to the following relation: $\frac{\partial \hat{y}_t^{oe}}{\partial v_t} > \frac{\partial \hat{y}_t^{ce}}{\partial v_t}$ in absolute terms[19]. In other words, openness rises the sensitivity of output to monetary policy shock. Thus, output is lower in open-economy compared to closed-economy. Intuition behind this result stems from two sources. The first source, intra-temporal elasticity of substitution σ is common for both cases. The second source, the interaction between the substitutability between domestic and foreign goods ν, and the degree of openness α, leads to this result. Monetary policy shock causes appreciation of domestic currency and imported goods become cheaper. Demand for home goods and thus, domestic production decline. Due to weak relation between domestic inflation and current variables in the open-economy and relatively cheaper imported goods, CPI inflation decreases less in the open-economy. For higher CPI inflation and lower output, nominal interest rate is higher in the open-economy compared to the closed-economy. Moreover, trend inflation strengthens the effect of openness on the dynamics of the model through these channels. Thus, all the IRFs shift outward.



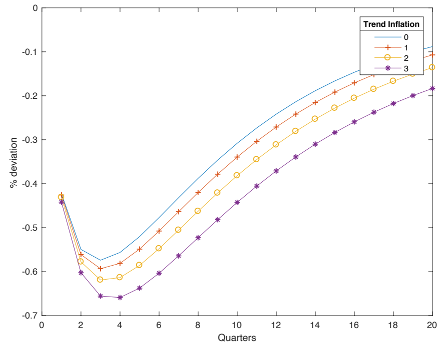
(a) CPI Inflation (b) Output

Figure 4.7 Impulse Response Functions of 1 Percent Monetary Policy Shock

[19] Derivation is presented in appendix III-A.2.



(c) Interest Rate



(d) Terms of Trade

Figure 4.7 (Con't) Impulse Response Functions of 1 Percent Monetary Policy Shock

4.7. Conclusion

In this paper, two features, which are heterogeneity-in-price stickiness and positive trend inflation, are incorporated into the standard two-open economy New-Keynesian model. The positive trend inflation extends the standard model with heterogeneity-in-price stickiness in three ways. First, it increases the weight of forward-looking variables and decreases the weight of current variables. The second, the price dispersion becomes effective on the model. Third, it enriches the model through extra variables, the expected marginal cost and CPI inflation. On the other hand, positive trend inflation induces each sector to affect each other through CPI inflation.

The effects of the degree of heterogeneity on the coefficients of NKPC are discussed at different rates of trend inflation. More rigidity increases the effects of trend inflation on the coefficients. In more rigid (flexible) sector, the increased trend inflation makes NKPC depend on the forward-looking variables more (less) and current variables less (more). Then, it is evaluated how trade openness multiplies the effect of trend inflation in the short-run and long-run dynamics of the model, using for Multiple Calvo model. It is found that openness lessens the effect of trend inflation on the slope of the NKPC in the short-run. However, openness magnifies the effect of trend inflation on OMC-NKPC in the long-run.

It is analysed how determinacy region responds to change in degree of openness at the different trend inflation rates for both one-sector model and multiple-sector model. At zero-trend inflation, the degree of openness does not lead to any change in the determinacy region. With positive trend inflation, the degree of openness has implications on the determinacy region. With the increased trend inflation, the determinacy region shrinks more in a more open economy, but the determinacy region is even narrower in the MC model at positive trend inflation rates. The results for the effect of zero-trend inflation contradict to those in Araujo (2016) and, Llosa and Tuesta (2006). They mainly find that degree of openness enlarges the determinacy region at zero trend inflation rate, but it does not hold in the model. It is found that the model with inertial Taylor rule is robust to the results. However, in the inertial Taylor rule, the determinacy region is even larger at positive trend inflation rates. Moreover, it is shown that in the case of inertial Taylor rule, determinacy region is larger compared to the standard Taylor rule.

The set of monetary policy rules' pairs applied by the central bank to guarantee determinacy region is narrower with the increased openness at positive trend inflation rates. This means that policy alternatives to keep economy in equilibrium determinacy declines. More particularly, the central bank should strongly respond to fluctuations in CPI inflation and weakly respond to fluctuations in output to achieve determinacy equilibrium at positive trend inflation rates. Otherwise, the economy exposes to indeterminacy. In case of inertial Taylor rule, this region enlarges at different trend inflation rates regardless of the degree of openness.

It is discussed how openness affects the dynamics of monetary policy transmission mechanism compared to closed-economy. There are two channels by which openness has effects on the dynamics of the model. First, the slope of NKPC is flatter in open-economy compared to the closed-economy. In particular, when trade openness parameter is set to a positive value, the slope of NKPC decreases. Second, the sensitivity of output to monetary policy shock is higher in open-economy compared to closed-economy. Thus, decrease in output is higher in the open-economy. It can be concluded that the degree of openness has effects on transmission mechanism of monetary policy shock and so the dynamics of the variables. Lastly, the impulse response functions of the variables are drawn at different rates of trend inflation.

There are several policy implications for central banks that can be derived from this study. First, the central banks should care about the heterogenic behaviour of price-resetting firms, inflation target rates adopted by the central banks and the degree of trade openness when they decide monetary policy. Otherwise, economy could be exposed to instability and the central banks might not control inflation rates. Second, when the model is featured with more realistic assumptions (i.e. open economy, positive trend inflation and heterogeneity in price stickiness), central banks face more limited monetary policy alternatives. At higher trend inflation rates, the central bank should strongly respond to the fluctuations of inflation rate and weakly respond to the fluctuations of output as trade openness increases.

CHAPTER 5

CONCLUSION

Across developed countries, average inflation rates have fluctuated considerably over the last 50 years. Prior to the 1980s, average inflation rates are quite high for those countries, but following the 1980s, they significantly have decreased to around two percent. Correspondingly, central banks have targeted trend inflation rates around two percent. However, following the 2008-9 financial crisis, nominal interest rates in the developed economics radically decrease to zero to stimulate aggregate demand. However, this situation has left no more room to decrease nominal interest rates further. This phenomenon is known as Zero-Lower Bound. To overcome this deadlock, targeting higher trend inflation rate become one of the main debates in economics literature. Blanchard et al. (2010), Williams (2009) and Ball (2013) suggest targeting higher trend inflation by the central banks, leading higher nominal interest rate. However, Bernanke (2010) opposes this suggestion and notes that higher trend inflation destabilize inflation expectations and in turn leads to higher inflationary environment.

Since King et al. (1996) and Ascari (2000), targeting higher trend inflation rate has become an issue of New-Keynesian framework. Following them, there are plenty of studies all of which based on closed-economy assumption. However, it is apparent that this assumption is unrealistic because all economies are more or less open. Thus, all papers analyse higher trend inflation issue by ignoring the interaction between trend inflation and openness. This would lead to biased results. To overcome this biasedness, higher trend inflation in open economies is taken as the central issue of this thesis.

This thesis consists of two essays. In the first essay, positive trend inflation rate is incorporated into the small open economy model as in Gali and Monacelli (2005) for Canada and the UK. With positive trend inflation, New-Keynesian Philips Curve (NKPC) depends on more forward-looking variables and less contemporaneous variables like the studies by Ascari et al. (2000, 2004, 2007, 2009) In other words, the short-run slope of NKPC flattens. The intuition behind this dynamics is that price-resetting firms become more forward-looking with the increased trend inflation and set higher prices when they obtain opportunity to reset their prices. According to the findings, openness does not affect the importance of contemporaneous and forward-looking variables on New-Keynesian Philips Curve. It is indicated that the interaction between openness and trend inflation affects the dynamics of real exchange rate and so the dynamics of the model. In open-economy, higher trend inflation leads to more persistent real exchange rate and increases the effect of shocks on the real exchange rate.

The effects of higher trend inflation on macroeconomic variables in response to monetary policy shock, demand shock and cost-push shock are discussed and it is found that higher trend inflation has crucial effects on macroeconomic variables. It is next evaluated how openness stimulates trend inflation rate by plotting the impulse response functions expressed as deviations from the closed-economy in response to the shocks. It is found that openness has crucial effects on CPI inflation and output through the real exchange rate dynamics mentioned above. It is also analysed whether higher trend inflation solves the Purchasing Power Parity and Delayed-Overshooting Puzzles or not. Depending on the type of shocks and type of monetary policy rule, higher trend inflation rate may solve the puzzles.

In the second essay, the effect of higher trend inflation on determinacy region is evaluated in an open economy. For this reason, positive trend inflation is incorporated in two open and identical open economies version of Gali and Monacelli (2005) with heterogeneity-in-price stickiness assumption for the US economy. In line with the first essay, higher trend inflation increases the importance of forward-looking variable and decreases the importance of contemporaneous variables. As opposed to the first essay, openness decreases the short-run slope of New-Keynesian Philips Curve. However, at higher trend inflation rates, openness increases the slope of long-run NKPC in absolute terms. The intuition behind this dynamics is that in a more open economy, households prefer imported goods than domestic goods due to the relative cheapness of imported goods at higher trend inflation rates. In turn, domestic production decreases.

Next, the effects of trend inflation on determinacy region with/out heterogeneity in price-stickiness are evaluated. It is found that openness does not affect determinacy region at zero-trend inflation rate. However, with the increased trend inflation determinacy region shrinks. In a more open economy, it is even narrower with increased trend inflation. Compared to the model with heterogeneity-in-price stickiness, determinacy region is larger in the model with homogeneity-in-price stickiness at positive trend inflation rates. It is discussed how monetary transmission mechanism differs between open-economy and closed-economy. It is indicated that there are two channels through which openness affects the dynamics of the model. First, openness makes the NKPC flatten. Second, the sensitivity of output to monetary policy shock is higher in the open-economy. Thus, decrease in output is larger in the open-economy.

Some economies-like Turkey, reduce nominal interest rate to lower bound well above zero interest rate. This phenomenon is known as *effective lower bound*. Falling nominal interest rate below effective lower bound would yield instability in the economy. To analyse the effects of trend inflation on the level of effective lower bound would be the next research topic. Within this context, how targeting higher trend inflation affects the level of effective lower bound would be discussed. For this purpose, positive trend inflation can be incorporated into the non-linear version of the small open-economy model.

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APPENDICES

APPENDIX A: DERIVATIONS, FIGURES AND TABLES

APPENDIX I

In this appendix, Equilibrium Determinacy condition is derived. The equations NKPC, Euler Equation and Policy Rule are rewritten as follows:

$$\hat{\pi}_t = \kappa \hat{y}_t + \beta \hat{\pi}_{t+1} \tag{I-1}$$

$$\hat{y}_t = \hat{y}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1}) \tag{I-2}$$

$$\hat{\imath}_t = \phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t \tag{I-3}$$

First, substituting equation I-3 into equation I-2 yields.

$$\hat{y}_t = \hat{y}_{t+1} - \sigma^{-1}(\phi_\pi \hat{\pi}_t + \phi_y \hat{y}_t - \hat{\pi}_{t+1}) \tag{I-4}$$

Then, taking equation I-4 into co-factor parenthesis and re-writing I-1 and I-4 as follows:

$$\hat{\pi}_t - \kappa\hat{y}_t = \beta\hat{\pi}_{t+1} \tag{I-5}$$

$$(\sigma + \phi_y)\hat{y}_t + \phi_\pi\hat{\pi}_t = \sigma\hat{y}_{t+1} + \hat{\pi}_{t+1} \tag{I-6}$$

When the above equations are written in matrix notation,

$$\begin{bmatrix} 1 & -\kappa \\ \phi_\pi & \sigma + \phi_y \end{bmatrix} \begin{bmatrix} \hat{\pi}_t \\ \hat{y}_t \end{bmatrix} = \begin{bmatrix} \beta & 0 \\ 1 & \sigma \end{bmatrix} \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{y}_{t+1} \end{bmatrix}$$

Let A be $\begin{bmatrix} 1 & -\kappa \\ \phi_\pi & \sigma + \phi_y \end{bmatrix}$.

$$A \begin{bmatrix} \hat{\pi}_t \\ \hat{y}_t \end{bmatrix} = \begin{bmatrix} \beta & 0 \\ 1 & \sigma \end{bmatrix} \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{y}_{t+1} \end{bmatrix}$$

Multiplying this equation by the inverse of matrix A.

$$\begin{bmatrix} \hat{\pi}_t \\ \hat{y}_t \end{bmatrix} = A^{-1} \begin{bmatrix} \beta & 0 \\ 1 & \sigma \end{bmatrix} \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{y}_{t+1} \end{bmatrix}$$

$$Det\ A = \sigma + \phi_y + \kappa\phi_\pi$$

$$A^{-1} = \frac{1}{\sigma + \phi_y + \kappa\phi_\pi} \begin{bmatrix} \sigma + \phi_y & \kappa \\ -\phi_\pi & 1 \end{bmatrix}$$

Then, matrix form above is re-written as follows:

$$\begin{bmatrix} \hat{\pi}_t \\ \hat{y}_t \end{bmatrix} = B \begin{bmatrix} \hat{\pi}_{t+1} \\ \hat{y}_{t+1} \end{bmatrix}$$

where $B = \frac{1}{\sigma+\phi_y+\kappa\phi_\pi} \begin{bmatrix} \beta(\sigma+\phi_y)+\kappa & \kappa\sigma \\ 1-\beta\phi_\pi & \sigma \end{bmatrix}$

Following Bullard and Mitra (2002), a necessary and sufficient condition for matrix B to obtain two eigenvalues within the unit circle is

$$(\phi_\pi) + \frac{(1-\beta)\phi_y}{\kappa} > 1 \tag{I-7}$$

APPENDIX II-A.1

In this appendix, Small-Open Economy New-Keynesian Model is derived.

1.Demand Side

The utility function is specified as follows:

$$U(C_t, N_t) = \beta^k E_t \sum_{k=0}^{\infty} [\frac{C_{t+k}^{1-\sigma}}{1-\sigma} - \frac{N_{t+k}^{1+\varphi}}{1+\varphi}] \qquad \text{II-A.1.1}$$

subject to

$$P_t C_t + E_t Q_{t,t+1} B_{t+1} = W_t N_t + B_t + D_t \qquad \text{II-A.1.2}$$

where C_t is the composite consumption index, N_t is labour hours and B_{t+1} is nominal pay-off in period *t+1* of the portfolio purchased at time *t*. P_t is the Consumer Price Index (CPI). $Q_{t,t+1} = (1 + i_t)^{-1}$ is the stochastic discount factor between the periods *t* and *t+1* where i_t is the nominal interest rate. D_t is dividend. σ and φ, positive constants, are the relative risk aversion parameter and the inverse Frisch elasticity of labour supply, respectively. $\beta \in (0,1)$ is the intertemporal discount factor and E_t is the expectation operator on time-t information.

Households maximises the present value of discounted utility with respect to C_t and N_t.

$$Euler\ Equation: E_t\{(\frac{C_{t+1}}{C_t})^{\sigma} P_{t+1}\} = \beta(1+i_t)P_t \qquad \text{II-A.1.3}$$

$$Labour - leisure\ choice:\ \ \frac{W_t}{P_t} = C_t^{\sigma}\ N_t^{\varphi} \qquad \text{II-A.1.4}$$

$C_t = [(1-\alpha)^{\frac{1}{\eta}}\left(C_{H,t}\right)^{\frac{\eta-1}{\eta}} + (\alpha)^{\frac{1}{\eta}}\left(C_{F,t}\right)^{\frac{\eta-1}{\eta}}]^{\frac{\eta}{\eta-1}}$ is the composite consumption index where $C_{H,t} = [\int_0^1 \left(C_{H,j.t}\right)^{\frac{\epsilon-1}{\epsilon}} dj]^{\frac{\epsilon}{\epsilon-1}}$ is the index of domestic consumption goods, $C_{F,i,t} = [\int_0^1 \left(C_{F,i,j,t}\right)^{\frac{\epsilon-1}{\epsilon}} dj]^{\frac{\epsilon}{\epsilon-1}}$ is the index of imported consumption goods from country *i* and, $C_{F,t} = [\int_0^1 \left(C_{F,i,t}\right)^{\frac{\gamma-1}{\gamma}} di]^{\frac{\gamma}{\gamma-1}}$ is the index of imported goods. Note that ϵ is the elasticity of substitution among differentiated goods, η is the substitutability between domestic and imported goods, and γ is the substitutability between goods produced in different foreign countries. α is the degree of trade openness and j is good variety.

Using cost-minimisation, the following demand functions are obtained:

$$C_{H,j,t} = \left(\frac{P_{H,i,t}}{P_{H,t}}\right)^{-\epsilon} C_{H,t};$$

$$C_{H,t} = (1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t$$

$$C_{i,j,t} = \left(\frac{P_{i,j,t}}{P_{F,i,t}}\right)^{-\epsilon} C_{i,t};\ C_{i,t} = \left(\frac{P_{F,i,t}}{P_{F,t}}\right)^{-\gamma} C_{F,t};$$

$$C_{F,t} = \alpha\left(\frac{P_{F,t}}{P_t}\right)^{-\eta} C_t$$

$P_t = [(1-\alpha)(P_{H,t})^{1-\eta} + \alpha(P_{F,t})^{1-\eta}]^{\frac{1}{1-\eta}}$ is Consumer Price Index where $P_{H,t} = [\int_0^1 (P_{H,j,t})^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ is the price index of domestic goods, $P_{F,i,t} = [\int_0^1 (P_{F,i,j,t})^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ is the price index of imported goods from country *i*, $P_{F,t} = [\int_0^1 (P_{F,i,t})^{1-\gamma} di]^{\frac{1}{1-\gamma}}$ is the aggregate price index for imported goods, $P_{H,j,t}$ is the price of domestic good *j* and $P_{F,i,j,t}$ is the price of imported good *j* from country *i*.

The Law of One Price (LOOP) is assumed to hold for all goods. This assumption implies that

$$P_{F,i,j,t} = \varepsilon_{i,t} P^i_{F,ij,t} \qquad \text{II-A.1.5}$$

where $\varepsilon_{i,t}$ is the bilateral nominal exchange rate between home country and country *i* , and $P^i_{F,i,j,t}$ is the price level of good *j* produced in country *i* in terms of country *i*'s currency.

In the case of η = 1, CPI evolves to $P_t \equiv (P_{H,t})^{1-\alpha} (P_{F,t})^{\alpha}$. Bilateral terms of trade $S_{i,t}$ is defined as the ratio of the price index of country *i* to price index of domestic price index. It is equal to $\frac{P_{F,i,t}}{P_{H,t}}$. Terms of trade S_t is the aggregation of bilateral terms of trade over *i*. It is equal to $\frac{P_{F,t}}{P_{H,t}} = (\int_0^1 S_{i,t}^{1-\gamma} di)^{\frac{1}{1-\gamma}}$.

The bilateral real exchange rate $Q_{i,t}$ is defined as the ratio of country *i*'s CPI inflation and home CPI inflation. It is shown as follows:

$$Q_{i,t} = \frac{\varepsilon_{i,t} P_t^i}{P_t} \qquad \text{II-A.1.6}$$

The real exchange rate Q_t is the aggregation of the bilateral real exchange rate over *i*.

$$Q_t = \int_0^1 \left(Q_{i,t}^{1-\gamma} di\right)^{\frac{1}{1-\gamma}} \qquad \text{II-A.1.7}$$

International Risk Sharing

Assume that stochastic discount factors for home country and country *i* are equal.

$$Euler\ equation\ for\ home\ country{:}\ \beta E_t \frac{P_t}{P_{t+1}} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} = Q_{t,t+1} \qquad \text{II-A.1.8}$$

$$Euler\ equation\ for\ country\ i:\ \beta E_t \frac{P_t^i}{P_{t+1}^i} \left(\frac{C_{t+1}^i}{C_t^i}\right)^{-\sigma} \frac{\varepsilon_t^i}{\varepsilon_{t+1}^i} = Q_{t,t+1} \qquad \text{II-A.1.9}$$

Substituting equation II-A.1.9 into equation II-A.1.8,

$$\beta E_t \frac{P_t}{P_{t+1}} \left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} = \beta E_t \frac{P_t^i}{P_{t+1}^i} \left(\frac{C_{t+1}^i}{C_t^i}\right)^{-\sigma} \frac{\varepsilon_t^i}{\varepsilon_{t+1}^i} \qquad \text{II-A.1.10}$$

Using the real exchange definition,

$$\left(\frac{C_{t+1}}{C_t}\right)^{-\sigma} = \mathcal{Q}_{i,t}\mathcal{Q}_{i,t+1}^{-1}\left(\frac{C_{t+1}^i}{C_t^i}\right)^{-\sigma} \qquad \text{II-A.1.11}$$

Rearranging equation II-A.1.11,

$$\frac{C_t^\sigma}{\left(C_t^i\right)^\sigma \mathcal{Q}_{i,t}} = \frac{C_{t+1}^\sigma}{\left(C_{t+1}^i\right)^\sigma \mathcal{Q}_{i,t+1}} \qquad \text{II-A.1.12}$$

$$\frac{C_t^\sigma}{\left(C_t^i\right)^\sigma \mathcal{Q}_{i,t}} = \vartheta_i(t) \text{ and } \frac{C_{t+1}^\sigma}{\left(C_{t+1}^i\right)^\sigma \mathcal{Q}_{i,t+1}} = \vartheta_i(t+1) \qquad \text{II-A.1.13}$$

These two equations indicate that ϑ_i is constant. This value can be normalized to 1. International risk sharing condition between home country and country *i* is

$$C_t^\sigma = \left(C_t^i\right)^\sigma \mathcal{Q}_{i,t} \qquad \text{II-A.1.14}$$

Aggregation of this condition over *i* and international risk sharing condition between home-country and the rest of the world:

$$C_t^\sigma = (C_t^*)^\sigma \mathcal{Q}_{,t} \qquad \text{II-A.1.15}$$

2. Equilibrium

Domestic production for good *j* in home country $Y_{j,t}$ clears the sum of domestic demand $C_{H,j,t}$ and country *i*'s demand $C^{i}_{H,j,t}$ for domestically produced good *j.*

$$Y_{j,t} = C_{H,j,t} + \int_0^1 C^{i}_{H,j,t} di \qquad \text{II-A.1.16}$$

Plugging $C_{Hj,t} = (1-\alpha)\left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon}\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t$ and $C^{i}_{H,j,t} = \alpha(\frac{P_{H,t}}{\varepsilon_{i,t}P^{i}_{F,t}})^{-\gamma}\left(\frac{P^{i}_{F,t}}{P^{i}_{t}}\right)^{-\eta} C^{i}_{t}$ into equation (II-A1.19) yields[20].

$$Y_{j,t} = \left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon}[(1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha\int_0^1 \left(\frac{P_{H,t}}{\varepsilon_{i,t}P^{i}_{F,t}}\right)^{-\gamma}\left(\frac{P^{i}_{F,t}}{P^{i}_{t}}\right)^{-\eta} C^{i}_{t} di]$$

To obtain the domestic demand constraint for good *j*, the following optimisation problem is set.

$$\max\int_0^1 P_{H,j,t}Y_{j,t}dj - \lambda_t[\int_0^1 Y_{j,t}^{\frac{\epsilon}{\epsilon-1}}dj]^{\frac{\epsilon-1}{\epsilon}}$$

where $\lambda_t = P_t$.

The domestic demand constraint is obtained as follows: $Y_{j,t} = (\frac{P_{H,j,t}}{P_{H,t}})^{-\epsilon}Y_t$.

[20] See Gali and Monacelli (2005) for detailed derivation of demand functions.

$$Y_{j,t} = \left(\frac{P_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} \underbrace{[(1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha \int_0^1 (\frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i})^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di]}_{Y_t}$$

The aggregate domestic output is obtained.

$$Y_t = [(1-\alpha)\left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t + \alpha \int_0^1 (\frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i})^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} C_t^i di]$$

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t[(1-\alpha) + \alpha \int_0^1 (\frac{P_{H,t}}{\varepsilon_{i,t} P_{F,t}^i})^{-\gamma} \left(\frac{P_{F,t}^i}{P_t^i}\right)^{-\eta} \left(\frac{P_{H,t}}{P_t}\right)^{\eta} C_t^{-1} C_t^i di]$$

Substituting the international risk sharing condition $C_t^{\sigma} = \left(C_{i,t}\right)^{\sigma} Q_{i,,t}$ and the bilateral real exchange rate $Q_{i,t} = \frac{\varepsilon_{i,t} P_t^i}{P_t}$ into this equation yields:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t[(1-\alpha) + \alpha \int_0^1 (\frac{\varepsilon_{i,t} P_{F,t}^i}{P_{H,t}})^{\gamma-\eta} Q_{i,t}^{\eta - \frac{1}{\sigma}} di]$$

Note that $S_t^i = \frac{\varepsilon_{i,t} P_{F,t}^i}{P_t^i}$ and $S_{i,t} = \frac{P_t^i}{P_{H,t}}$.

$\frac{\varepsilon_{i,t} P_{F,t}^i}{P_{H,t}}$ is re-written as the multiplication of $\frac{\varepsilon_{i,t} P_{F,t}^i}{P_t^i}$ and $\frac{P_t^i}{P_{H,t}}$. Thus, $\frac{\varepsilon_{i,t} P_{F,t}^i}{P_{H,t}}$ equals $S_t^i\, S_{i,t}$. The last equation becomes:

$$Y_t = \left(\frac{P_{H,t}}{P_t}\right)^{-\eta} C_t[(1-\alpha) + \alpha \int_0^1 (S_t^i\, S_{i,t})^{\gamma-\eta} Q_{i,t}^{\eta-\frac{1}{\sigma}} di] \qquad \text{II-A.1.17}$$

In the special case of $\sigma = \eta = \gamma = 1$, the condition $Y_t P_{H,t} = P_t C_t$ is obtained. This condition is known as the balanced trade condition. Using this equation, the following equation is obtained:

$$Y_t = C_t S_t^{\alpha} \qquad \text{II-A.1.18}$$

Net Export equation is as follows:

$$nx_t = \frac{1}{\overline{Y}}(Y_t - \frac{P_t}{P_{H,t}} C_t) \qquad \text{II-A.1.19}$$

where $\overline{Y}$ is the steady state output.

2.Supply Side

2.1. Production

The production function of intermediate goods producer *j* is

$$Y_{j,t} = A_t N_{j,t} \qquad \text{II-A.1.20}$$

Labour demand for firm *j*

$$N_t = \int_0^1 N_{j,t} dj = \int_0^1 \frac{Y_{j,t}}{A_t} dj \qquad \text{II-A.1.21}$$

Plugging the demand for good *j* into the labour demand equation,

$$N_t = \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} \frac{Y_t}{A_t} dj = \frac{Y_t}{A_t} \int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} dj \qquad \text{II-A.1.22}$$

Price Dispersion equation z_t equals $\int_0^1 \left(\frac{P_{j,t}}{P_t}\right)^{-\epsilon} dj$. Thus, equation II-A.1.22, labour demand equation, is

$$N_t = \frac{Y_t}{A_t} z_t \qquad \text{II-A.1.23}$$

2.2.Price Dispersion

As shown by Schmitt-Grove and Uribe (2007), under the assumptions of the Calvo model z_t can be rewritten as:

$$z_t = (1-\theta)\left(\frac{P^*_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} + \theta(1-\theta)\left(\frac{P^*_{H,j,t-1}}{P_{H,t}}\right)^{-\epsilon} + \theta^2(1-\theta)\left(\frac{P^*_{H,j,t-2}}{P_{H,t}}\right)^{-\epsilon} + \cdots.$$

Rearranging above equation as follows:

$$z_t = (1-\theta)\left(\frac{P^*_{H,j,t}}{P_{H,t}}\right)^{-\epsilon} + \theta\pi^{\epsilon}_{H,t}[(1-\theta)\left(\frac{P^*_{H,j,t-1}}{P_{H,t-1}}\right)^{-\epsilon} + \theta^2(1-\theta)\left(\frac{P^*_{H,j,t-2}}{P_{H,t-1}}\right)^{-\epsilon} + \cdots]$$

Note that $\frac{P^*_{H,j,t}}{P_{H,t}} = p^*_{H,j,t}$

$$z_t = (1-\theta)\left(p^*_{H,t}\right)^{-\epsilon} + \theta\pi^{\epsilon}_{H,t}z_{t-1} \qquad \text{II-A.1.24}$$

2.3. Firms

Firm *j* chooses the Price level $P^*_{H,j,t}$ which maximises the current market value of the profits generated as follows:

$$\max_{P^*_{H,j,t}} E_t \sum_{k=0}^{\infty} Q_{t,t+k}\, \theta^k [P^*_{H,j,t}Y_{H,j,t+k} - W_{t+k}\frac{Y_{H,j,t+k}}{A_{t+k}}] \qquad \text{II-A.1.25}$$

subject to the demand constraint $Y_{H,j,t+k} = \left(\frac{P^*_{H,j,t}}{P_{H,t+k}}\right)^{-\epsilon} Y_{t+k}$.

Note that $Q_{t,t+k} = \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-\sigma} \frac{P_t}{P_{t+k}}$.

Firstly, substituting the demand constraint and then taking derivative of the equation with respect to $P^*_{H,j,t}$ yields:

$$E_t \sum_{k=0}^{\infty} Q_{t,t+k}\theta^k [(1-\epsilon)\left(\frac{P^*_{H,j,t}}{P_{H,t+k}}\right)^{-\epsilon} Y_{t+k} P^*_{H,j,t} + \epsilon \left(\frac{P^*_{H,j,t}}{P_{H,t+k}}\right)^{-\epsilon} \frac{W_{t+k}Y_{t+k}}{A_{t+k}}] = 0$$

Note that balanced trade condition holds for each period (*i.e.* $Y_t P_{H,t} = C_t P_t$). Substituting both the stochastic discount factor and balanced trade condition into above equation, and setting $\sigma = 1$ leads to the following equation:

$$E_t \sum_{k=0}^{\infty} \beta^k \left(\frac{C_{t+k}}{C_t}\right)^{-1} \frac{P_t}{P_{t+k}} \theta^k [(1-\epsilon)\left(\frac{1}{P_{H,t+k}}\right)^{-\epsilon} \left(P^*_{H,j,t}\right)^{1-\epsilon} \frac{C_{t+k}P_{t+k}}{P_{H,t+k}}$$
$$+ \left(P^*_{H,j,t}\right)^{-\epsilon-1} \epsilon \left(\frac{1}{P_{H,t+k}}\right)^{-\epsilon} \frac{W_{t+k}}{A_{t+k}} \frac{C_{t+k}P_{t+k}}{P_{H,t+k}}] = 0$$

After deleting common and constant variables,

$$E_t \sum_{k=0}^{\infty} (\beta\theta)^k [(1-\epsilon)\left(\frac{1}{P_{H,t+k}}\right)^{1-\epsilon} \left(P^*_{H,j,t}\right) + \epsilon \left(\frac{1}{P_{H,t+k}}\right)^{-\epsilon} \frac{W_{t+k}}{A_{t+k}} \frac{1}{P_{H,t+k}}] = 0$$

Assuming $mc^r_{H,t} = \frac{W_t}{P_{H,t}A_t}$ is equal for all the individual firms. Then,

$$P^*_{H,j,t} = \frac{\epsilon}{\epsilon-1}\frac{\sum_{k=0}^{\infty}(\beta\theta)^k mc^r_{H,t+k}\frac{1}{P^{-\epsilon}_{H,t+k}}}{\sum_{k=0}^{\infty}(\beta\theta)^k \frac{1}{P^{1-\epsilon}_{H,t+k}}}$$

Dividing both sides by $P_{H,t}$ yields,

$$\frac{P^*_{H,j,t}}{P_{H,t}} = \frac{\epsilon}{\epsilon-1}\frac{\sum_{k=0}^{\infty}(\beta\theta)^k mc^r_{H,t+k}\frac{1}{\Pi^{-\epsilon}_{H,t,t+k}}}{\sum_{k=0}^{\infty}(\beta\theta)^k \frac{1}{\Pi^{1-\epsilon}_{H,t,t+k}}} \qquad \text{II-A.1.26}$$

$$p^*_{H,j,t} = \frac{P^*_{H,j,t}}{P_{H,t}}$$

$$\psi_t = \sum_{k=0}^{\infty}(\beta\theta)^k mc^r_{H,t+k}\frac{1}{\Pi^{-\epsilon}_{H,t,t+k}}$$

$$\phi_t = \sum_{k=0}^{\infty}(\beta\theta)^k \frac{1}{\Pi^{1-\epsilon}_{H,t,t+k}}$$

$$p^*_{H,t} = \frac{\epsilon}{\epsilon-1}\frac{\psi_t}{\phi_t} \qquad \text{II-A.1.27}$$

ψ_t and ϕ_t are re-written recursively as follows:

$$\psi_t = mc^r_{H,t} + \beta\theta E_t(\pi^{\epsilon}_{H,t+1}\psi_{t+1}) \qquad \text{II-A.1.28}$$

$$\phi_t = 1 + \beta\theta E_t(\pi^{\epsilon-1}_{H,t+1}\phi_{t+1}) \qquad \text{II-A.1.29}$$

The aggregate domestic price level $P_{H,t} = [\int_0^1 P_{H,j,t}{}^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ follows Calvo-pricing rule. In each period, (1-θ) of firms re-optimise the nominal price $P^*_{H,j,t}$ and θ of firms keep their price level constant.

$$P_{H,t} = \left[\int_0^{\theta} (P_{H,j,t-1})^{1-\epsilon} dj + \int_{\theta}^{1} (P^*_{H,j,t-1})^{1-\epsilon} dj\right]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.1.30}$$

This pricing rule is re-written as follows:

$$P_{H,t} = \left[\theta P^{1-\epsilon}_{H,t-1} + (1-\theta)(P^*_{H,j,t})^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.1.31}$$

Divide equation (II-A-1.31) by $P_{H,t}$.

$$1 = \left[\theta\left(\frac{P_{H,t-1}}{P_{H,t}}\right)^{1-\epsilon} + (1-\theta)\left(\frac{P^*_{H,j,t}}{P_{H,t}}\right)^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

$$1 = \left[\theta \pi_{H,t}^{\epsilon-1} + (1-\theta)(p_{H,j,t}^{*})^{1-\epsilon}\right]^{\frac{1}{1-\epsilon}}$$

Reset pricing rule is as follows:

$$p_{H,j,t}^{*} = \left[\frac{1-\theta \pi_{H,t}^{\epsilon-1}}{1-\theta}\right]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.1.32}$$

3. Monetary Policy

The classical Taylor rule is followed by the central bank.

$$\frac{1+i_t}{1+\bar{\iota}} = \left(\frac{\pi_t}{\bar{\pi}}\right)^{\phi_\pi} \left(\frac{Y_t}{\bar{Y}}\right)^{\phi_y} e^{v_t} \qquad \text{II-A.1.33}$$

where $\bar{\iota}$ is the steady state value of nominal interest rate, $\bar{\pi}$ is the steady state value of trend inflation and v_t is monetary policy shock. v_t follows AR(1). ϕ_π and ϕ_y are monetary policy coefficients of CPI inflation and output, respectively.

Log-linearization: log-linear approximation around the steady state are taken. $\hat{x}_t$means deviation of variable x_t from its deterministic steady state.

The log-linearized terms of trade around the symmetric steady state is as follows:

$$\hat{s}_t = \hat{p}_{F,t} - \hat{p}_{H,t} \qquad \text{II-A.1.34}$$

The log-linearization of CPI with equation II-A.1.34 yields the following equation.

$$\hat{p}_t = \hat{p}_{H,t} + \alpha\, \hat{s}_t \qquad \text{II-A.1.35}$$

$$\hat{p}_{t-1} = \hat{p}_{H,t-1} + \alpha\, \hat{s}_{t-1} \qquad \text{II-A.1.36}$$

Using equations II-A.1.35 and II-A.1.36, the relation between CPI inflation and domestic inflation can be written as follows:

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha\, \Delta\, \hat{s}_t \qquad \text{II-A.1.37}$$

Substituting Law of One Price equation into $P_{F,i,t} = [\int_0^1 \left(P_{F,i,j,t}\right)^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$, and then substituting it into $P_{F,t}$ and log-linearizing it around symmetric steady state yields:

$$\hat{p}_{F,t} = \int_0^1 (\hat{e}_{i,t} + \hat{p}_{i,t}^{i})\, di = \hat{e}_t + \hat{p}_t^*$$

Plugging this equation into II-A.1.34 yields:

$$\hat{s}_t = \hat{e}_t + \hat{p}_t^* - \hat{p}_{H,t} \qquad \text{II-A.1.38}$$

Log-linearization of bilateral real exchange rate yields $\hat{q}_{i,t} = \hat{e}_{i,t} + \hat{p}^i{}_t - \hat{p}_t$. Aggregation of this relation is as follows:

$$\hat{q}_t = \hat{e}_t + \hat{p}_t{}^* - \hat{p}_t \qquad \text{II-A.1.40}$$

Combining this equation with equations II-A.1.35 and II-A.1.38 yields the following relation:

$$\hat{q}_t = (1 - \alpha)\, \hat{s}_t \qquad \text{II-A.1.40}$$

Note that $\int_0^1 \hat{s}_t^i di = 0.$ Log-linearization of the market clearing condition is as follows:

$$\hat{y}_t = \hat{c}_t + \alpha\gamma\hat{s}_t + \alpha(\eta - \frac{1}{\sigma})\hat{q}_t \qquad \text{II-A.1.41}$$

Substitution of equation II-A.1.40 into equation II-A.1.41 yields;

$$\hat{y}_t = \hat{c}_t + \frac{\alpha\omega}{\sigma}\hat{s}_t \qquad \text{II-A.1.42}$$

where

$$\omega = \sigma\gamma + (1-\alpha)(\sigma\eta - 1)$$

It also holds for any other country. It is rewritten as follows: $\hat{y}^i{}_t = \hat{c}^i{}_t + \frac{\alpha\omega}{\sigma}\hat{s}^i{}_t$. Then, aggregating this equation over i,

$$\int_0^1 \hat{y}^i{}_t \, di = \int_0^1 \hat{c}^i{}_t \, di + \frac{\alpha\omega}{\sigma}\int_0^1 \hat{s}^i{}_t \, di$$

The following clearing condition is obtained:

$$\hat{y}^*{}_t = \hat{c}^*{}_t \; since \int_0^1 \hat{s}^i{}_t \, di = 0$$

Log-linearization of the standard Euler Equation is as follows:

$$\hat{c}_t = \hat{c}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1}) \qquad \text{II-A.1.43}$$

Log-linearization of the labour-leisure choice is as follows:

$$\widehat{w}^r{}_t = \sigma\hat{c}_t + \varphi\hat{n}_t \qquad \text{II-A.1.44}$$

Substituting equations II-A.1.37 and II-A.1.42 into the standard Euler equation, the Euler equation in terms of output can be expressed as:

$$\hat{y}_t = \hat{y}_{t+1} - \frac{1}{\sigma}\left(\hat{\imath}_t - \hat{\pi}_{H,t+1}\right) - \frac{\alpha\Theta}{\sigma} E_t(\Delta\hat{s}_{t+1}) + d_t \qquad \text{II-A.1.45}$$

where $\Theta = \omega - 1$

Thus far, all of the log-linearized equations are standard as in Gali and Monacelli (2005). We now turn to log-linearize equations in supply block. To do, first, deterministic steady state values of equations II-A.1.24, II-A.1.27-29 and II-A.1.32 are taken below.

$$z = \frac{(1-\theta)(p_H^*)^{-\epsilon}}{(1-\theta\pi^{\epsilon})} \qquad \text{II-A.1.46}$$

$$p_H^* = \frac{\epsilon}{\epsilon - 1}\frac{\psi}{\phi} \qquad \text{II-A.1.47}$$

$$\psi = \frac{mc_H^r}{(1-\beta\theta\pi^{\epsilon})} \qquad \text{II-A.1.48}$$

$$\phi = \frac{1}{(1-\beta\theta\pi^{\epsilon-1})} \qquad \text{II-A.1.49}$$

$$p_H^* = [\frac{1-\theta\pi^{\epsilon-1}}{1-\theta}]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.1.50}$$

The log-linearized Price Dispersion equation yields:

$$z\, z_t = (1-\theta)(p_H^*)^{-\epsilon}(-\epsilon\hat{p}_{H,t}^*) + \theta\pi^{\epsilon} z[\epsilon\hat{\pi}_{H,t} + \hat{z}_{t-1}]$$

Plugging equation II-A.1.46 leads to the following equation:

$$\hat{z}_t = [-\epsilon(1-\theta\pi^{\epsilon})]\hat{p}_{H,t}^* + (\theta\pi^{\epsilon})[\epsilon\hat{\pi}_{H,t} + \hat{z}_{t-1}] \qquad \text{II-A.1.51}$$

Log-linearization of the relative optimal price is straightforward and it is as follows

$$\hat{p}^*_{H,t} = \hat{\psi}_t - \hat{\phi}_t \qquad \text{II-A.1.52}$$

Equation $\hat{\psi}_t$ is log-linearized as:

$$\psi\hat{\psi}_t = mc^r_H \widehat{mc}^r_{H,t} + \theta\beta\pi^{\epsilon} E_t(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1})$$

Plugging equation II-A.1.48 into this equation yields the log-linearization of $\hat{\psi}_t$:

$$\hat{\psi}_t = (1 - \beta\theta\pi^{\epsilon})\widehat{mc}^r_{H,t} + \beta\theta\pi^{\epsilon} E_t(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1}) \qquad \text{II-A.1.53}$$

Equation $\hat{\phi}_t$ is log-linearized as:

$$\phi\hat{\phi}_t = \phi\beta\theta\pi^{\epsilon-1} E_t((\epsilon - 1)\hat{\pi}_{H,t+1} + \hat{\phi}_{t+1})$$

Deleting ϕ leads to the following equation:

$$\hat{\phi}_t = \beta\theta\pi^{\epsilon-1} E_t((\epsilon - 1)\hat{\pi}_{H,t+1} + \hat{\phi}_{t+1}) \qquad \text{II-A.1.54}$$

Reset pricing equation is re-written as follows

$$(1-\theta)\left(p_{H,t}^{*}\right)^{1-\epsilon}=1-\theta\left(\pi_{H,t}\right)^{1-\epsilon}$$

Log-linearizing reset pricing equation is as follows:

$$(1-\theta)(p_{H}^{*})^{1-\epsilon}((1-\epsilon)\hat{p}_{H,t}^{*}==-\theta\,(\pi)^{1-\epsilon}((1-\epsilon)\hat{\pi}_{H,t})$$

Plugging equation II-A.1.50 into this equation becomes as follows:

$$\hat{p}_{H,t}^{*}=\frac{\theta\pi^{\epsilon-1}}{1-\theta\pi^{\epsilon-1}}\hat{\pi}_{H,t} \qquad \text{II-A.1.55}$$

Using equations II-A.1.52-55 the NKPC is obtained as follows:

$$\hat{\pi}_{H,t}=\kappa_{1}\widehat{mc}_{H,t}^{r}+\kappa_{2}\hat{\pi}_{H,t+1}+\kappa_{3}\hat{\psi}_{t+1} \qquad \text{II-A.1.56}$$

where

$\kappa_{1}=\frac{(1-\beta\theta\pi^{\epsilon})(1-\theta\pi^{\epsilon-1})}{\theta\pi^{\epsilon-1}}$, $\kappa_{2}=\beta[(1-\theta\pi^{\epsilon-1})(\pi-1)\epsilon+1]$ and

$$\kappa_{3}=\beta(1-\theta\pi^{\epsilon-1})(\pi-1)$$

$$\hat{\psi}_{t}=(1-\theta\beta\pi^{\epsilon})\left(\widehat{mc}_{H,t}^{r}\right)+\theta\beta\pi^{\epsilon}(\epsilon\hat{\pi}_{H,t+1}+\hat{\psi}_{t+1})$$

APPENDIX II-A.2

In this appendix, the dynamics of real exchange is derived.

NKPC is as follows:

$$\hat{\pi}_{H,t} = \kappa_1\left(\widehat{mc}^r_{H,t}\right) + \kappa_2\hat{\pi}_{H,t+1} + \kappa_3\hat{\psi}_t + u_t$$

where $\kappa_1 = \frac{(1-\beta\theta\pi^{\epsilon})(1-\theta\pi^{\epsilon-1})}{\theta\pi^{\epsilon}}$, $\kappa_2 = \beta[(1-\theta\pi^{\epsilon-1})(\pi-1)\epsilon+1]$, $\kappa_3 = \beta(1-\theta\pi^{\epsilon-1})(\pi-1)$ and $\hat{\psi}_t = (1-\beta\theta\pi^{\epsilon})\widehat{mc}^r_{H,t} + \beta\theta\pi^{\epsilon}E_t(\epsilon\hat{\pi}_{H,t+1} + \hat{\psi}_{t+1})$

Plugging $\widehat{mc}^r_t$ in equation (3.46) into NKPC becomes as follows:

$$\hat{\pi}_{H,t} = \kappa_1(\varphi\hat{z}_t + (\sigma_\alpha+\varphi)\hat{y}_t + (\sigma-\sigma_\alpha)\hat{y}^*_t - (1+\varphi)\hat{a}_t) + \kappa_2\hat{\pi}_{H,t+1} + \kappa_3\hat{\psi}_t + u_t \qquad \text{II-A.2.1}$$

For simplicity, $\varphi = 0$ and $\sigma = 1$ are set, and since no technology shock occurs in the domestic economy $\hat{a}_t$ equals 0. Equation II-A.2.1 becomes as follows:

$$\hat{\pi}_{H,t} = \kappa_1(\hat{y}_t) + \kappa_2\hat{\pi}_{H,t+1} + \kappa_3\hat{\psi}_t + u_t \qquad \text{II-A.2.2}$$

Note that since no world shock occurs, all the variables related to the world economy equals 0. Thus, using international risk sharing condition, the following relation is obtained:

$$\hat{c}_t = \hat{q}_t \qquad \text{II-A.2.3}$$

Simplifying the relation between domestic output, domestic consumption and terms of trade: $\hat{y}_t = \hat{c}_t + \frac{\alpha\omega}{\sigma}\hat{s}_t$ by using the above parameters, σ and φ yields the following equation:

$$\hat{y}_t = \hat{c}_t + \alpha\hat{s}_t \qquad \text{II-A.2.4}$$

Substituting equations II-A.2.3 and II-A.1.40 into equation II-A.2.4, the following equation is obtained:

$$\hat{y}_t = \frac{1}{1-\alpha}\hat{q}_t \qquad \text{II-A.2.5}$$

Then, using this equation, NKPC is written as follows:

$$\hat{\pi}_{H,t} = \frac{\kappa_1}{1-\alpha}\hat{q}_t + \kappa_2\hat{\pi}_{H,t+1} + \kappa_3\hat{\psi}_t + u_t \qquad \text{II-A.2.6}$$

Substituting equation II-A.1.42 into equation II-A.39 yields the following relation:

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\alpha}{1-\alpha}(\hat{q}_t - \hat{q}_{t-1}) \qquad \text{II-A.2.7}$$

Substituting equation II-A.2.3 into the standard Euler equation is as follows:

$$\hat{\imath}_t = \hat{q}_{t+1} - \hat{q}_t + \hat{\pi}_{t+1} + d_t \qquad \text{II-A.2.8}$$

Next, assume that ϕ_y is 0 and $\phi_\pi \beta$ is 1 and Taylor rule is expressed as follows: $\hat{\imath}_t = \phi_\pi \pi_t + v_t$. When the new Taylor rule is multiplied with β and the Taylor rule becomes:

$$\beta \hat{\imath}_t = \pi_t + \beta v_t$$

Substituting $\hat{\pi}_t = \hat{\pi}_{H,t} + \frac{\alpha}{1-\alpha}(\hat{q}_t - \hat{q}_{t-1})$ into Taylor rule.

$$\beta \hat{\imath}_t = \hat{\pi}_{H,t} + \frac{\alpha}{1-\alpha}(\hat{q}_t - \hat{q}_{t-1}) + \beta v_t \qquad \text{II-A.2.9}$$

Multiplying equation II-A.2.8 by β,

$$\beta \hat{\imath}_t = \beta \hat{q}_{t+1} - \beta \hat{q}_t + \beta \hat{\pi}_{t+1} + \beta d_t \qquad \text{II-A.2.10}$$

Equating equations II-A.2.9 and II-A.2.10, and substituting equation II-A.2.6 into them generates the dynamic equation of real exchange rate becomes as follows:

$$\hat{q}_t = \frac{1}{\Lambda}[\frac{\alpha}{1-\alpha}\hat{q}_{t-1} + \beta\hat{q}_{t+1} - \kappa_3\hat{\psi}_t + \beta\hat{\pi}_{t+1} - (\kappa_2)\,\hat{\pi}_{H,t+1} - u_t - \beta v_t + \beta d_t] \qquad \text{II-A.2.11}$$

Where $\Lambda = \frac{\kappa_1}{1-\alpha} + \beta + \frac{\alpha}{1-\alpha}$

APPENDIX II-A.3

In this part, Domestic inflation indexation feature is incorporated into the SOE-NK model constructed in Appendix II-A.1. In both appendices, the demand sides are identical. Differences between the appendices reveal in the supply section, particularly price dispersion and firm pricing. Only the different parts are derived below.

Price Dispersion:

As shown by Schmitt-Grove and Uribe (2007), under the assumptions of the Calvo model z_t can be rewritten as:

$$z_t = (1-\theta)\left(\frac{P^*_{H,t}}{P_{H,t}}\right)^{-\epsilon} + \theta(1-\theta)\left(\frac{P^*_{H,t-1}\pi^{\varrho}_{H,t-1}}{P_{H,t}}\right)^{-\epsilon} + \theta^2(1-\theta)\left(\frac{P^*_{H,t-2}\pi^{\varrho}_{H,t-1}\pi^{\varrho}_{H,t-2}}{P_{H,t}}\right)^{-\epsilon} + \cdots$$

$$z_t = (1-\theta)\left(\frac{P^*_{H,t}}{P_{H,t}}\right)^{-\epsilon} + \theta\pi^{\epsilon}_{H,t}\,\pi^{-\epsilon\varrho}_{H,t-1}z_{t-1} \qquad \text{II.A.3.1}$$

1.Firms

Firm j chooses the Price level $P^*_{H,j,t}$ which maximises the current market value of the profits generated as follows

$$\max_{P^*_{H,j,t}} E_t \sum_{k=0}^{\infty} Q_{t,t+k} \theta^k [P^*_{H,j,t} Y_{H,j,t+k} - W_{t+k} \frac{Y_{H,j,t+k}}{A_{t+k}}] \qquad \text{II.A.3.2}$$

subject to the demand constraint: $Y_{H,j,t+k} = \left(\frac{P^*_{H,j,t} \Pi^{\varrho}_{H,t-1,t+k-1}}{P_{H,t+k}}\right)^{-\epsilon} Y_{t+k}$

Firstly, the demand constraint is substituted into the above equation, and then the derivative of the equation with respect to $P^*_{H,j,t}$ is taken. Then, plugging the balanced trade condition and stochastic discount factor, and deleting common and constant variables yields the following equation:

$$P^*_{H,j,t} = \frac{\epsilon}{\epsilon - 1} [\frac{E_t \sum_{k=0}^{\infty} (\beta\theta)^k mc^r_{H,t+k} \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{P_{H,t+k}}\right)^{-\epsilon}}{E_t \sum_{k=0}^{\infty} (\beta\theta)^k \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{P_{H,t+k}}\right)^{1-\epsilon}}] \qquad \text{II-A.3.2}$$

$$P^*_{H,j,t} = \frac{\epsilon}{\epsilon - 1} [\frac{E_t \sum_{k=0}^{\infty} (\beta\theta)^k mc^r_{H,t+k} \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{\Pi_{H,t+k}}\right)^{-\epsilon}}{E_t \sum_{k=0}^{\infty} (\beta\theta)^k \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{\Pi_{H,t+k}}\right)^{1-\epsilon}}] \qquad \text{II-A.3.3}$$

$$p^*_{H,t} = \frac{\epsilon}{\epsilon - 1} \frac{\psi_t}{\phi_t}$$

$$\psi_t = E_t \sum_{k=0}^{\infty} (\beta\theta)^k mc^r_{H,t+k} \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{P_{H,t+k}}\right)^{-\epsilon}$$

$$\phi_t = E_t \sum_{k=0}^{\infty} (\beta\theta)^k \left(\frac{\Pi^{\varrho}_{H,t-1,t+k-1}}{P_{H,t+k}} \right)^{1-\epsilon}$$

ψ_t and ϕ_t in terms of recursive are written the below.

$$\psi_t = mc^r_{H,t} + \theta\beta\pi_{H,t}^{-\varrho\epsilon} E_t[\pi^{\epsilon}_{H,t+1}\psi_{t+1}]$$
$$\phi_t = 1 + \theta\beta\pi_{H,t}^{\varrho(1-\epsilon)} E_t[\pi^{\epsilon-1}_{H,t+1}\phi_{t+1}]$$

The aggregate domestic price level $P_{H,t} = [\int_0^1 \left(P^*_{H,j,t}\right)^{1-\epsilon} dj]^{\frac{1}{1-\epsilon}}$ follows Calvo-pricing rule. In each period, $1-\theta$ of firms re-optimize the nominal price and set $P^*_{H,j,t}$ and θ of firms keep their prices constant at period *t-1*.

$$P_{H,t} = \left[\int_0^{\theta} P^{1-\epsilon}_{H,j,t-1}\, dj + \int_{\theta}^{1} \left(P^*_{H,j,t}\right)^{1-\epsilon} dj \right]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.3.4}$$

This pricing rule is re-written as follows:

$$P_{H,t} == [\theta\pi^{(1-\epsilon)\varrho}_{H,t-1} P^{1-\epsilon}_{H,t-1} + (1-\theta)\left(P^*_{H,t}\right)^{1-\epsilon}]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.3.5}$$

Dividing the above equation by $P_{H,t}$:

$$1 = [\theta \left(\frac{P_{H,t-1}}{P_{H,t}} \right)^{1-\epsilon} + (1-\theta) \left(\frac{P^*_{H,t}}{P_{H,t}} \right)^{1-\epsilon}]^{\frac{1}{1-\epsilon}}$$

$$1 = [\theta\left(\pi_{H,t}\right)^{\epsilon-1} + (1-\theta)\left(p_{H,t}^{*}\right)^{1-\epsilon}]^{\frac{1}{1-\epsilon}}$$

Reset pricing rule is as follows:

$$p_{H,t}^{*} = [\frac{1-\theta\pi_{H,t-1}^{(1-\epsilon)\varrho}\pi_{H,t}{}^{\epsilon-1}}{1-\theta}]^{\frac{1}{1-\epsilon}} \qquad \text{II-A.3.6}$$

Log-linearization:

Price Dispersion:

$$\hat{z}_t = \left[-\epsilon\left(1-\theta\pi^{\epsilon(1-\varrho)}\right)\right]\hat{p}_{H,t}^{*} + \left(\theta\pi^{\epsilon(1-\varrho)}\right)[-\epsilon\varrho\hat{\pi}_{H,t-1} + \epsilon\hat{\pi}_{H,t} + \hat{z}_{t-1}] \qquad \text{II-A.3.7}$$

Log-linearization of reset prices:

$$\hat{p}_{H,t}^{*} = \hat{\psi}_t - \hat{\phi}_t \qquad \text{II-A.3.8}$$

where

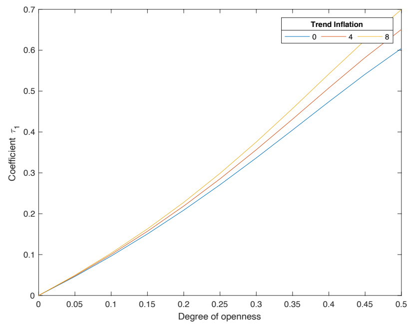
$$\hat{\psi}_t = \left(1-\theta\beta\pi^{\epsilon(1-\varrho)}\right)\widehat{mc}^{r}{}_{H,t} + \theta\beta\pi^{\epsilon(1-\varrho)}E_t(\epsilon\hat{\pi}_{H,t+1} - \epsilon\varrho\hat{\pi}_{H,t} + \hat{\psi}_{t+1}$$

$$\hat{\phi}_t = \theta\beta\pi^{(\epsilon-1)(1-\varrho)}E_t[\hat{\pi}_{H,t+1}(1-\epsilon) + \varrho(1-\epsilon)\hat{\pi}_{H,t} + \hat{\phi}_{t+1}]$$

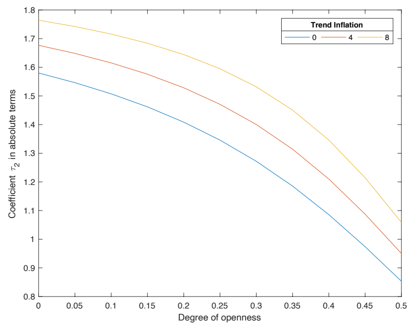
$$\hat{p}^*_{H,t} = \frac{\theta\pi^{(\epsilon-1)(1-\varrho)}}{1-\theta\pi^{(\epsilon-1)(1-\varrho)}}(\hat{\pi}_{H,t} - \varrho\hat{\pi}_{H,t-1}) \tag{II-A.3.9}$$

APPENDIX II-B.1

In this appendix, Coefficients of Backward-looking variable $\hat{q}_{t-1}$ and v_t for the UK are displayed.



(a) Coefficient of Backward-looking variable



(b): Coefficient of v_t

Figure II-B.1.1 the Coefficients of the Backward-looking Variable and Monetary Policy Shock Variable

APPENDIX II-B.2

In this appendix, the IRFs in response to monetary policy shock, demand shock and cost-push shock for the UK are displayed.

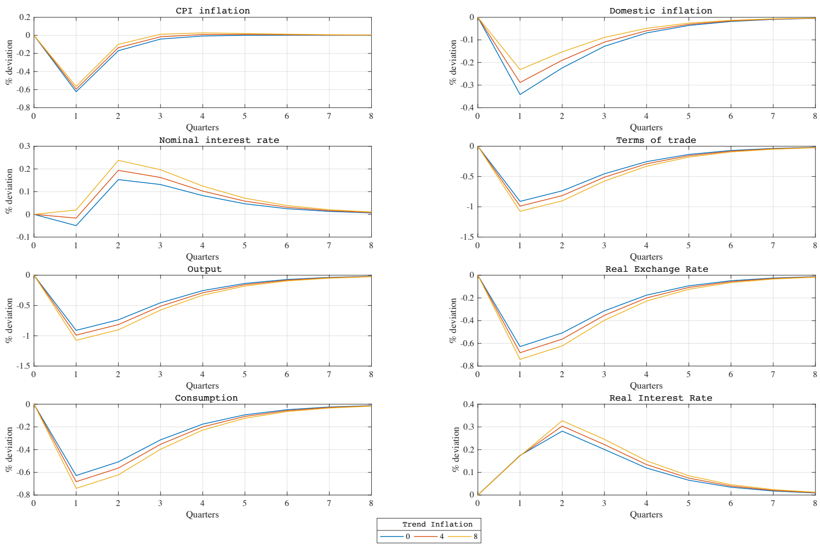


Figure II-B.2.1 IRFs of the 1 Percent Monetary Policy Shock

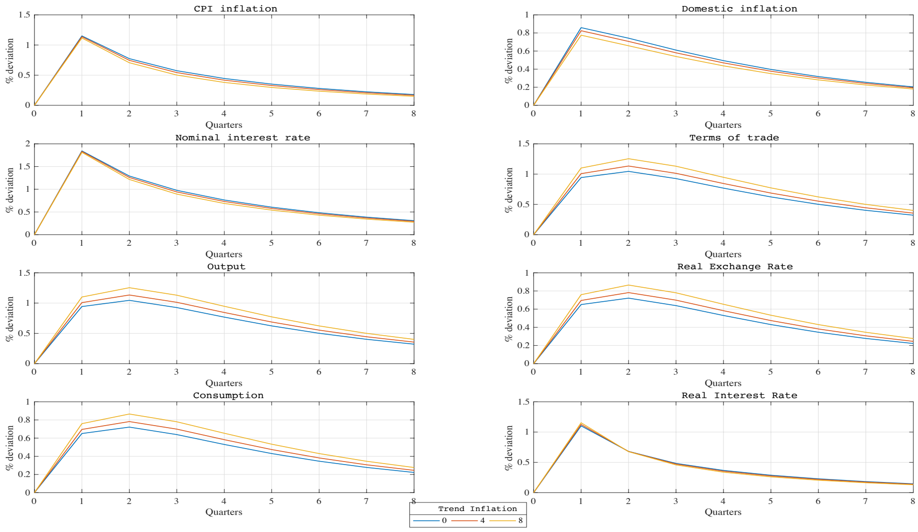


Figure II-B.2.2 IRFs of 1 Percent Demand Shock

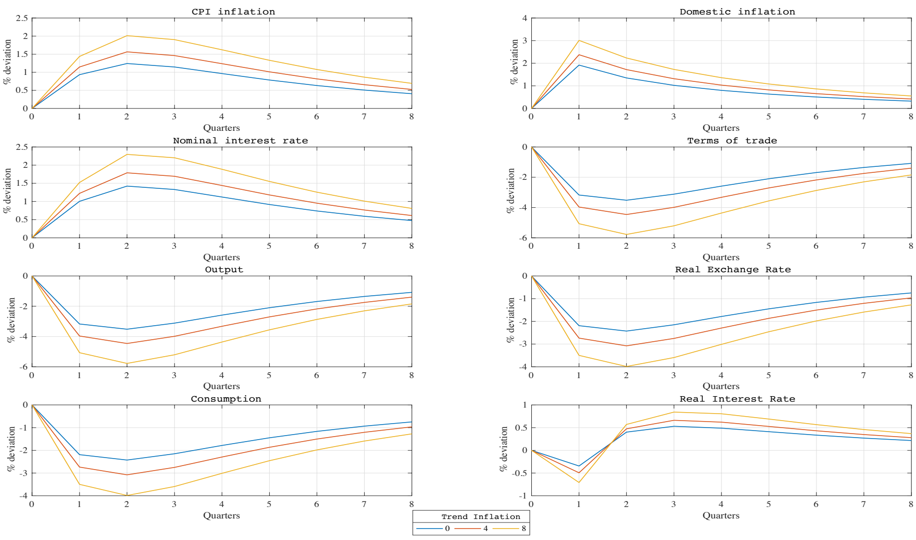
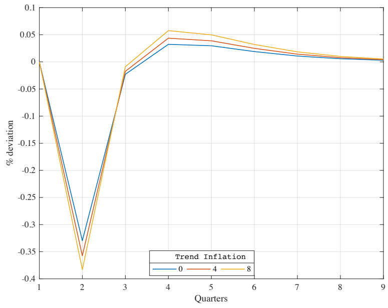


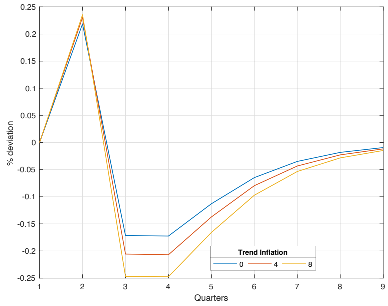
Figure II-B.2.3 IRFs of 1 Percent Cost-Push Shock

APPENDIX II-B.3

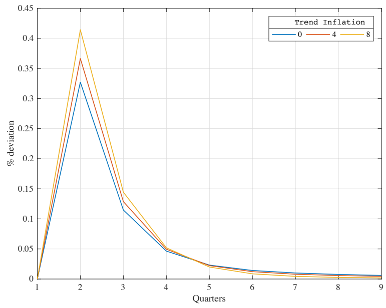
In this appendix, the IRFs for the UK are displayed in Section IV.



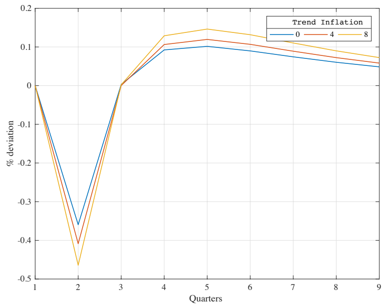
(a) CPI inflation-Monetary Policy Shock



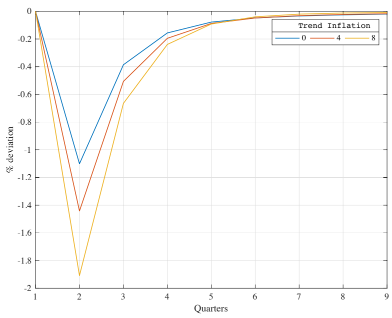
(b) Output- Monetary Policy Shock



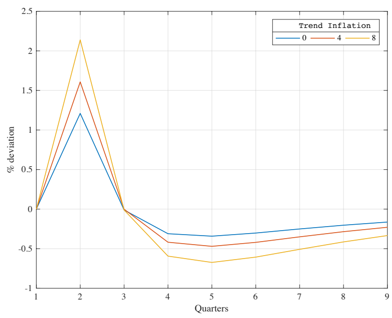
(c) CPI inflation- Demand Shock



(d) Output- Demand Shock



(e) CPI Inflation-Cost-Push Shock

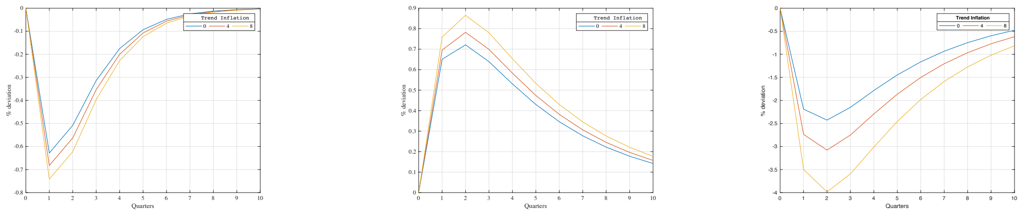


(f) Output-Cost-Push Shock

Figure II-B.3.1IRFs in Response to 1 Percent Shocks

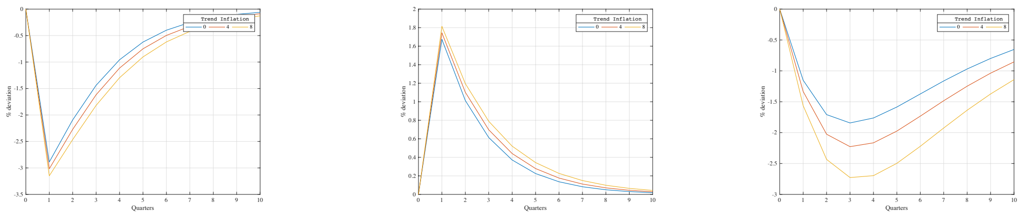
APPENDIX II-B.4

In this appendix, the IRFs of the real exchange rate under alternative scenarios for the UK are displayed.



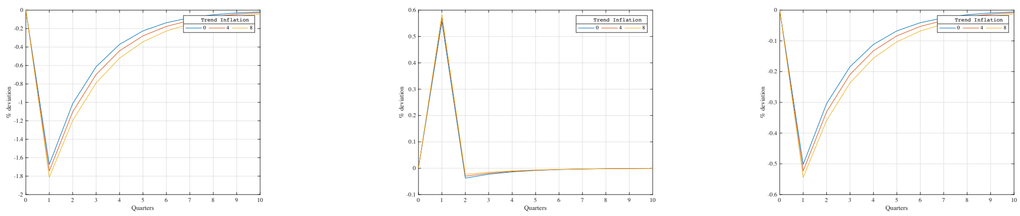
(a) Monetary Policy Shock (b) Demand Shock (c) Cost-Push Shock

Figure II-B.4.1 Standard Taylor Rule with 1 Percent Persistent Shock



(a) Monetary Policy Shock (b) Demand Shock (c) Cost-Push Shock

Figure II-B.4.2 Inertial Taylor Rule with 1 Percent Persistent Shock



(a) Monetary Policy Shock (b) Demand Shock (c) Cost-Push Shock

Figure II-B.4.3 Inertial Taylor Rule with 1 Percent *i.i.d.* Shock

APPENDIX II-B.5

In this appendix, real exchange rate properties for the UK are shown.

Table II-B.5.1 Real Exchange Rate Properties under different Monetary Policy Shock Specifications and Policy Rules

	$\rho_i = 0$ and $\rho_v = 0.50$					$\rho_i = 0.80$ and $\rho_v = 0.50$					$\rho_i = 0.80$ and $\rho_v = 0$				
π	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.
0	1.95	3.89	1	0.70	0.89	1.94	3.88	1	0.70	4.04	1.38	2.76	1	0.61	2.10
4	2.02	4.04	1	0.71	0.98	2.14	4.27	1	0.72	4.37	1.51	3.02	1	0.63	2.25
8	2.09	4.18	1	0.72	1.08	2.35	4.71	1	0.75	4.74	1.67	3.33	1	0.66	2.41

Table II-B.5.2 Real Exchange Rate Properties under different Demand Shock Specifications and Policy Rules

	$\rho_i = 0$ and $\rho_d = 0.80$					$\rho_i = 0.80$ and $\rho_d = 0.80$					$\rho_i = 0.80$ and $\rho_d = 0$				
π	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.
0	5.90	11.79	1	0.89	1.47	1.38	2.76	2	0.61	2.10	0.50	0.25	1	-0.06	0.56
4	6.11	12.21	1	0.89	1.60	1.51	3.02	2	0.63	2.25	0.50	0.25	1	-0.05	0.57
8	6.32	12.65	1	0.90	1.78	1.67	3.33	2	0.66	2.41	0.50	0.25	1	-0.04	0.58

Table II-B.5.3 Real Exchange Rate Properties under different Cost-Push Shock Specifications and Policy Rules

	$\rho_i = 0\ and\ \rho_u = 0.50$					$\rho_i = 0.80\ and\ \rho_v = 0.50$					$\rho_i = 0.80\ \ and\ \rho_u = 0$				
π	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.	HL	QL	UL	ρ	S.S.
0	5.90	11.79	3	0.89	4.94	13.63	27.25	3	0.95	4.39	1.38	2.76	1	0.61	0.63
4	6.11	12.21	3	0.89	6.29	14.95	29.90	3	0.95	5.42	1.51	3.02	1	0.63	0.68
8	6.32	12.65	3	0.90	8.19	16.47	32.95	4	0.96	6.82	1.67	3.33	1	0.66	0.72

APPENDIX II-B.6

In this appendix, the features of standard model are compared with the model featured by domestic inflation indexation for the UK.

Table II-B.6.1 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation for Monetary Policy Shock

	CPI Inflation				**Output**			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	0.65	0.63	0.27	0.31	1.29	1.24	0.70	0.66
4	0.61	0.61	0.22	0.27	1.42	1.34	0.71	0.67
8	0.57	0.58	0.17	0.23	1.57	1.45	0.72	0.69

Table II-B.6.2 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation for Demand Shock

	CPI Inflation				**Output**			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	1.67	1.67	0.72	0.76	2.13	1.96	0.89	0.85
4	1.62	1.65	0.75	0.76	2.32	2.05	0.89	0.85
8	1.54	1.61	0.69	0.75	2.58	2.17	0.90	0.88

Table II-B.6.3 Comparison of the Standard Model with the Model Featured by Domestic Inflation Indexation for Cost-Push Shock

	CPI Inflation				Output			
	Standard Deviation		Autocorrelation		Standard Deviation		Autocorrelation	
π	Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ		Degree of Indexation ϱ	
	0	0.20	0	0.20	0	0.20	0	0.20
0	2.53	3.17	0.91	0.93	7.15	9.03	0.89	0.90
4	3.21	3.88	0.92	0.93	9.12	11.10	0.89	0.91
8	4.17	4.82	0.92	0.93	11.87	13.85	0.90	0.91

APPENDIX II-B.7

The IRFs for the UK in response to monetary policy shock, demand shock and cost-push shock with *i.i.d*. shock are displayed.

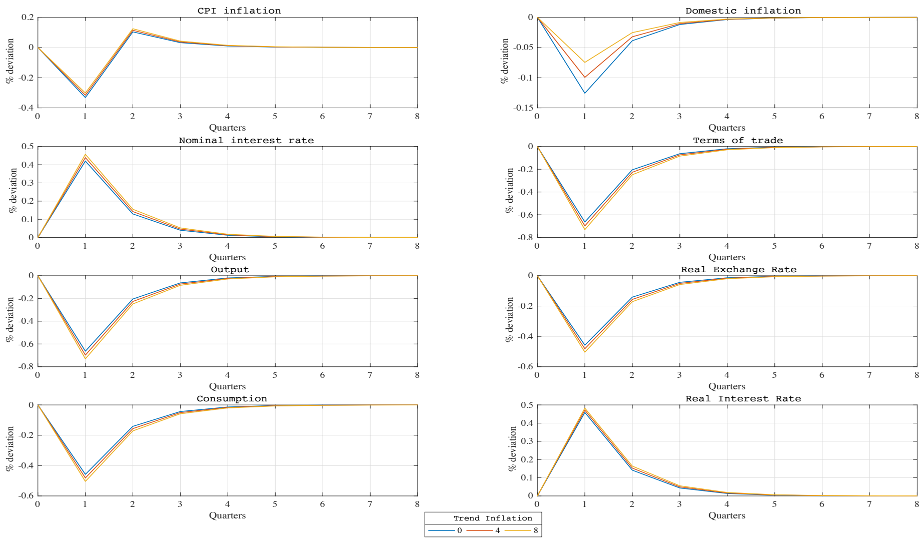


Figure II-B.7.1 IRFs of 1 Percent *i.i.d.* Monetary Policy Shock

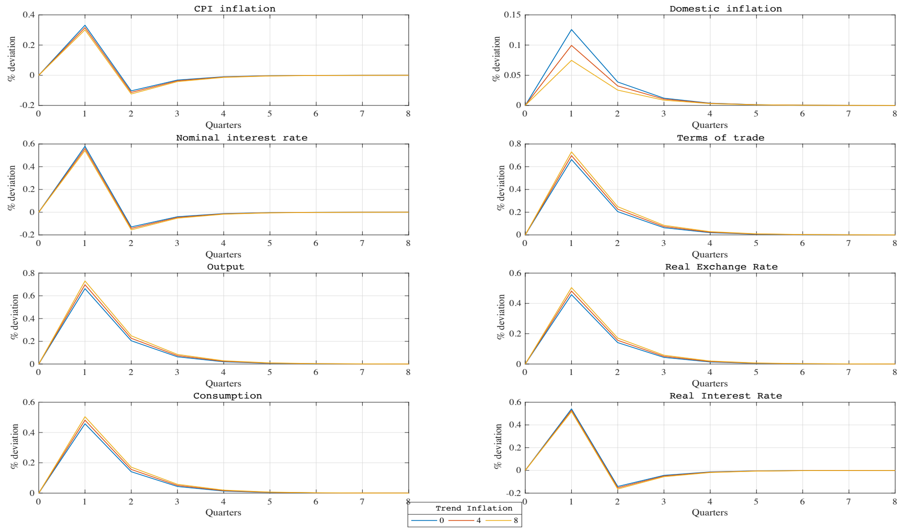


Figure II-B.7.2 IRFs of 1 Percent *i.i.d.* Demand Shock

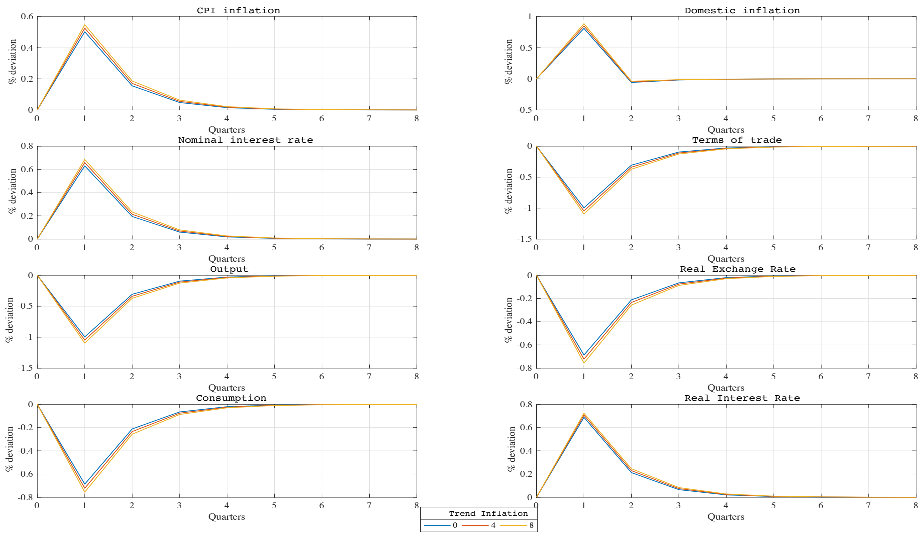


Figure II-B.7.3 IRFs of 1 Percent *i.i.d.* Cost-Push Shock

APPENDIX III-A.1

In this appendix, the sectoral price dispersion and sectoral Calvo pricing equations are derived.

Sectoral Price Dispersion

$$N_t = \sum_{k=1}^{n} f_k \, N_{k,t} = \sum_{k=1}^{n} f_k \frac{Y_{k,t}}{A_t} = \sum_{k=1}^{n} f_k \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \frac{Y_t}{A_t}$$
$$= \frac{Y_t}{A_t} \sum_{k=1}^{n} f_k \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \qquad \text{III-A-1.1}$$

$$\hat{z}_t = \sum_{k=1}^{n} f_k \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \qquad \text{III-A-1.2}$$

$$\hat{z}_t = \sum_{k=1}^{n} f_k \hat{z}_{k,t} \qquad \text{III-A-1.3}$$

$$\hat{z}_{k,t} = \left(\frac{P_{H,k,t}}{P_{H,t}}\right)^{-\zeta} \qquad \text{III-A.1.4}$$

Multiplying and dividing equation by III-A.1.4 with $P_t^{-\zeta}$ and following Schmitt-Grohé and Uribe (2007), sectoral price dispersion is expressed as

$$z_{k,t} = (1-\theta_k)\left(p^*_{H,k,t}\frac{P_t}{P_{H,t}}\right)^{-\zeta} + \theta_k \pi^{\zeta}_{H,t} z_{k,t-1} \qquad \text{III-A.1.5}$$

Sectoral Calvo Pricing

$$P_{H,k,t} = \left[(1-\theta_k)\left(P^*_{H,k,t}\right)^{1-\epsilon} + \theta_k P^{1-\epsilon}_{H,k,t-1}\right]^{\frac{1}{1-\epsilon}} \qquad \text{III-A.1.6}$$

After dividing equation III-A.1.6 by P_t note that relative sectoral price in domestic economy is $p_{H,k,t} = \frac{P_{H,k,t}}{P_t}$.

$$\frac{P_{H,k,t}}{P_t} = [(1-\theta_k)\left(\frac{P^*_{H,k,t}}{P_t}\right)^{1-\epsilon} + \theta_k (\frac{P_{H,k,t-1}}{P_t})]^{\frac{1}{1-\epsilon}} \qquad \text{III-A.1.7}$$

$$\frac{P_{H,k,t}}{P_t} = [(1-\theta_k)\left(\frac{P^*_{H,k,t}}{P_t}\right)^{1-\epsilon} + \theta_k (\frac{P_{H,k,t-1}}{P_{t-1}}\frac{P_{t-1}}{P_t})]^{\frac{1}{1-\epsilon}} \qquad \text{III-A.1.8}$$

$$p_{H,k,t} = \left[(1-\theta_k)\left(p^*_{H,k,t}\right)^{1-\epsilon} + \theta_k p^{1-\epsilon}_{H,k,t-1}\pi^{1-\epsilon}_t\right]^{\frac{1}{1-\epsilon}} \qquad \text{III-A.1.9}$$

APPENDIX III-A.2

In this appendix, the sensitivity of output to nominal interest rate shock is derived for both open economy and closed-economy. For this reason, the log-linearization of some equations are re-written below.

$$\hat{y}_t = -\nu\hat{p}_{H,t} + \hat{c}_t + \alpha^*\left(\nu - \frac{1}{\sigma}\right)\hat{q}_t \qquad \text{III-A.2.1}$$

$$\hat{c}_t = \hat{c}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1}) \qquad \text{III-A.2.2}$$

$$\hat{\imath}_t = \phi_\pi\hat{\pi}_t + \phi_y\hat{y}_t + v_t \qquad \text{III-A.2.3}$$

$$0 = (1-\alpha)\hat{p}_{H,t} + \alpha\hat{p}_{F,t} \qquad \text{III-A.2.4}$$

$$\hat{\pi}_t = \hat{\pi}_{H,t} + \alpha\Delta\hat{s}_t \qquad \text{III-A.2.5}$$

Using terms of trade definition, equation III-A.2.4 is re-written as follows

$$\hat{p}_{H,t} = -\alpha\hat{s}_t \qquad \text{III-A.2.6}$$

$$Q_t = \frac{e_t P_t^*}{P_t} \qquad \text{III-A.2.7}$$

$$S_t = \frac{P_{F,t}}{P_{H,t}} = \frac{e_t P_t^*}{P_{H,t}} \qquad \text{III-A.2.8}$$

Then, substituting each log-linearized equations III-A.2.7 and III-A.2.8 to each other with III-A.2.6 leads to the following equation:

$$\hat{q}_t = (1-\alpha)\hat{s}_t \qquad \text{III-A.2.9}$$

$$\hat{q}_t = \sigma(\hat{c}_t - \hat{c}_t^*) \qquad \text{III-A.2.10}$$

Substituting equations III-A.2.6 and III-A.2.9 into equation III-A.2.1 leads to the following relation:

$$\hat{y}_t = \alpha\nu\hat{s}_t + \hat{c}_t + \alpha^*(1-\alpha)\left(\nu - \frac{1}{\sigma}\right)\hat{s}_t \qquad \text{III-A.2.11}$$

We assume that trade openness of each country is equal. (*i.e.* $\alpha = \alpha^*$)

$$\hat{y}_t = \hat{c}_t + \alpha(\nu + (1-\alpha)\left(\nu - \frac{1}{\sigma}\right))\hat{s}_t \qquad \text{III-A.2.12}$$

$$\hat{y}_t = \hat{c}_t + \alpha\Theta\hat{s}_t \qquad \text{III-A.2.13}$$

Where

$$\Theta = (\nu + (1-\alpha)\left(\nu - \frac{1}{\sigma}\right))$$

Substituting equation III-A.2.13 into III-A.2.2

$$\hat{y}_t = \hat{y}_{t+1} - \sigma^{-1}(\hat{\imath}_t - \hat{\pi}_{t+1}) - \alpha\Theta\Delta\hat{s}_{t+1} \qquad \text{III-A.2.14}$$

Substituting $\hat{\pi}_{t+1} = \hat{\pi}_{H,t+1} + \alpha\Delta\hat{s}_{t+1}$ into III-A.2.14

$$\hat{y}_t = \hat{y}_{t+1} - \sigma^{-1}\left(\hat{\imath}_t - \hat{\pi}_{H,t+1}\right) - \alpha(\Theta - \sigma^{-1})\Delta\hat{s}_{t+1} \qquad \text{III-A.2.15}$$

Analogously, equation III-A.2.13 is written for foreign country

$$\hat{y}^*{}_t = \hat{c}^*{}_t - \alpha\Theta\hat{s}_t \qquad \text{III-A.2.16}$$

Then, subtracting equation III-A.2.13 from III-A.2.16 leads to the following equation:

$$\hat{y}_t - \hat{y}^*{}_t = \hat{c}_t - \hat{c}^*{}_t + 2\alpha\Theta\hat{s}_t \qquad \text{III-A.2.17}$$

Plugging equation III-A.2.9 into equation III-A.2.10 and then into equation III-A.2.17

$$\hat{y}_t - \hat{y}^*{}_t = \left(\frac{1-\alpha}{\sigma} + 2\alpha\Theta\right)\hat{s}_t = \chi\hat{s}_t \qquad \text{III-A.2.18}$$

where $\chi = \left(\frac{1-\alpha}{\sigma} + 2\alpha\Theta\right)$

Taking the first order difference of equation III-A.2.18

$$\hat{y}_{t+1} - \hat{y}_t - \Delta\hat{y}^*{}_{t+1} = \chi\Delta\hat{s}_{t+1} \qquad \text{III-A.2.19}$$

Substituting equation III-A.2.19 into equation III-A.2.15 yields the aggregate demand as follows:

$$\hat{y}_t = \hat{y}_{t+1} - \frac{1}{\sigma_\alpha}\left(\hat{\imath}_t - \hat{\pi}_{H,t+1}\right) - \frac{\alpha}{\chi}\left(\frac{1}{\sigma} - \Theta\right)\left(1 + \frac{\alpha}{\chi}\left(\frac{1}{\sigma} - \Theta\right)\right)^{-1}\Delta\hat{y}^*{}_{t+1} \qquad \text{III-A.2.20}$$

$$\text{where } \sigma_\alpha = \sigma\left(1 + \frac{\alpha}{\chi}\left(\frac{1}{\sigma} - \Theta\right)\right)$$

In case of closed economy, $\alpha = 0$, σ_α increases. Thus, it can be concluded that since $\sigma_{\alpha=0}$ is greater than $\sigma_{\alpha>0}$, the sensitivity of output to monetary policy shock is greater in open-economy.

APPENDIX B: CURRICULUM VITAE

PERSONAL INFORMATION

Surname, Name: Yilmaz, Yusuf Omur
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EDUCATION

Degree	Institution	Subject	Year of Graduation
Integrated PhD	Middle East Technical University	Economics	2020
MS	University of Exeter	Financial Economics	2010
BA	Bahcesehir University	Business Administration	2008
BA	Bahcesehir University	Political Science and International Relations	2010

WORK EXPERIENCE

Year	Place	Enrollment
09.2012-Present	University of Mardin Artuklu	Research Assistant
01-0.8. 2012	Istanbul Stock Exchange Clearing and Settlement Bank	Deputy Specialist

INTEREST AREAS

Computable Macroeconomics, Open Economy Macroeconomics

SKILLS

Microsoft Offices, MATLAB and Latex

FOREIGN LANGUAGES

Advanced English

APPENDIX C: TURKISH SUMMARY/TÜRKÇE ÖZET

1980'lerden itibaren Dinamik Stokastik Genel Denge (DSGD) modelleri, iş döngüsünün, merkez bankalarının ve hükümetlerin uyguladığı politika uygulamalarının değerlendirilmesinde giderek önem kazanan optimizasyon temelli makroekonomik bir yöntemdir. Bu modellerin dört temel özelliği vardır: Dinamik, Stokastik, Genel ve Denge. Dinamiklik, analizde kısıtlı bir dönem yerine, sonsuz dönemin dikkate alınmasıdır. Stokastiklik, ekonominin rassal şoklardan etkilenmesidir. Genel denge ise tüm piyasalardaki arz ve talebin birbirleriyle etkileşim içinde dengeye ulaşmasıdır.

Dinamik Stokastik Genel Denge modellerinin doğuşu Lucas Kritiğine dayanır. Lucas (1976) zamanın makroekonomik düşüncesine devrimsel bir eleştiri getirmiştir. Lucas (1976) makroekonomik modellerin mikro temellerden ziyade belirli hipotezler üzerinde oturması, makroekonomik modellerin yanlış sonuçlar vermesine yol açabilir eleştirisini getirmiştir. Dinamik Stokastik Genel Denge modellerinin doğuşu bu eleştiriye dayanır.

Dinamik Stokhastik Genel Denge modelleri, talep, arz ve merkez bankası olmak üzere üç bloktan oluşur. Bu bloklardaki birimler rasyonel ve optimal davranırlar. Birimler belli kısıtlar altında dinamik optimizasyon yaparlar. Talep bloğu ve arz bloğundaki denklemler mikro temellere dayanmaktadır. Talep bloğunda, hane halkı firmalara sermaye ve iş gücü sağlar. Hane halkı, firmaların ürettiği çıktıları tüketim malı olarak kullanır. Hane halkı, tüketim ve işgücü arzı ile ilgili toplam faydasını bütçe kısıtı altında optimize eder. Arz bloğunda firmalar emek ve sermayeyi kullanarak, mal üretirler. Sermaye ve emek fiyatları dışsal olarak belirlenir. Bunları kullanarak firmalar kârlarını maksimize etmeyi hedeflerler. Ekonomide tüm pazarlar dengededir.

Firmaların talep ettiği emek miktarı, hane halkı tarafından sağlanan emek miktarına eşittir. Benzer şekilde, hane halkı tarafından talep edilen mal miktarı, firmalar tarafından üretilen mal miktarına eşittir.

Standart Dinamik Stokastik Genel Denge modelleri ekonomideki birimlerin aynı olduğunu varsayar. Böylece, birimler temsili bir temsilci tarafından temsil edilebilirler. Temsili bir hane halkı tüm hane halklarını ve temsili bir firma tüm firmaları temsil eder. Bu varsayım modellere teorik sadeleştirme sağlar. Aksi takdirde, ekonomik birimler arasındaki heterojenlik modellemeyi çok karmaşık hale getirebilir.

Dinamik Stokastik Genel Denge modelleri rasyonel beklentiler teorisine dayanmaktadır. Temsilcilerin mevcut tüm bilgileri kullanarak gelecekteki olaylar hakkında tahminlerde bulunduğu varsayılmaktadır. Tahminler her dönemde doğru olmayabilir, ancak ekonomideki birimler geçmiş hatalarından ders alırlar. Ortalama olarak, tahminler doğrudur ve gelecekteki olaylardan elde edilen gerçek sonuçlarla aynı olur.

Dinamik Stokastik Genel Denge modelleri temel olarak iki okula ayrılır. Bunlar Reel İş Döngüsü ve Yeni-Keynesyen okullarıdır. Bu okulların yapısal özellikleri benzer olmakla birlikte, market yapısı, fiyat katılıkları ve kısa dönemde paranın yansızlığı özelliklerinde ayrışırlar.

Reel İş Döngüsü modeli ilk olarak Kydland ve Prescott (1982) tarafından geliştirmiştir. Bir ekonomideki durgunluk, depresyon ve büyüme gibi makroekonomik dalgalanmaları, teknolojik şoklar, tüketici tercihleri ve verimlilik şokları ile açıklamaya çalışan sürtüşmesiz (frictionless) modeldir. Öte yandan, faiz şokları, döviz kuru şokları gibi nominal şokların model üzerinde bir etkisi yoktur. Model, sürtüşmesiz olduğundan etkin sonuçlar verir.

Reel İş Döngüsü modeli, hane halkı ve firmalar olmak üzere iki bloktan oluşur. Ne hükümetin ne de merkez bankasının, ekonomi üzerinde herhangi bir etkisi yoktur. Temsilci hane halkı, bütçe kısıtlamasına tabi olan sonsuz ufka sahip toplam faydanın bugünkü değerini maksimize eder. Optimizasyon sonuçları, toplam mal talebini ve işgücü arzını verir. Temsilci firma, üretim fonksiyonu kısıtı altında her dönem karını maksimize etmeyi hedefler ve sonuç olarak iş gücü talebini elde eder. Mal arzı fonksiyonu ise diktir. Literatürde, standart Reel İş Döngüsü modeline hükümet, yabancı sektör ve finansal kurumlar eklenerek genişletilen çalışmalar bulunabilir.

Reel İş Döngüsü modellerinin ayırt edici özellikleri şu şekilde özetlenebilir: Tam rekabet piyasaları (mal piyasası ve iş gücü piyasası), esnek fiyatlar ve paranın yazsızlığıdır. Her firma (işçi) aynı ürünü (işgücü) satar (kiralar). Pazardaki tüm firmalar (işçiler) fiyat (ücret) alıcılarıdır. Firmaların (işçi) denge fiyatı (ücreti) üzerinde herhangi bir etkisi yoktur. Ayrıca, ücret dahil tüm fiyatlar oldukça esnektir. Tüm pazarlar eksiksizdir ve bilgi asimetrisi yoktur. Son olarak, paranın yansızlığında para arzındaki değişiklikler sadece nominal değişkenleri etkilerken reel değişkenleri etkilemez.

Dinamik Stokastik Genel Denge modellerindeki diğer okul, Yeni Keynesyen Okul'dur. Yeni Keynesyen modellerle ilgili yapılan öncü çalışmalar Yun (1996), Rotemberg & Woodford (1995), Gali (2002) ve Woodford (2003) tarafından yapılmıştır. Yeni Keynesyen modeller, hane halkı, firmalar ve para otoritesi olmak üzere üç bloktan oluşur. Hane halkı davranışı, Reel İş Döngüsü modelindekine benzer. Talep bloğundaki optimizasyon sonuçları, mallar için toplam mal talebini ve iş gücü arzını verir. Arz bloğunda ara mal üreten firmalar ve nihai mal üreten firma olmak üzere iki tür firma vardır. Ara malı üreten firmalar, tekelci rekabet piyasasında farklılaştırılmış ürünler üretip nihai mal üreten firmaya satarlar. Nihai mal üreten firma, bu malları bir araya toplayıp bir sepet yapar ve bu sepeti tüketicilere tam rekabet piyasasında satar. Bu blokta optimizasyon sonuçları toplam mal arzını sağlar. Toplam üretim fonksiyonuyla, iş gücü talebi elde edilir. Son olarak, Merkez Bankası nominal faiz oranını kontrol etmektedir.

Yeni Keynesyen modellerin üç tane ayırt edici özelliği vardır: tekelci rekabet piyasası, fiyat (ücret) katılığı ve kısa dönemde paranın yansız olmamasıdır. Tekelci rekabet piyasasında, farklılaştırılmış ürünler üreten N tane firma vardır. Farklılaştırılmış ürünler üretmek, firmalara pazar gücü sağlar. Böylece firmalar talep eğrilerinin elastik tarafında faaliyet gösterebilirler. Nominal fiyat katılığının ampirik bulguları doğrultusunda, bazı firmaların değişen koşullar karşısında kârlarını maksimize etmek için nominal fiyatlarını seviyelerde yeniden ayarlamalarına rağmen geri kalanlarının fiyatlarını sabit tutabilecekleri iddia edilebilir. Fiyat güncellemesi yapan firmalar, fiyatları sabit tutan diğer firmalara tüm taleplerini kaybetmezler.

Nominal katılık, Yeni Keynesyen modellerin en önemli özelliklerinden biridir. Literatürde nominal fiyat katılığıyla ilgili birçok çalışma vardır. Bu çalışmalar, Tablo 2.1 özetlenmiştir. Aucremanne & Dhyne (2005) Belçika için, Barros vd. (2009) Brezilya için, Amirault vd. (2006) Kanada için ve Hall vd. (2010) Birleşik Krallık için aylık bazda fiyat değişiklerinin sıklığı üzerinde çalışmalar yapmışlardır. Öte taraftan Fabiani vd. (2005) ve Dhyne vd. (2006) Euro Bölgesi için fiyat değişiminin (price spell) ne kadar süre içinde olduğuna dair çalışmalar yapmışlardır. Klenow & Kryvtsov (2008) ve Bils & Klenow (2004) ABD ekonomisi için aynı çalışmayı yapmışlardır. Tüm çalışmalar, farklı ülkelerde fiyat katılığının varlığını göstermektedir. Öte taraftan, Dhyne vd. (2006) Euro Bölgesi için ve Bils & Klenow (2004) Amerikan ekonomisi için fiyat katılıklarını tartışmışlardır. Dhyne vd. (2006) göre, Euro bölgesinde sektörler arasında heterojen fiyat katılığı vardır. Bu çalışmada, en yüksek fiyat değişikliği sıklığı enerji sektöründe ve en düşük fiyat değişikliği sıklığı servis sektöründedir. Bils & Klenow (2004) göre fiyat değişim sıklığı sektörler arasında heterojendir. Bu çalışamaya göre, en yüksek sıklık ham madde sektöründeyken en düşük sıklık tıbbi bakım sektöründedir.

Nominal katılık iki gruba ayrılır. Bunlar, zamana bağlı nominal katılık (time-dependent nominal rigidity) ve duruma bağlı nominal katılıktır (state-dependent nominal rigidity). Zamana bağlı nominal katılık kendi içinde ikiye ayrılır. Bunlar Calvo türü nominal katılık ve Taylor türü nominal katılıktır. Calvo türü nominal katılığa göre, her dönem belli bir ihtimal dahilinde fiyatlar veya ücretler güncellenir. Taylor tarzı nominal katılığa göre, piyasadaki tüm firmalar N tane ücret güncellemesi yapan zaman dilimine bölünmüş. Bu kurala göre, her dönem, 1/N tane firma ücret güncellemesi yapar. Duruma bağlı katılıkta ise, fiyat güncellemesi yapan firmalar, fiyat değiştirmenin fayda ve maliyeti dikkate alınarak fiyat güncelleme zamanını belirlenir.

Yeni Keynesyen modellerin üçüncü özelliği kısa dönemde paranın yansız olmamasıdır. Bu özellik kısa dönemde nominal faiz oranı gibi nominal şokların çıktı ve tüketim gibi reel değişkenler üzerinde etkiye sahip olmasıdır. Ekonomilerde paranın rolü, para politikası kurallarıyla tanımlanabilir. Bunlardan en popüleri Taylor kuralıdır. Taylor (1993) sabit bir politika kuralı önermiştir. Bu kurala göre, nominal faiz oranı çıktı açığı ve enflasyon oranı gibi makroekonomik değişkenlere bağlıdır. Literatürde çeşitli Taylor kuralı türleri vardır. Nominal faiz oranı, geçmiş dönem faiz oranından, güncel değişkenlerden, beklenen değişkenlerden, geçmiş değişkenlerden etkilenerek değişebilir. Clarida vd. (1998), Ball (1999), Taylor (1999), Svensson (2000) ve Judd & Rudebusch (1998) farkı Taylor kuralı türlerini çalışmışlardır.

Standart Yeni Keynesyen model, sıfır trend enflasyon, kapalı ekonomi ve homojen fiyat katılığı özelliklerine sahiptir. Fakat, bu özellikler genellikle gözlenen gerçeklerle ters düşmektedir. Şekil 2.1 ve 2.2'den görülebileceği gibi hem ülkelerin tüketici fiyat endeksi enflasyonu hem de merkez bankalarının uyguladığı enflasyon hedeflemesi politikası sıfırın üstündedir. Bu nedenle, trend enflasyonu sıfır varsaymak gerçeğe aykırıdır. Öte yandan günümüz global dünyasında ekonomiler, birbirleriyle ithalat ve ihracat yaparak az veya çok ilişki içindedirler. Bu çalışmada ekonominin açıklık oranı ithalatın toplam gayri safi yurt içi hasılasına oranı şeklinde ifade edilmiştir. Şekil

2.3’den görülebileceği gibi, seçilen her bir ülke için, bu oran zaman içinde dalgalanma gösterse de her zaman sıfırdan büyüktür. Bir başka ifadeyle, ekonomiyi kapalı varsaymak, gerçeğe aykırıdır. Bir diğer özellik de homojen fiyat katılığıdır. Bu varsayıma göre, tüm ürünler aynı katılık katsayısına sahiptirler. Fakat Bils & Klenow (2004)’a göre ürünler homojen fiyat katılığı özelliği göstermesinden ziyade heterojendir. Yani, ürün fiyatları farklı katılık derecelerine sahiptirler.

2008-9 Küresel Finansal krizin daraltıcı etkisini ortadan kaldırmak, daralan talebi tekrar canlandırmak için gelişmiş ülkelerdeki birçok merkez bankası, nominal faiz oranlarını sıfıra yakın seviyeye düşürdüler. Bu durum 'Sıfır Alt Sınır' (Zero-Lower Bound) olarak bilinir. Bu durum iktisat literatüründe, trend enflasyon konusunda tartışmalara yol açmıştır. Blanchard vd. (2010), Williams (2009) ve Ball (2013) merkez bankalarının daha yüksek trend enflasyon hedeflemesi gerektiğini savunmuşlardır. Bu sayede, yüksek enflasyon doğar ve nominal faiz oranı da yüksek olur. Böylece ekonomiyi etkilemek için daha fazla politika aracı elde edilir. Bernanke (2010)’ye göre ise yüksek enflasyon hedeflemesi enflasyon beklentilerinde bozulmaya ve ekonomide istikrarsızlıklara yol açar.

King & Wolman (1996) ve Ascari (2000) 'den bu yana, pozitif trend enflasyonunun etkileri Yeni-Keynesyen modelllerin en cazip konulardan biri olmuştur. Ascari (2004), Ascari & Ropele (2007), Ascari & Ropele (2009), Ascari & Sbordone (2014), Sahuc (2006) ve Bakhshi (2007) pozitif trend enflasyonunun Yeni Keynesyen modellerin dinamikleri üzerindeki etkilerini tartışmaktadır.

Ascari (2004) standart Yeni-Keynesyen modeli pozitif trend enflasyonla geliştirmiştir ve pozitif trend enflasyonun modelin kısa ve uzun dönem dinamikleri üzerindeki etkilerini tartışmıştır. Öte yandan Ascari (2004), parasal büyüme şokunun farklı trend enflasyon oranlarında çıktının dinamiği üzerindeki etkilerini analiz eder ve trend enflasyonun çıktı dinamikleri üzerinde önemli etkileri olduğu sonucuna varır. Ascari

(2004) bu çalışmasında trend enflasyon arttıkça Yeni Keynesyen Philips Eğrisi'nin eğiminin azaldığını ve trend enflasyonunun Yeni Keynesyen Philips Eğrisi üzerindeki etkisinin model endekslendiğinde zayıfladığını bulmuştur.

Ascari & Ropele (2007), pozitif trend enflasyonunun refah ve değişkenlerin dinamikleri üzerindeki etkilerini optimal para politikası kullanılarak tartışmışlardır. Çalışmadaki modelde, trend enflasyon arttıkça, hem taahhüt (commitment) hem de ihtiyari (discretionary) optimum para politikaları altında toplam refah kaybı artmaktadır. Yüksek trend enflasyon, her iki tür optimum para politikasında enflasyon oranındaki oynaklığı artırırken çıktı oynaklığını azaltmaktadır.

Ascari & Ropele (2009) pozitif trend enflasyonun denge belirliliği (equilibrium determinacy) bölgesi üzerindeki etkisini standart Taylor ve ataletli Taylor kurallarını kullanarak endekssiz, kısmi endeksleme ve tam endeksleme durumlarında analiz etmişlerdir. Çalışmada, endekssiz ve kısmi endeksleme durumlarında trend enflasyon oranının her iki para politikası kuralı altında denge belirliliği bölgesi üzerinde etkileri olduğu bulunmuştur. Tam endeksleme durumunda, trend enflasyon denge belirliliği bölgesini etkilemez.

Ascari & Sbordone (2014) pozitif trend enflasyonunun denge belirliliği bölgesini nasıl etkilediği tartışmışlardır. Aynı zamanda, geliştirilen modelde, pozitif trend enflasyon durumunda, şokların makroekonomik değişkenleri nasıl etkilediği analiz edilmiştir. Yazarlar, daha yüksek trend enflasyonunun denge belirliliği bölgesini daralttığını ve trend enflasyonun farklı şok türlerinde değişken dinamikleri etkilediğini bulunmuşlardır. Öte yandan, analitik olarak da pozitif trend enflasyonda şokların değişkenleri nasıl etkilediğini tartışmışlardır.

Ascari (2004), Ascari & Ropele (2007), Ascari & Ropele (2009) ve Ascari & Sbordone (2014), olumlu trend enflasyonun Yeni-Keynesyen modelinin dinamikleri üzerinde etkileri olduğu konusunda fikir birliğine varmışlardır.

Yüksek trend enflasyonunun Yeni Keynesyen Philips Eğrisi üzerindeki etkisi ekonometrik olarak da tartışılmıştır. Cogley & Sbordone (2008), trend enflasyon arttıkça, güncel değişkenlerin ve beklenen değişkenlerin eğri üzerindeki etkilerinin değiştiğini bulmuşlardır. Daha yüksek trend enflasyon, eğrinin eğimini düzleştirir, ancak eğri üzerinde beklenen değişkenlerin etkisi artar. Bulgular, Ascari (2004), Ascari & Ropele (2007), Ascari & Ropele (2009) ve Ascari & Sbordone (2014)'ın çalışmalarıyla tutarlıdır.

Bu tezin ana araştırma konusu, trend enflasyon üzerindeki tartışmalardan doğmuştur ve bu tez yüksek trend enflasyonun makroekomi üzerindeki etkilerini açık ekonomilerde araştırmayı amaçlamaktadır. Çalışma iki makaleden oluşmaktadır. Birinci makalenin başlığı *The Macroeconomic Effects of Trend Inflation in a Small-Open Economy* ve ikinci makaleninki ise *Trade Opennes, Trend Inflation and Aggregate Instability* dir. Birinci makalede Gali & Monacelli (2005)'nin çalışmasındaki küçük açık ekonomi modeli esas alınmıştır. Bu model, pozitif trend enflasyon ile genişletilmiş; Kanada ve Birleşik Krallık için makroekomik bir analiz yapılmıştır. Bu iki ülkenin seçilmesinin nedenleri: her iki ülkenin küçük açık ekonomilere iyi birer örnek olması; enflasyon hedeflemesi politikası takip etmeleri ve faiz oranlarını sıfıra yakın düzeye kadar indirmeleridir. Kanada ve Birleşik Krallık ekonomileri farklı açıklık derecelerine ve farklı Calvo parametrelerine sahiptirler.

İlk makalede, Gali & Monacelli (2005)'nin modeli pozitif trend enflasyonla genişletilmiştir. Bu çalışmada geliştirilen model, standart Yeni Keynesyen modelden farkı olarak pozitif trend enflasyon ve açıklık varsayımlarına dayanır. Fakat, homojen fiyat katılığı varsayımı, standart Yeni-Keynesyen modelinkiyle aynıdır.

Modelde, çok sayıda küçük açık ekonomi vardır. Her bir ülkede, sonsuza kadar yaşayan bir hane halkı vardır. Ülkeler başlangıçta aynı koşullara sabittirler. İş gücü piyasasında sürtüşme yoktur. Hane halkı, yerli aracı firmalara işgücü sağlamakta ve hem yurt içinde üretilen hem de ithal edilen malları içeren tüketim endeksi satın almaktadır. Hane halkı, uluslararası olarak işlem gören devlet tahvilleri satın alabilir. Dahası, her ülkede, tekelci rekabet yapan ara malı üreten çok sayıda firma ve nihai bir mal üreten bir firma vardır. Aracı firmalar, farklılaştırılmış ürünler üretir. Her bir aracı firma belli bir ihtimalle her dönem fiyat güncellemesi yapar.

Modelin kalibrasyon parametreleri farklı makalelerden ve literatürde kabul edilen standart değerlerden alınmıştır. Kanada için fiyat katılığı Gali & Monacelli (2005) makalesinden alınmış ve bu değer 0.75'dır. Birleşik Krallık için, Fragetta & Kirsanova (2010) çalışmasından alınmış ve 0.70'dır. Farklılaştırılmış ürünler için elastikiyet her iki ülke için 6'dır. Bu değer, Kanada için Gali & Monacelli (2005) makalesinden ve Birleşik Krallık için Brittion vd. (2000) makalesinden alınmıştır. Ticaret açıklığı, Kanada için 0.33 ve Birleşik Krallık için 0.31'dir. Bu değerler, yazarın kendi hesaplamalarıdır. Bu oranlar, ülkelerin ithalatlarının Gayri Safi Yurt İçi Hasılalarına (GDP) oranlayarak elde edilmiştir. İki ülke için ortak olarak kullanılan kalibrasyon parametreleri: stokhastik indirim faktörü, riskten kaçınma (risk aversion) parametresi, farklı yabancı ülkelerde üretilen mallar arasındaki elastikiyet, yurt içi ve yurt dışında üretilen mallar arasındaki elastikiyet, para politikası şoku tutarlılığı, talep şoku tutarlılığı ve maliyet şoku tutarlılığıdır. Stokhastik indirim oranı 0.99'dur. Riskten kaçınma parametresi, farklı ülkelerde üretilen mallar arasındaki elastikiyet, yurt içi ve yurt dışında üretilen mallar arasındaki elastikiyet 1'dir. Para politikası şokunun tutarlılığı 0.50, talep şokunun tutarlılığı 0.80 ve maliyet şokunun tutarlılığı 0.80'dir.

Modelin talep bloğunda, hane halkı fayda fonksiyonun bugünkü değerini bütçe kısıtı altında maksimize eder. Buradan elde edilen sonuçlar: Euler eşitliği yani toplam talep ve iş gücü arzıdır. Arz bölümde, yapılan kar maksimizasyonu ve Calvo kuralı kullanılarak Yeni-Keynesyen Philips Eğrisi eşitliği elde edilir. Bu aynı zamanda toplam arz eşitliğidir. Toplam üretim fonksiyonundan ise, iş gücü talep eşitliği elde edilir. Modelde para politikası olarak standart Taylor kuralı kullanılmıştır. Geliştirilen modelin talep ve piyasa dengesi (market clearing) bölümleri Gali & Monacelli (2005) ile aynıyken, arz bölümü Gali & Monacelli (2005)'ninkinden belli noktalarda farklılık gösterir.

Bunlardan ilki, Yeni-Keynesyen Philips Eğrisinin dinamiğinde olur. Bu eğri hem güncel hem de beklenen değişkenlerden etkilenmektedir. Modele pozitif trend enflasyon eklenince, güncel değişkenlerin eğri üzerindeki etkisi azalırken, beklenen değişkenlerinki artmaktadır. Öte taraftan, Gali & Monacelli (2005)'deki beklenen yurt içi enflasyondan farklı olarak beklenen marjinal maliyet değişkeni de eğriyi etkilemektedir. Son olarak, fiyat dağılımı (price dispersion) değişkeni pozitif trend enflasyonla birlikte modeli etkilemeye başlamıştır.

Bu çalışmada geliştirilen modelde, fiyat güncellemesi yapan firmaların yüksek trend enflasyon durumunda fiyatlama davranışları değişiklik gösterir. Bu firmalar, fiyatlama davranışı yaparken güncel değişkenlerden ziyade gelecekteki değişkenleri dikkate alırlar. Bununla birlikte bu dönem fiyat güncellemesi yapan bir firma ancak gelecek dönem belli bir ihtimal içinde fiyatını günceller. Böylece firma yüksek enflasyon hedeflemesinde fiyatlarını gelecek dönem fiyat güncellemesi yapmama ihtimaline karşı ortalama fiyat seviyesinden daha fazla arttırır. Bahsedilen bu dinamikler, pozitif trend enflasyon durumunda Yeni-Keynesyen Philips Eğrisinde meydana gelen değişiklerin nedenlerini açıklar.

Daha sonra çalışmanın birinci makalesinde, ticaret açıklığının Yeni-Keynesyen Philips Eğrisi üzerinde herhangi bir etkisi olup olmadığı tartışılmıştır. Açıklık derecesinin modelde yapılan varsayımlar sebebiyle eğrinin üzerinde herhangi bir etkisi yoktur. Daha sonra, trend enflasyon ve ticaret açıklığın etkileşimi reel döviz kuru kanalı üzerinden modeli etkileyip etkilemediği tartışılmıştır. Modelde bazı varsayımlar ve basitleştirmeler yapılarak, tahmin et ve doğrula (guess and verify) metodu kullanılmış ve reel döviz kuru dinamiği türetilmiştir. Şekil 3.1'de görülebileceği gibi, belli bir ticari açıklık seviyesinde, para politikası şokunun reel döviz kuru üzerindeki etkisi ve reel döviz kurunun tutarlılığı trend enflasyon arttıkça artmaktadır.

Daha sonra, modele para, talep ve maliyet şokları uygulanarak, farklı trend enflasyon seviyelerinde makroekonomik değişkenlerin artan trend enflasyona nasıl tepki verdiği tartışılmıştır. Tartışmada ilk olarak, para politikası şokunun makroekonomik değişkenler üzerindeki etkisi hem sıfır trend hem de pozitif trend enflasyon durumlarında incelenmiştir. Yapılan analiz sonucunda elde edilen bulgular şunlardır: Sıfır trend enflasyonda, para politikası şoku nominal faiz oranını ve reel faiz oranını artırır. Reel faiz oranındaki artış, yerli mallara olan talebin düşmesine neden olmaktadır. Yurt içi enflasyon azalmaktadır. Şok iç tahvillere olan talebi arttırdığından, yerli para birimine olan talep artmakta ve böylece nominal yerli para birimi değer kazanmaktadır. Böylece ticaret haddi ve reel döviz kuru azalmaktadır. Başka bir deyişle, ithal mallar nispeten daha ucuz hale gelir. Bu nedenle tüketici fiyat endeksi enflasyonu yurt içi enflasyondan daha düşük olur ve toplam yurt içi üretim azalır.

Geliştirilen modelde yüksek trend enflasyon Yeni Keynesyen Philips Eğrisinin eğimini daha düz hale geldiğinden, güncel değişkenler ile yurtiçi enflasyon arasındaki ilişki zayıflamaktadır. Böylece, para politikası şoku nedeniyle yurtiçi mallara olan talepteki ilk düşüş, trend enflasyon yükseldikçe yurtiçi enflasyonun daha az düşmesine neden olmaktadır. Diğer taraftan, yurtiçi enflasyon beklentilerindeki düşüş nedeniyle reel faiz oranı yüksek trend enflasyon oranlarında daha yüksektir. Öte yandan reel faiz oranındaki artış, yurt içi mallara olan talepteki önemli düşüşü beraberinde getirmektedir. Ticaret haddi ve reel döviz kuru daha çok düşer. Başka bir deyişle, ithal mallar yüksek trend enflasyon oranlarında nispeten daha ucuz hale gelmektedir. Yurtiçi enflasyonun ve ticaret haddinin ters dinamikleri, trend enflasyonun tüketici fiyat endeksi enflasyonu üzerindeki etkisinin sınırlı kalmasına neden olmaktadır. Ayrıca, trend enflasyon arttıkça toplam yurt içi üretim daha da azalmaktadır.

Daha sonra geliştirilen modelde, talep şokunun makroekonomik değişkenler üzerindeki etkisi hem sıfır trend hem de pozitif trend enflasyon durumlarında tartışılmıştır. Sıfır trend enflasyonda, talep şoku ilk olarak iç talepte artışa neden olmaktadır. İç talepteki artış, yurt içi fiyat seviyesinde ve yurt içi enflasyonda artışa yol açar. Uluslararası risk paylaşım koşuluna göre reel döviz kuru artar. Bu, ithal edilen malların nispeten daha pahalı hale geldiği anlamına gelir. Yurt içi enflasyonun ve ithal malların fiyatlarındaki göreli artış, tüketici fiyat endeksi enflasyonunun yükselmesine neden olmaktadır. Ayrıca, toplam yurt içi üretim artmaktadır. Politika kuralına göre, nominal faiz oranı artar.

Trend enflasyondaki artış, Yeni Keynesyen Philips Eğrisinin daha düz eğimli olmasına yol açar. Talep şoku durumunda, iç talepteki artış, trend enflasyon arttıkça yurt içi fiyat seviyesinin ve yurt içi enflasyonun daha az artmasına neden olmaktadır. Trend enflasyon arttıkça, ticaret haddi ve reel döviz kuru daha da artar. İthal mallar nispeten daha pahalı hale gelir. Yurt içi enflasyonun ve ticaret haddinin pozitif trend enflasyon durumundaki ters dinamikleri, pozitif trend enflasyonun tüketici fiyat endeksi enflasyonu üzerindeki etkisini sınırlamaktadır. Öte yandan, yüksek içi talep ve nispeten pahalı ithal mallar, trend enflasyon arttıkça toplam yurt içi üretimde daha fazla artışa neden olmaktadır.

Çalışmanın birinci makalesinde maliyet şokunun hem sıfır trend enflasyon hem de pozitif trend enflasyon durumunda makroekonomik değişkenler üzerindeki etkisi tartışılmıştır. Sıfır trend enflasyon durumunda, maliyet şoku yurt içi fiyat seviyesini ve yurt içi enflasyon oranını arttırır. Yurt içi mallara olan talebi azaltır. Ticaret haddi ve reel döviz kuru azalır. İthal mallar nispeten daha ucuz hale gelir. Öte yandan, ithal malların göreli ucuzluğuna bağlı olarak tüketici fiyat endeksi enflasyonundaki artış yurt içi enflasyondaki artıştan daha az olmaktadır. Toplam yurt içi üretim azalmaktadır. Politika kuralına göre, nominal faiz oranı artar.

Birinci makalede geliştirilen modelde pozitif trend enflasyonunun etkileri iki kanal üzerinden yürür. Birincisi, güncel değişkenlerin Yeni Keynesyen Philips Eğrisi üzerindeki önemidir. İkincisi, beklentiler kanalı üzerinden çalışır. Beklenti kanalı o kadar güçlüdür ki, ilk kanalın yurt içi enflasyon üzerindeki etkisini baskılar. Böylece, yüksek trend enflasyon, yurt içi fiyat seviyesini ve yurt içi enflasyonu daha da artırmaktadır. Trend enflasyon arttıkça, ticaret haddi ve reel döviz kuru daha da azalmaktadır. Bu, ithal malların nispeten daha ucuz hale gelmesine ve dolayısıyla tüketici fiyat endeksi enflasyonundaki artışın yurt içi enflasyondaki artıştan daha az olmasına neden olur. Ayrıca, toplam yurt içi üretim düşmüştür.

Daha sonra makalede, farklı pozitif trend enflasyon düzeylerinde açıklık etkisi farklı şok durumlarında tartışılmıştır. Bu tartışmada, her bir değişken için açık ekonomi etki-tepki fonksiyonundan kapalı ekonomi etki-tepki fonksiyonu çıkartılarak, fark etki-tepki fonksiyonu oluşturulmuş ve bunlar üzerinden analizler yapılmıştır. Sonuç olarak farklı trend enflasyon düzeylerinde, her bir şok türü için açıklığın tüketici fiyat endeksi enflasyonu ve yurtiçi üretim üzerinde önemli etkisi olduğu görülmüştür.

Çalışmada trend enflasyonun makroekonomin iki bilmecesi olan Geçikmiş Sıçrama (Delayed Overshooting Puzzle) bilmecesi ve Satın Alma Gücü Paritesi (Purchasing Power Parity Puzzle) bilmecesine çözüm olup olmadığı farklı senaryolar altına tartışılmıştır. Yüksek, trend enflasyon iki durumda reel döviz kurunun sıçramayla tepki vermesine sebep olur. Bunlar, standart para politikası durumunda tutarlı talep şoku ve hem standart hem de ataletli para politikalarında tutarlı maliyet şokudur. Öte taraftan, yüksek trend enflasyon, sıfır tutarlı talep şoku ve ataletli para politikası durumu hariç daha tutarlı ve oynak reel döviz kuruna yol açar.

Daha sonra birinci makalede, yurt içi enflasyon endekslemesi yapılarak, bulgular ana modeldeki bulgularla kıyaslanmıştır. Para politikası şoku durumunda, tüketici fiyat endeksi enflasyonu ve yurt içi üretimin standart sapması ana modelde (benchmark model) daha yüksektir. Endeksleme yurt içi üretimin oto-korelasyonunu düşürürken, tüketici fiyat endeksi enflasyonunun oto-korelasyonunu arttırmaktadır. Talep şoku durumunda, endeksleme tüketici fiyat endeksi enflasyonunun oto-korelasyonunu ve standart sapmasını arttırırken, yurt içi üretimin oto-korelasyonunu ve standart sapmasını düşürmektedir. Maliyet şokunda, endeksleme hem tüketici fiyat endeksi enflasyonunun hem de yurt içi üretimin oto-korelasyonunu ve standart sapmasını arttırmaktadır. Bu bulgular, yüksek trend enflasyon durumunda da geçerlidir. Öte taraftan, birbirinden bağımsız ve aynı dağılıma sahip para politikası, talep ve maliyet şokları verilerek etki-tepki analizi yapılmıştır. Yurt içi enflasyon oranı hariç, yüksek enflasyonun değişkenler üzerindeki etkisi önemli ölçüde zayıflamıştır.

Daha sonra, birinci makalede bulunan sonuçlar var olan Yeni-Keynesyen literatürüyle karşılaştırılmıştır. Ascari (2004), Ascari & Ropele (2007), Ascari & Ropele (2009) & Ascari & Sbordone (2014) trend enflasyonun kapalı ekonomiyi nasıl etkilediğine dair buldukları birinci makaledeki sonuçlar ile paralellik göstermektedir. Öte taraftan, Ascari & Ropele (2009) maliyet şokunun yüksek trend enflasyon durumunda makro ekonomik değişkenler üzerine yaptığı tartışmalar ile çalışmadaki sonuçlar benzerlik göstermektedir. Ascari & Sbordone (2014), yüksek trend enflasyon durumunda para politikası şokunun makroekonomik değişkenler üzerindeki etkisini analiz etmişlerdir ve birinci makalede Ascari & Sbordone (2014)'ınkine benzer sonuçlar elde edilmiştir. Gali & Monacelli (2005) ve Cooke (2011), açıklık derecesinin Yeni Keynesyen Philips Eğrisi eğimi üzerinde bir etkisi olup olmadığını tartışmışlardır. Gali & Monacelli (2005) açıklık derecesinin eğrinin eğimi üzerinde hiçbir etkisi olmadığını bulurken, Cooke (2011) bunun tersini bulmuştur. Bu bağlamda bu çalışmada, açıklık derecesinin Yeni Keynesyen Philips Eğrisinin eğimi üzerinde herhangi bir etkisi olup olmadığı tartışılmıştır. Gali & Monacelli (2005)'ninkine benzer şekilde bu çalışmada da açıklığın çalışmada geliştirilen model üzerindeki etkisi sadece reel döviz kuru kanalıyla oluşmaktadır. Bu kanal trend enflasyonunun tüketici fiyat endeksi enflasyonu üzerindeki etkilerini hafifletmekte ve trend enflasyonunun çıktı üzerindeki etkilerini artırmaktadır.

Cooke & Kara (2018), yüksek trend enflasyon durumunda, para politikası şoku reel döviz kurunu nasıl etkilediğini hem homojen fiyat katılığında hem de heterojen fiyat katılığında tartışmışlardır. Trend enflasyon arttıkça, homojen fiyat katılığında reel döviz kuru şoka daha güçsüz ve daha az tutarlı bir şekilde tepki verirken, heterojen fiyat katılığında daha güçlü ve daha tutarlı tepki verir. Cooke & Kara (2018)'nın aksine bu çalışmada geliştirilen modelde pozitif trend enflasyon, homojen fiyat katılığı durumunda para politikası reel döviz kurunun daha tutarlı hale getirir.

Merkez bankaları için bu çalışmadan çıkarılabilecek çeşitli politika uygulamaları vardır. Merkez bankalarının izlediği yüksek enflasyon hedeflemesi politikasının politika yapıcılar için hem faydaları hem de maliyetleri vardır. Bu faydalar ve maliyetler, şok türlerine göre değişiklik gösterir. Para politikası şoku ve maliyet şoku durumlarında, yüksek trend enflasyonu, enflasyon beklentilerini bozmaktadır. Merkez bankaları, enflasyon oranındaki ve üretimdeki dalgalanmalarla mücadele etmek için nominal faiz oranını önemli ölçüde artırır. Bu nedenle merkez bankaları uzun vadeli trend enflasyon oranını hedef seviye olarak benimsemelidir. Ancak, talep şoku söz konusu olduğunda, daha yüksek trend enflasyonun nominal faiz oranı üzerindeki etkisi sınırlıdır. Bu nedenle, merkez bankasının daha yüksek trend enflasyonuna nominal faiz oranını artırarak cevap vermez. Böylece, merkez bankaları talep şoku durumunda daha yüksek enflasyon oranını hedefleyebilir.

İkinci makalede, Gali & Monacelli (2005) modelinin açık ve özdeş iki ekonomi versiyonu pozitif trend enflasyon ve heterojen fiyat katılığıyla, Kara & Yates (basılacak) çalışması temel alınarak genişletilmiştir. Geliştirilen bu model Amerikan ekonomisi üzerinde uygulanmıştır.

Bu makalenin talep bloğu Gali & Monacelli (2005) modelinkine benzer. Talep bloğunda hane halkı fayda fonksiyonunu maksimize eder. Bu maksimizasyondan toplam talep ve iş gücü arzı fonksiyonları elde edilir. Arz bloğundaki her bir sektörde bulunan firmalar kar maksimizasyonu yapar. Maksimizasyon sonucunda, Sektörel Yeni-Keynesyen Philips Eğrisi (Sectoral New Keynesian Philips Curve) bulunur. Bu eğri aynı zamanda, sektörel arz fonksiyonudur. Arz bloğundaki, toplam üretim fonksiyonundan iş gücü talep fonksiyonu elde edilir. Para politikası olarak standart Taylor kuralı kullanılmıştır.

1980 öncesinde Amerikan ekonomisinde oldukça oynak GSYİH, yüksek işsizlik ve yüksek enflasyon gözlemlenmiş ve trend enflasyon %5 düzeyine çıkmıştır. 1980'lerin ortasından itibaren, enflasyon oranı düşmüştür. Bu dönem iktisat literatüründe, Büyük Ilımlılık (Great Moderation) dönemi olarak isimlendirilir. Bernanke (2004)'ye göre, Büyük Ilımlığın arkasında güçlü para politikası yatmaktadır. Clarida, Gali & Gerther (2000), Lubik & Schorfheide (2004), Boivin & Giannoni (2006) ve Mavroeidis (2010)'nin bulduğu ampirik kanıtlar Bernanke (2004)'nin açıklamasını desteklemektedir.

Ascari & Ropele (2009) yüksek trend enflasyonun denge belirliliği bölgesini daralttığını bulmuşlardır. Bu durum, Merkez Bankası'nın dengeyi elde etmek için enflasyon oranındaki dalgalanmalara agresif bir şekilde tepki vermesi gerektiğini göstermektedir. Kara & Yates (basılacak), Ascari & Ropele (2009) ile benzer sonuçlara ulaşır. Kara ve Yates (basılacak), denge belirliliği bölgesini hem homojen fiyat katılığı ve hem de heterojen fiyat katılığı modellerinde tartışmışlardır. Yazarlar, pozitif trend enflasyonda, denge belirliliği bölgesi, heterojen fiyat katılığı modelinde, homojen fiyat katılığı olan modele kıyasla bölgenin daha küçük olduğunu bulmuştur. Bu makalede, trend enflasyonun denge belirliliği bölgesi üzerindeki etkisi açık ekonomi durumunda nasıl değiştiği tartışılmıştır.

Trend enflasyonu açık ekonomi modeline eklemek, ilk makaledekine benzer sonuçlar vermiştir. İlk olarak güncel değişkenlerin Sektörel Yeni-Keynesyen Philips Eğrisi üzerindeki önemi azalırken, beklenen değişkenlerin önemi artmaktadır. Öte taraftan, ilave değişkenler Sektörel Yeni-Keynesyen Philips Eğrisine yeni değişkenler girmesine sebep olur. Bunlar, beklenen sektörel marginal gelir, tüketici fiyat endeksi enflasyonu ve yurt içi enflasyonudur. Sektörel fiyat dağılımı pozitif trend enflasyonu sayesinde modeli etkiler ve bu değişkenin dinamiğinden dolayı modele tutarlılık katar.

Kalibrasyon parametreleri olarak, çeşitli makalelerden faydalanılmıştır. Farklılaştırılmış ürünler arasındaki elastikiyet Ascari & Sbordone (2014)'dan alınmış ve 10'dur. Sektörler arasındaki elastikiyet Carvalho & Nechio (2011 ve 2016) makalelerinden alınmış ve 1'dir. Yurt içi ve yurt dışı mallar arasındaki elastikiyet Carvalho & Nechio (2011) makalesinden alınmış ve 1.5'dir. Riskten kaçınma parametresi Carvalho & Nechio (2011)'den alınmış ve 3'tür. Stokhastik indirim faktörü 0.99 olarak alınmıştır. Parasal şokun tutarlılığı 0.85 ve Frisch elastikiyetin tersi 0 olarak alınmıştır. Heterojenlikle ilgili Kara (2015)'nın makalesi takip edilmiş ve tüm ekonomi fiyat katılığı derecelerine göre 10 sektöre ayrılmıştır.

Ticari açıklığın, fiyat katılığında heterojenlik derecesinin ve trend enflasyon oranının Yeni-Keynesyen Philips Eğrisi üzerindeki etkileri tartışıldı. Bu sebeple modelden bu varsayımlar ilk olarak kaldırılmış ve teker teker eklenerek bu varsayımların model üzerindeki etkileri analiz edilmiştir. Heterojenlik ve açıklık varsayımı 2. Makaledeki modelden çıkartılırsa, Yeni Keynesyen Philips Eğrisi eşitlik 4.51'deki gibi olur. Trend enflasyonun eğri üzerindeki etkisi incelendiğinde, ilk olarak güncel değişkenlerin model üzerindeki etkileri azalırken, beklenen değişkenlerin eğri üzerindeki etkileri artmaktadır. İkinci olarak, beklenen marjinal gelir eğriyi eşitliğine girer. Son olarak, fiyat dağımı modeli etkilemeye başlar.

Öte taraftan, heterojen fiyat katılığını basitleştirilen modele eklemek trend enflasyonun model üzerindeki etkisini değiştirir. Fiyat katılığının yüksek olduğu sektörlerde trend enflasyonun güncel değişkenler üzerindeki etkisi azalırken, beklenen değişkenler üzerindeki etkisi artmaktadır. Tam tersi de daha esnek sektörler için geçerlidir. Heterojen fiyat katılığı trend enflasyonla birlikte, yurt içi enflasyon Yeni-Keynesyen Philips Eğrisini etkilemeye başlar.

Ek olarak ticaret açıklığı Yeni-Keynesyen Philips Eğrisi üzerindeki etkisi tartışılmış ve ticaret açıklığının sadece güncel değişkenler üzerinde etkili olduğu gösterilmiştir. Açıklık oranı arttıkça kısa dönemde Yeni-Keynesyen Philips Eğrisinin eğimi farklı trend enflasyon seviyelerinde azalmaktadır. Uzun dönemde ise, Yeni-Keynesyen Philips Eğrisi eğimi pozitif trend enflasyon oranlarında açıklık derecesi arttıkça mutlak değer olarak artmaktadır. Sıfır trend enflasyon oranında ise, açıklık oranı arttıkça eğimde ciddi değişim olmaz.

Çalışmada ayrıca farklı trend enflasyon ve açıklık oranlarında denge belirliliği bölgesinin standart Taylor kuralı durumunda nasıl değiştiği tartışılmıştır. Sıfır trend enflasyon altında, ticaret açıklığındaki değişimin bu bölge üzerinde herhangi bir etkisi yoktur. Bunun nedeni, Yeni-Keynesyen Philips Eğrisinin düze yakın olmasıdır. Pozitif trend enflasyon oranlarında, ticaret açıklığı arttıkça bu bölge daralır. Nedeni ticaret açıklığı trend enflasyonun eğri eğimi üzerindeki etkisini arttırmasıdır. Buradan çıkarılacak sonuç, merkez bankaları yüksek trend enflasyon altında dengeyi korumak için yurt içi üretimdeki değişime daha zayıf tepki ve tüketici fiyat endeksi enflasyonundaki değişime daha güçlü tepki vermesi şeklinde özetlenebilir. Buna ek olarak, heterojen fiyat katılığı durumunda bulgularımız, homojen fiyat katılığı durumundaki bulgularımız ile kıyaslanmıştır. Pozitif trend enflasyon durumlarında, her bir ticaret açıklığı derecesi için heterojen fiyat katılığında, bölgeler homojen fiyat katılığı durumuna göre her zaman daha dardır.

Daha sonra, farklı trend enflasyon ve açıklık oranlarında denge belirliliği bölgesinin ataletli Taylor kuralı durumunda nasıl değiştiği tartışılmıştır. Sıfır trend enflasyon oranında, açıklık derecesindeki artış denge belirliliği bölgesini hem homojen hem de heterojen fiyat katılıklarında etkilemez. Pozitif trend enflasyon oranı durumunda, açıklık derecesindeki artış hem homojen hem de heterojen fiyat katılıklarında, denge belirliliği bölgesini daraltır. Pozitif trend enflasyon durumunda, her bir açıklık derecesinde, bu bölge heterojen fiyat katılığında daha dardır. Her durumda, ataletli Taylor kuralında denge belirliliği bölgesi standart Taylor kuralına göre daha geniştir.

Son olarak, ikinci makalede ticaret açıklığının para politikası aktarım mekanizması üzerinde herhangi bir etkisi olup olmadığı tartışılmıştır. Ticaret açıklığı ekonomiyi iki farklı kanaldan etkiler. Bunların ilki, Yeni-Keynesyen Philips Eğrisinin eğimini daha yatay yapmasıdır. İkincisi ise toplam talep eğrisinin para politikası şokuna olan duyarlılığı arttırmasıdır. Yani açık ekonomilerde, parasal şok toplam talebi daha fazla düşürür.

Bu kanallar dikkate alınarak, % 1 para politikası şokunun tüketici fiyat endeksi enflasyonu, yurt içi üretim, ticaret haddi ve nominal faiz oranı üzerindeki etkileri farklı trend enflasyonu oranlarında tartışıldı. Şekil 4.7'deki etki tepki fonksiyonları, açık ekonomideki değişkenlerinin kapalı ekonomideki değişkenlerden farkı olarak tanımlanmıştır. Açık ekonomide, toplam talep yurt içi üretim türünden tanımlanmış ve kapalı ekonomiyle kıyaslanmıştır. Açık ekonomilerde, toplam talebin parasal şoka olan duyarlılığı arttığı gösterilmiştir. Bu nedenle, parasal şok açık ekonomilerde toplam talebi daha çok düşürür. Öte taraftan, para politikası şoku yerel para biriminin değer kazanmasına neden olur ve ithal edilen mallar daha ucuz hale gelir. Açık ekonomilerde, güncel değişkenlerle yurt içi enflasyon arasındaki ilişki zayıflamaktadır. Bu dinamik daha ucuz ithal mallarla birlikte düşünüldüğünde, tüketici fiyat endeksi açık ekonomilerde daha az düşer. Açık ekonomilerde, daha yüksek tüketici fiyat endeksi enflasyonu ve daha düşük yurt içi üretimden dolayı, nominal faiz oranı açık ekonomilerde daha yüksektir. Ayrıca trend enflasyon, değişkenlerin dinamiklerini kuvvetlendirdiği için, etki tepki fonksiyonlarını dışa kaydırır.

İkinci makaleden Merkez bankaları için çıkarılabilecek çeşitli politika sonuçları vardır. Birincisi, merkez bankaları para politikasına karar verirken fiyat güncellemesi yapan firmaların heterojen davranışlarını, merkez bankaları tarafından konulan enflasyon hedeflerini ve ticarete açıklık derecelerine dikkat etmelidirler. Aksi takdirde ekonomi istikrarsızlığa maruz kalabilir ve merkez bankaları enflasyon oranlarını kontrol edemeyebilir. İkinci olarak, model daha gerçekçi varsayımlarla (yani açık ekonomi, pozitif eğilim enflasyonu ve fiyat yapışkanlığında heterojenlik) öne çıkarıldığında, merkez bankaları daha kısıtlı para politikası alternatifleriyle karşı karşıya kalır. Yüksek trend enflasyon oranlarında, ticari açıklık derecesi arttıkça merkez bankası enflasyon oranındaki dalgalanmalara güçlü bir şekilde yanıt vermeli ve çıktı dalgalanmalarına daha zayıf bir şekilde yanıt vermelidir.

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Bölümü / Department : ....İktisat...

TEZİN ADI / TITLE OF THE THESIS (**İngilizce** / English) :

ESSAYS ON TREND INFLATION IN THE OPEN ECONOMY
....
....
....

TEZİN TÜRÜ / DEGREE: **Yüksek Lisans** / Master ☐ **Doktora** / PhD ■

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