Nominal Rigidity and Some New Evidence on the New Keynesian Theory of the Output-Inflation Tradeoff

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Abstract: This paper develops a series of tests to check whether the New Keynesian nominal rigidity hypothesis on the output-inflation tradeoff withstands new evidence. In so doing, I summarize and evaluate different estimation methods that have been applied in the literature to address this hypothesis. Both cross-country and over-time variations in the output-inflation tradeoff are checked with the tests that differentiate the effects on the tradeoff that are attributable to nominal rigidity (the New Keynesian argument) from those ascribable to variance in nominal growth (the alternative new classical explanation). I find that in line with the New Keynesian hypothesis, nominal rigidity is an important determinant of the tradeoff. Given less rigid prices in high-inflation environments, changes in nominal demand are transmitted to quicker and larger movements in prices and lead to smaller fluctuations in the real economy. The tradeoff between output and inflation is hence smaller.

Key words: the output-inflation tradeoff, nominal rigidity, trend inflation, aggregate variability

JEL-Classification: E31, E32, E61

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1. Introduction

One of the key arguments of the Keynesian economics is that demand policy have an impact on real output and employment (at least in the short run). This non-neutrality arises because nominal prices (and wages) do not instantly adjust after changes in the nominal aggregate demand. Nominal rigidities play an important role in the propagation of nominal disturbances to real economic activities.

In a seminal paper elaborating the New Keynesian macroeconomics, Ball, Mankiw and Romer (1988) (BMR) argue that the degree of nominal rigidity, arising from costly price adjustment ("menu costs" in their model) and staggered price setting, is not fixed, but depends on trend inflation.[2] Following the New Keynesian approach, they (BMR) model nominal rigidity as an outcome of firms' optimization decisions. After observing a change in the nominal aggregate demand, firms would not alter prices if the benefits from price adjustment are smaller than the associated costs. However, when inflation is high, to keep prices unchanged is becoming more costly and firms tend to adjust prices more frequently so that prices are less rigid. Consequently, nominal disturbances (originated from demand policy, for example) lead to quicker and larger movements in prices in high-inflation countries and smaller fluctuations in the real economy. Therefore, the slope of the Phillips curve, measuring the tradeoff between real output and inflation, is smaller. Hence, there exists a negative relationship between trend inflation and real effects of demand policy.

Along with this New Keynesian argument, there exists an alternative new classical view about the short-run output-inflation tradeoff. In two papers, Lucas (1972, 1973) models the formation of expectation given imperfect information. The short-run tradeoff between real output and inflation is observable only when firms misinterpret a change in the price level as a movement in relative prices and thereby adjust their production. When observing a price change of their own product, the producer does not know whether it is an idiosyncratic shock or an aggregate shock. And the producer's expectations depend on the relative volatility of an individual price to the aggregate price level. The more volatile is the aggregate price level, the less likely it is that an observed price change is idiosyncratic. It follows that the more volatile is nominal aggregate demand, where the price level is nested, the less often a misperception occurs at the firm level. In his 1973's paper, Lucas (1973)

[2] This argument differs from the traditional Keynesian economics, which emphasizes rigidities in nominal wages and assumes that these rigidities are exogenous and fixed.

tests this hypothesis with data from 18 countries and finds supportive evidence that increased nominal aggregate variability is associated with a deteriorating output-inflation tradeoff.[3] Thus, in countries with more volatile nominal GDP, demand policy is less effective on real output.

BMR (1988) confirm this observation based on a 43-country sample. However, their interpretation of this finding is different from that of Lucas: more variable nominal demand implies higher uncertainty, which induces firms to follow a more flexible pricing strategy. Analogous to high trend inflation, the uncertainty (arising from high nominal aggregate variability) increases nominal flexibility, which results in diminishing effectiveness of demand policy. Moreover, BMR find that the cross-country differences in the output-inflation tradeoff are well explained by trend inflation, also when the effects of nominal aggregate variability on the tradeoff are considered. This finding supports strongly the nominal rigidity hypothesis.

As both new classical and New Keynesian theories are consistent with the effects of nominal aggregate viability, they cannot be distinguished by testing the hypothesis whether such an inverse relation exists between it and the tradeoff (see Ball, Mankiw and Romer 1988; Akerlof, Rose and Yellen 1988). Instead, the predicted role of trend inflation for a smaller tradeoff can be used to rationalize the New Keynesian theory. By contrast, the new classical imperfect-information model argues that the expectation does not depend on average inflation and thus predicts no relationship between trend inflation and the output-inflation tradeoff. Therefore, in this paper I test the New Keynesian theory on nominal rigidity by investigating whether trend inflation has impact on the size of real effects of demand policy.

In this paper, I extend the BMR (1988) analysis and many subsequent studies, e.g., Defina (1991), Katsimbris and Miller (1996) and Khan (2004), to check whether the New Keynesian economic nominal rigidity hypothesis on the output-inflation tradeoff withstands new evidence. In so doing, I summarize and evaluate four estimation approaches that have been used by those studies.

The first approach is the baseline two-stage cross-country comparison, applied by BMR (1988). With this approach, the tradeoff for each country is estimated at the first stage and the cross-country

[3] A few studies use extended samples and provide supportive evidence for Lucas's hypothesis (see, e.g., Alberro 1981; Jung 1985; Ram 1984), while some other do not (see, e.g., Froyen and Waud 1980; Katsimbris 1990, 1990). Besides the cross-country evidence, Kandil and Woods (1995) examine cross-industry data and do not find support for the imperfect-information model.

variations in those tradeoffs are explained at the second stage. The New Keynesian hypothesis implies that demand policy is less effective in countries with high trend inflation, where prices are less rigid. A large variation in trend inflation across countries thus provides a rationale for cross-country comparisons.

Different from the base-line approach, the other three approaches allow the tradeoff to vary over time. The New Keynesian hypothesis implies that the output-inflation tradeoff in a country is not stable if trend inflation in this country changes over time. It is thus expected to have a smaller tradeoff during the period when inflation remains high. I consider this implication in my analysis. Approach two is the two-stage cross-country panel comparison. At the first stage, the time-varying tradeoffs are estimated for each country with the rolling regression, as done in Katsimbris and Miller (1996). At the second stage, those estimates are pooled together to create a cross-country panel dataset, which contains both cross-country and over-time variations in the tradeoffs. These variations are then explained. Approach three is the two-stage inter-temporal comparison. It continues to use those time-varying tradeoffs estimated with the rolling regression, but at the second stage focuses on the explanation of the over-time variations in the tradeoff in each country. Finally I follow Defina (1991) and Khan (2004) to examine the over-time variations in the tradeoffs in a framework of one-stage regression.

The synthetic evaluation of all these estimation approaches is new in the literature and by doing so, my paper provides a comprehensive corroboration for the existing evidence offered by other researchers. Methodologically, I find that the one-stage approach is preferred for analyzing the over-time changes in the tradeoff as it can avoid potential efficiency loss arising from two-stage estimation. Qualitatively, my results provide further evidence for the New Keynesian theory on the output-inflation tradeoff. I extend BMR's analysis to the current great moderation period and find that nominal rigidity continues to explain both cross-country and over-time differences in the output-inflation tradeoff.

The paper is extended as follows. In Section 2, I review the existing studies on nominal rigidity, both theoretically and empirically. Section 3 shortly describes the data. Section 4 offers a baseline cross-country analysis of differences in the output-inflation tradeoff. Section 5 presents an analysis based on pooled cross-country and over-time variations in the tradeoff. Section 6 checks the BMR's hypothesis with a country-by-country time-series comparison. Section 7 investigates the intra-country time variation of the tradeoff with one-stage regressions. Section 8 then concludes.

2. Literature Review on Nominal Rigidity

2.1 Why wages or prices are sticky

Nominal rigidity is crucial for understanding short-run economic fluctuations. Incomplete adjustment of prices implies that changes in aggregate demand are transmitted to output and employment. Nominal rigidity is the cornerstone for the Keynesian economists to explain the nonneutrality of demand policy (see, e.g., Christiano, Eichenbaum, and Evans 2005; Clarida, Galí, and Gertler 1999; Mankiw and Romer 1995; Roberts 1995). However, nominal rigidity was assumed *ad hoc* in the traditional Keynesian macroeconomic model. Only in response to the Keynesian economic theoretical crisis of the 1970s, studies emerged that provided solid microeconomic foundations of nominal rigidities (see Mankiw and Romer 1995).[4]

Two lines are adopted to offer a micro-foundation of nominal rigidities. The first line focuses on price adjustment costs. It is argued that nominal rigidity can arise from costly price adjustment. Such adjustment costs can be as trivial as menu costs (see Mankiw 1985). At the micro-level, firms face physical costs or restrictions of changing a nominal price, which prevent firms from adjusting prices frequently.[5]

Surprisingly, these trivial menu costs can cause large business cycles (see Akerlof and Yellen 1985; Mankiw 1985). For an individual firm, the resulting profit loss is small as long as the deviation of the predetermined price from the profit-maximizing price is small. In this case, the private incentives to adjust prices are small, and these firms do not change prices continuously. Despite these small private costs, price rigidity can impose large costs on the economy in the presence of aggregate-demand externalities (see Blanchard and Kiyotaki 1987). That is, “rigidity in one firm’s price

[4] For a good review on those studies, see Blanchard (1990).
[5] The term menu cost may be misleading, as Ball, Mankiw and Romer (1988) point out, “because the physical costs of printing menus and catalogs may not be the most important barriers to flexibility. Perhaps more important is the lost convenience of fixing prices in nominal terms – the cost of learning to think in real terms and of computing the nominal price changes corresponding to desired real price changes” (Ball, Mankiw and Romer 1988: 18).

contributes to rigidity to the price level, which causes fluctuations in real aggregate demand and thus harms all firms" (Ball, Mankiw, and Romer 1988: 15).

The second line focuses on rigidity in the price level due to the wage- and price-setting behaviors. It is observed that in fact not all prices or wages are free to change every period. Much efforts are made to model asynchronized wage or price changes due to long-term, multi-period or staggered contracts (see, e.g., Blanchard 1982; Calvo 1983; Fischer 1977; Fuhrer and Moore 1995; Taylor 1979, 1980). This asynchronized timing of price changes by different firms leads to gradual adjustment of the price level after nominal disturbances. It implies that at the presence of staggering pricing, nominal disturbances can have large and long-lasting effects on output and employment even if there are no rigidities in individual prices.

Following these two lines, a series of studies have provided nominal rigidity with rich micro-foundations and laid solid theoretical foundation for the New Keynesian Phillips curve.[6] "Menu costs cause prices to adjust infrequently. For a given frequency of individual adjustment, staggering slows the adjustment of the price level. Large aggregate rigidities can thus be explained by a combination of staggering and nominal frictions: the former magnifies the rigidities arising from the latter" (Ball, Mankiw, and Romer 1988: 12). Due to nominal rigidity arising from adjustment costs or staggered contracts, prices do not adjust fully to compensate shifts in nominal demand, and as a result changes in nominal demand have real effect.

It is also agreed that nominal rigidity by itself is not sufficient in accounting for the nonneutrality of aggregate demand shocks. Many studies focus on explaining the real effects of changes in nominal demand through combining nominal rigidity with real rigidity arising from efficiency wages, customer markets, implicit contracts, insider-outsider relationships, etc; or through combining nominal rigidities with information imperfections. In this way, nominal rigidities are further magnified and non-neutralities of demand policy increase greatly (see, e.g., Akerlof and Yellen 1986, 1988; Ball and Romer 1990; Mankiw and Reis 2002; Smets and Wouters 2007; Yellen 1984).

[6] Besides the theoretical contributions on why prices are sticky, some economists try to answer this question directly. For example, Blinder (1994), based on surveying firms on their price adjustment decisions, finds that prices are indeed sticky and the reasons for that, however, are divergent across firms. It suggests that "price stickiness is a macroeconomic phenomenon without a single microeconomic explanation" (Mankiw 2006: 543).

2.2 How rigid prices are

The literature on the price stickiness can be traced back to studies using sectoral data on some specific products or markets – for example, scanner data on grocery products, newsstand prices of American magazines, catalog prices, and food products.[7] These studies examine how frequently sectoral prices change, and have showed the existence of price rigidities and the degree of rigidities varied across sectors.

Thanks to the openness of CPI and PPI micro-data to researchers in various countries, the last decade has seen an explosion of research on micro price-setting behavior based on large-scale data sets of individual prices. Baharad and Eden (2004) examine the Israeli CPI data set during 1991-1992 and find that on average 24 percent of stores changed their prices in each month, which implied an average price duration of about 4 months. Baumgartner et al. (2005) find that prices are quite sticky by examining Austrian CPI data set and estimate the weighted average price duration between 10 to 14 months. Vilmunen and Laakkonen (2004) provide micro-level evidence from CPI on frequency of price changes in Finland and their estimate of average duration of consumer price spells ranges from 6 to 9 months. Bils and Klenow (2004), Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008) use CPI research data set provided by the Bureau of Labor Statistics and obtain different conclusions on the patterns of price changes in the United States. Bils and Klenow (2004) find that the median duration of prices is 4.3 months, while Klenow and Kryvtsov (2008) and Nakamura and Steinsson (2008) exclude temporary price changes due to sales and find that the median duration for regular prices is 7.2 months and between 8 and 11 months, respectively.[8] A series of studies look into the frequency of price changes in the Euro Area, including, e.g., Álvarez et al. (2006), Angeloni et al. (2006) and Dhyne et al (2006), find that prices in the euro area are sticky with the average price duration close to one year.[9]

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[7] Dhyne et al. (2006) and Baumgartner et al. (2005) both give a good overview of this literature.

[8] As indicated in these three papers, the calculation of the median duration of prices is very sensitive to how the sales in the data are treated. For more discussion of this issue, see Klenow and Kryvtsov (2008), Nakamura and Steinsson (2008), Boivin, Giannoni, and Mihov (2009), Maćkowiak and Smets (2009) and Klenow and Malin (2010), among others.
An alternative way to deal with this problem is suggested by Eichenbaum, Jaimovich, and Rebelo (2011), in which they focus on reference prices – the most often quoted prices – and find that the duration of reference prices is about one year, and the nominal rigidities take form of inertia in reference prices.

[9] Some interpret the micro evidence (especially, the Bils and Klenow's (2004) findings) as a challenge of New Keynesian macroeconomic models, where prices are assumed to reset once per year (see, e.g., Christiano, Eichenbaum, and Evans 2005). However, studies argue that despite less rigidity of prices at the micro level, prices are stickier at the macro level, due to price asynchronization, real rigidities, information imperfections, and asymmetric responses of disaggregated

A summary of those studies reveals that although price stickiness is common in many countries, the magnitude of price stickiness varies. Reviews contributed by Álvarez (2008) and Klenow and Malin (2010) provide good surveys of the recent micro-evidence found in various studies, which are represented in Table 1.[10] The listed studies investigate the monthly average frequency of price changes in various countries during the given periods. The variation of this frequency is huge across countries. The highest monthly frequency of price changes is found in Sierra Leone during the period from the end of 1999 to the early 2003, amounting to 51.5. That implies that on average, half of all prices change in each month. This frequency is more than five times higher than the minimum average frequency of price change found in Italy during the period from 1996 to 2003. In general, prices are stickier in Euro Area countries. On the other hand, prices change much more often in Latin American countries, as in Brazil, Chile and Mexico.

To check whether the frequency of price changes depends positively on the average rate of inflation, I match the average inflation rate that those countries experienced during the given period with the price change frequency, as presented in Table 1. A close examination of the last two columns suggests that there is a positive relation between the average inflation rate and the monthly frequency of price changes – the correlation coefficient of these two is 0.35. That is, price changes are state-dependent – in high-inflation environments, consumer prices tend to change more often (see, e.g., Cecchetti 1986; Dias, Marques, and Santos Silva 2007; Kashyap 1995; Maćkowiak and Smets 2009; Taylor 1999).

prices to aggregate and idiosyncratic shocks (see, e.g., Ball and Romer 1990; Blanchard 1982; Boivin, Giannoni, and Mihov 2009; Mackowiak and Smets 2009).

[10] Klenow and Malin (2010) present a modified version of this table, in which three additional studies are included.

Table 1: Monthly average frequency of consumer price changes and average inflation (annualized) (both in %), various countries, selected period

Country	Paper	Sample period	Average frequency of price changes	Mean inflation
Austria	Baumgartner et al. (2005)	1996:1 - 2003:12	15.1	1.44
Belgium	Aucremanne and Dhyne (2004)	1989:1 - 2001:1	16.9	2.18
Brazil	Gouvea (2007)	1996:1 - 2006:12	37.0	7.80
Canada	Harchanoui et al. (2008)	1995:1 - 2006:12	28.1	2.04
Chile	Medina et al. (2007)	1999:1 - 2005:7	46.1	2.88
Denmark	Hansen and Hansen (2006)	1997:1 - 2005:12	17.3	2.09
Euro Area	Dhyne et al. (2006)	1996:1 - 2001:1	15.1	1.58
Finland	Vilmunen and Laakkonen (2005)	1997:1 - 2003:12	16.5	1.83
France	Baudry et al. (2007)	1994:7 - 2003:2	18.9	1.51
Germany	Hoffmann and Kurz-Kim (2006)	1998:2 - 2004:1	11.3	1.15
Hungary	Gábriel and Reiff (2008)	2001:12 - 2007:6	15.1	5.34
Israel	Baharad and Eden (2004)	1991:1 - 1992:12	24.5	15.50
Italy	Veronese et al. (2006)	1996:1 - 2003:12	10.0	2.48
Japan	Saita et al. (2006)	1999:1- 2003:12	23.1	-0.59
Luxembourg	Lünnemann and Mathä (2005)	1999:1 - 2004:12	17.0	2.20
Mexico	Gagnon (2006)	1994:1 - 2004:12	22.6	14.51
Netherlands	Jonker et al. (2004)	1998:11 - 2003:4	16.5	3.11
Norway	Wulfsberg and Ballangrud (2008)	1975:1 - 2004:12	25.4	4.73
Portugal	Dias et al. (2004)	1992:1 - 2001:1	22.2	3.97
Sierra Leone	Kovanen (2006)	1999:11 - 2003:4	51.5	7.93
Solvakia	Coricelli and Horváth (2006)	1997:1 - 2001:12	34.0	8.50
South Africa	Creamer and Rankin (2007)	2001:12 - 2006:2	16.0	5.03
Spain	Álvarez and Hernando (2006)	1993:1 - 2001:12	15.0	3.31
United States	Bils and Klenow (2004)	1995:1 - 1997:12	26.1	2.69
United States	Klenow and Kryvtsov (2005)	1988:2 - 2003:12	23.3	3.06
United States	Nakamura and Steinsson (2008)	1998:1 - 2005:12	21.1	2.48

Source: Monthly average frequency of consumer price changes is taken from Álvarez (2008: 10), while average inflation is author's calculations based on the data from IMF *World Economic Outlook Database*.

3. Data and Sample Description

I follow the BMR criterion to include possibly many large, industrialized and free market economies (Ball, Mankiw and Romer 1988: 34). All together, 37 countries are included[11] and the sample period is extended to 2007.[12] All the data – nominal and real GDP, and GDP deflator – are annual, from IMF *International Financial Statistics*. The earliest available data start with 1948; the time series for some countries are shorter due to the unavailability of the data.

The sample countries are listed in Table 2 with the sample period for each country for which data are available. The Table then presents the descriptive statistics of real growth, inflation, and nominal growth. The macroeconomic performance shows a large variation across countries. Southern American countries experienced high inflation – Colombia had an average annual inflation of 18 percent, Mexico 17 percent, Venezuela 16 percent. On the other hand, the newly industrialized country, Singapore showed a combination of fast real growth and low inflation: over nearly five decades, its average real growth rate was 7.6 percent with a low inflation rate of 2.6 percent.

[11] Compared to BMR (1988), I dropped off 6 countries from the sample of 43 countries: 2 African countries (Nicaragua and Zaire) with discontinuous data due to wars, 4 Latin American countries (Argentina, Bolivia, Brazil and Peru) that experienced hyperinflation around 1990.
[12] The sample does not include the current financial and macroeconomic crisis years. During the current crisis, financial-market disruptions appear to be central, which challenges the existing macroeconomic analysis and models (see Romer 2011). Exclusion of the crisis years avoids a big structural break at the end of the sample period.

Table 2: Descriptive statistics on inflation and output, 37 countries, selected periods

		Real growth		Inflation		Nominal growth	
country	Sample period	Mean	Standard deviation	Mean	Standard deviation	Mean	Standard deviation
Australia	1959-2007	0.042	0.047	0.051	0.040	0.093	0.047
Austria	1964-2007	0.031	0.022	0.034	0.027	0.066	0.032
Belgium	1953-2007	0.035	0.025	0.029	0.019	0.065	0.030
Canada	1948-2007	0.037	0.023	0.040	0.031	0.077	0.038
Colombia	1968-2007	0.041	0.023	0.175	0.076	0.214	0.077
Costa Riga	1960-2007	0.048	0.033	0.132	0.116	0.178	0.099
Denmark	1966-2007	0.021	0.020	0.053	0.035	0.076	0.038
Dominican Republic	1962-2007	0.050	0.046	0.114	0.138	0.165	0.127
Ecuador	1965-2007	0.043	0.046	0.044	0.124	0.087	0.141
El Salvador	1951-2006	0.038	0.043	0.054	0.075	0.092	0.071
Finland	1960-2007	0.033	0.028	0.056	0.041	0.090	0.052
France	1950-2007	0.034	0.019	0.050	0.040	0.084	0.044
Germany	1960-2007	0.028	0.024	0.031	0.023	0.061	0.040
Greece	1948-2007	0.044	0.039	0.095	0.068	0.139	0.062
Guatemala	1951-2007	0.039	0.024	0.067	0.080	0.105	0.079
Iceland	1960-2007	0.042	0.037	0.163	0.137	0.203	0.141
Iran	1966-2007	0.041	0.088	0.170	0.110	0.208	0.115
Ireland	1948-2007	0.043	0.027	0.060	0.048	0.103	0.053
Israel	1968-2007	0.054	0.094	0.282	0.379	0.331	0.360
Italy	1970-2007	0.023	0.018	0.080	0.057	0.107	0.069
Jamaica	1960-2007	0.019	0.035	0.141	0.116	0.159	0.109
Japan	1955-2007	0.046	0.039	0.033	0.043	0.079	0.063
Mexico	1948-2007	0.047	0.033	0.170	0.185	0.217	0.171
Netherlands	1956-2007	0.031	0.022	0.040	0.028	0.072	0.041
Norway	1966-2007	0.034	0.016	0.057	0.044	0.088	0.050
Panama	1950-2007	0.049	0.041	0.027	0.043	0.076	0.058
Philippines	1958-2005	0.039	0.031	0.092	0.068	0.129	0.058
Portugal	1977-2007	0.026	0.022	0.106	0.080	0.137	0.086
Singapore	1960-2007	0.076	0.039	0.026	0.037	0.101	0.062
South Africa	1950-2007	0.034	0.023	0.082	0.052	0.117	0.045
Spain	1954-2007	0.040	0.041	0.075	0.055	0.118	0.049
Sweden	1950-2007	0.028	0.018	0.052	0.039	0.080	0.037
Switzerland	1948-2007	0.026	0.027	0.030	0.025	0.056	0.036
Tunisia	1961-2007	0.050	0.035	0.056	0.040	0.105	0.054
United Kingdom	1948-2007	0.025	0.017	0.056	0.044	0.081	0.039
United States	1948-2007	0.033	0.023	0.034	0.022	0.067	0.028
Venezuela	1957-2007	0.035	0.051	0.164	0.173	0.199	0.163
Across-country values							
Mean		0.038	0.034	0.082	0.075	0.120	0.077
Standard deviation		0.011	0.017	0.058	0.067	0.059	0.061

Note: All data are annual. Growth rates are computed as differences in logarithms with the log of real output as y and the log of nominal output as x; the log of the price level is $p = x - y$. The criterion for selecting sample countries follows BMR (1988).

Source: Author's calculations with data from International Monetary Fund, *International Financial Statistics*.

4. International Evidence (1): Two-Stage Cross-Country Results

BMR (1988) found that the output-inflation tradeoffs varied across countries for the sample period from 1948 to 1986. Since the publication of their paper (1988), major industrialized countries experienced a period of low fluctuation of real output and at the same time a relatively low inflation rate, which is referred as the great moderation in the literature. It might lead to changes in some empirical macroeconomic relationships. The natural question following this is whether such a tradeoff relation still exists and if so, what kind of changes this tradeoff illustrates. This section tries to clarify these questions by replicating Lucas (1973)'s and BMR (1988)'s empirical tests with the sample period extended to 2007.

4.1Estimating the short-run output-inflation tradeoff

I follow Lucas (1973) and BMR (1988) to estimate the short-run output-inflation tradeoff by running the regression for each of these 37 countries:

$$y_{it} = con_i + \tau_i \Delta x_{it} + \theta_i y_{i,t-1} + \gamma_i Time + \varepsilon_i \text{, for } i = 1, 2, ..., 41 \qquad (1)$$

where y is real GDP in log; Δx is the first difference of the log nominal GDP; $\gamma Time$ measures the time trend; subscript i is a country index; subscripts t and $t\text{-}1$ are time indices. The residual, ε_i, reflects all the neglected factors that could affect output, including supply shocks. This residual will be discussed in the following section, when supply shocks are addressed. Δx measures the percentage change in nominal GDP. It is used as a proxy for a nominal disturbance. A monetary or fiscal expansion, such as an increase in the money supply or an increase in government purchases, is reflected in an increase in nominal GDP.

Equation 1 implies that output movements arise from two components – a long-run time trend and some short-run fluctuations due to aggregate demand disturbances, with the former approximated with $\gamma Time$ and the latter with $\tau\Delta x$. This paper focuses on the short-run fluctuations of real output. The coefficient, τ, is of our interest as it captures the short-run effects of a nominal disturbance on real output. A change in aggregate demand can be transmitted to real output, or to prices, or affect *both*. The larger τ is, the larger is the effect of a change in demand on the real economy. It results in a smaller $1\text{-}\tau$, the proportion of a change in demand that is passed into prices. On the other hand, a smaller τ corresponds to the situation that a nominal disturbance has more effects on prices. If $\tau = 1$, a change in nominal demand affects the real economy by one to one; while $\tau = 0$, a change in demand affects the price level only. For $0 < \tau < 1$, the effects of a change in demand fall partly on real output and partly on the price level. The coefficient, τ , measures the output-inflation tradeoff, a kind of variant of the slope of Phillips curve.

Table 3 reports the estimated values of the tradeoff parameters, τ , and its estimated standard errors for the full sample period and two subsample periods with 1985 as a cutoff. The second subsample corresponds to the great-moderation period and with this split, it is possible to have a close look at the estimates of the tradeoff for the great-moderation period.

The estimated short-run tradeoff varies a lot across countries. For the full sample, the standard variation of τ for the 37 countries is 0.25, which is close to its mean value. The estimated tradeoff is significant and large in many countries, such as Australia, Austria, Belgium, Canada, Denmark, Finland, Germany, Japan, Netherlands, Panama, Singapore, Switzerland, the United States, etc., ranging from 0.44 for to 0.74. However, in many other countries, the estimated tradeoff is small and close to zero. It indicates that the effect of demand policy on the real economy varies substantially across countries.

The last four columns present the estimated tradeoffs for two periods – the pre-great-moderation period and the great-moderation period – together with their estimated standard errors. A quick comparison of the estimation results suggests that the estimated tradeoff changes over time as well. On average, the estimated value of τ for the great-moderation period is 0.4, higher than 0.32, the one estimated with the earlier data. Some countries exhibit a substantial increase of the output-inflation tradeoff for the post-1985 period. For example, the tradeoff for the United Kingdom increases considerably – from -0.02 (point estimate, insignificant) to 0.91, close to 1. The tradeoff for the United States increases from 0.68 to 0.82 for the great-moderation period. However, the tradeoff in some other countries declines. Across countries, the correlation between τ estimated with the earlier data and τ estimated with the later data is relatively low, about 0.4. It implies that over time there are changes of the tradeoff. The time variation of the tradeoff will be discussed further in Section 5.

Table 3: Estimates of the output-inflation tradeoff, 37 countries, selected periods

		Full sample		Data through 1985		Data after 1985	
country	Sample period	Tradeoff parameter, τ	Standard error	Tradeoff parameter, τ	Standard error	Tradeoff parameter, τ	Standard error
Australia	1959-2007	0.547*	0.056	0.659*	0.087	0.425*	0.068
Austria	1964-2007	0.651*	0.100	0.725*	0.104	0.487**	0.244
Belgium	1953-2007	0.737*	0.075	0.631*	0.129	0.327**	0.133
Canada	1948-2007	0.438*	0.062	0.396*	0.085	0.701*	0.074
Colombia	1968-2007	0.141*	0.053	0.19***	0.128	0.192**	0.082
Costa Riga	1960-2007	-0.119**	0.050	-0.246*	0.095	0.006	0.067
Denmark	1966-2007	0.495*	0.113	0.642*	0.227	0.629*	0.136
Dominican Republic	1962-2007	-0.021	0.056	0.387*	0.118	-0.138*	0.048
Ecuador	1965-2007	0.161*	0.041	0.304*	0.088	0.1**	0.051
El Salvador	1951-2006	0.152***	0.086	0.406*	0.090	-0.110	0.225
Finland	1960-2007	0.522*	0.061	0.48*	0.109	0.691*	0.056
France	1950-2007	0.039	0.069	-0.033	0.086	0.548*	0.135
Germany	1960-2007	0.649*	0.066	0.552*	0.104	0.776*	0.074
Greece	1948-2007	0.138***	0.077	0.279*	0.103	0.165***	0.102
Guatemala	1951-2007	0.07***	0.043	0.31*	0.078	-0.023	0.030
Iceland	1960-2007	0.209*	0.046	0.204**	0.089	0.463*	0.059
Iran	1966-2007	0.359*	0.107	0.408*	0.155	0.229**	0.102
Ireland	1948-2007	0.161*	0.059	0.24*	0.073	0.638*	0.070
Israel	1968-2007	0.031	0.045	-0.192	0.201	0.179***	0.104
Italy	1970-2007	0.202*	0.067	0.403*	0.069	0.421*	0.149
Jamaica	1960-2007	0.027	0.048	0.082	0.149	0.048	0.039
Japan	1955-2007	0.481*	0.116	0.644*	0.180	0.742*	0.078
Mexico	1948-2007	-0.053***	0.027	-0.09***	0.051	-0.043	0.035
Netherlands	1956-2007	0.538*	0.047	0.599*	0.055	0.682*	0.091
Norway	1966-2007	0.103***	0.056	0.135	0.110	0.086	0.082
Panama	1950-2007	0.531*	0.065	0.328*	0.105	0.738*	0.077
Philippines	1958-2005	-0.023	0.090	-0.029	0.095	0.364**	0.170
Portugal	1977-2007	0.058	0.113			0.046	0.106
Singapore	1960-2007	0.524*	0.048	0.542*	0.073	0.573*	0.059
South Africa	1950-2007	0.155***	0.082	0.241*	0.085	0.618*	0.146
Spain	1954-2007	0.288***	0.156	0.201	0.228	0.674*	0.102
Sweden	1950-2007	0.083	0.078	0.011	0.095	0.571*	0.120
Switzerland	1948-2007	0.696*	0.066	0.714*	0.091	0.68*	0.050
Tunisia	1961-2007	0.534*	0.065	0.476*	0.101	0.609*	0.097
United Kingdom	1948-2007	-0.004	0.066	-0.024	0.104	0.911*	0.142
United States	1948-2007	0.605*	0.067	0.685*	0.090	0.818*	0.147
Venezuela	1957-2007	0.036	0.055	0.096***	0.063	0.019	0.095
Across-country values							
Mean		0.274	0.070	0.315	0.108	0.401	0.098
Standard deviation		0.254	0.026	0.270	0.043	0.305	0.049

Note: Regression results based on Equation 1. The output-inflation tradeoff, τ, is the estimated coefficient of Δx_{it}. *, ** and *** indicate that a null hypothesis of zero is rejected at the 1 percent, 5 percent and 10 percent levels, respectively.

Source: Author's estimates based on the data from IMF, *International Financial Statistics*.

4.2 The determinants of the tradeoff: Cross-country results

Figure 1 and Figure 2 show a scatter plot of the output-inflation tradeoff estimated for the full sample against the two candidate determinants – trend inflation and aggregate variability, respectively. Aggregate variability is measured with the standard deviation of nominal GDP growth and trend inflation with an average inflation rate. Figure 1 suggests that there is a negative relationship between the tradeoff and trend inflation. The tradeoff appears to be significant and large in countries with low inflation rates while in those countries with high inflation rates, the tradeoff is small. Figure 2 indicates that a negative nonlinear relationship exists between the tradeoff and the standard deviation of nominal GDP growth as well. Meanwhile, the negative relationship between the tradeoff and these two explanatory variables both appear to be nonlinear: the negative impact of trend inflation (or aggregate variability) on the tradeoff fades away with a rising value of trend inflation (or aggregate variability).

One way to capture the nonlinearity is to include the terms of squared explanatory variables, as BMR (1988) specified $\tau_i = con + \alpha_1\pi_i + \alpha_2\pi_i^2 + \beta_1\sigma_{xi} + \beta_2\sigma_{xi}^2 + e$. However, with this quadratic functional form the relationship between the tradeoff and trend inflation can be ambiguous. As Akerlof, Rose and Yellen (1988: 71) pointed out, when BMR estimate this quadratic equation for only OECD countries (without Iceland), the relationship between τ and π changes to be positive at a 7.2 percent inflation rate, which is close to the midpoint of inflation for the sample. Yet, the theory suggests an unambiguous negative relation between the tradeoff and trend inflation. The quadratic functional form is thus not optimal in describing a negative monotonic relationship between τ and π.

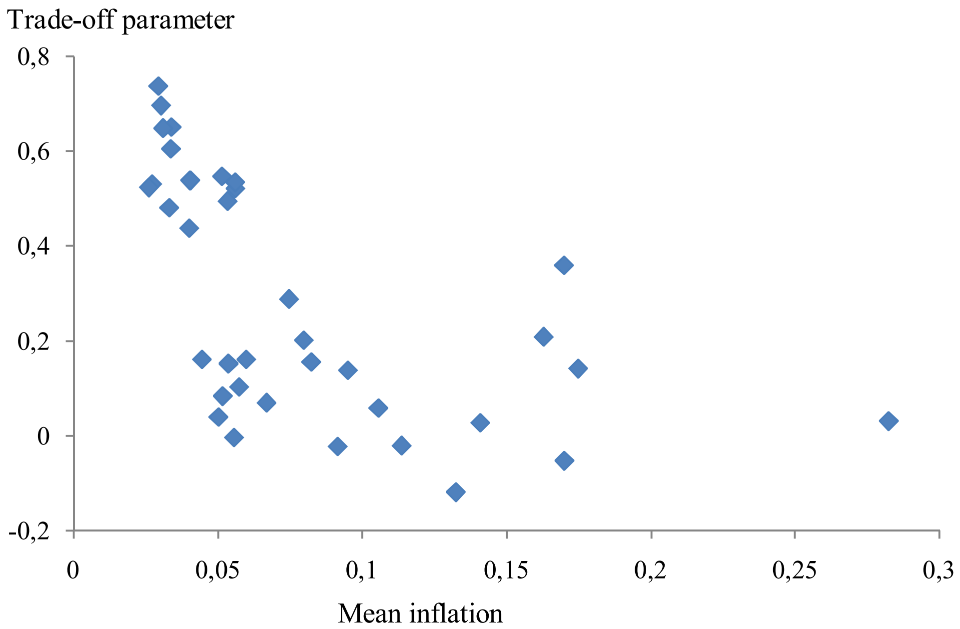
In this paper, I use an alternative nonlinear specification. A simple nonlinear form consistent with an unambiguous relationship between the tradeoff and explanatory variables would be:

$$\tau_i = c + \alpha / \pi_i + \beta / \sigma_{xi} + u \,, \qquad (2)$$

where τ is estimated tradeoff obtained from the regression of Equation 1; *i* is a country index; π is average inflation rate over the sample period and σ_x is the standard deviation of nominal GDP growth rate over the sample period. The key feature of the functional form in Equation 2 is that the nonlinear negative relation is modeled by including the inverse term of two explanatory variables. If the theory is right, the estimated α and β should be positive. In this way, the relationship between τ

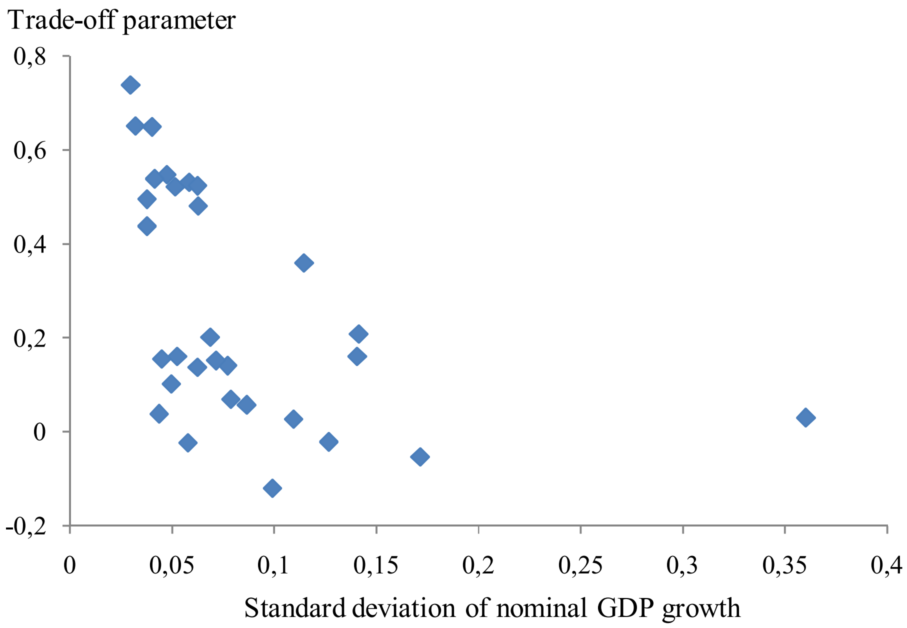
and π is monotonically negative and so is the relationship between τ and σ_x. This negative impact dies away when trend inflation (or/and aggregate variability) is getting bigger.

Figure 1: The output-inflation tradeoff and average inflation



Source: The output-inflation tradeoff, τ, is from Table 3. Average inflation is from Table 2.

Figure 2: The output-inflation tradeoff and standard deviation of nominal growth



Source: The output-inflation tradeoff, τ, is from Table 3. Standard deviation of nominal GDP growth is from Table 2.

Table 4 presents the regression results based on three variants.[13] The estimated coefficients, $\alpha's$ and $\beta's$, are all positive, as the theory predicts. The regression result based on the general specification, listed in column 4.3, suggests that trend inflation is a significant determinant of the output-inflation tradeoff, while aggregate variability is not when both explanatory variables are included.

However, aggregate variability turns to be a statistically significant determinant of the tradeoff when trend inflation is left out of the regression. This might be due to the fact that the two explanatory variables are highly correlated with the correlation coefficient of 0.75. With such a high correlation, omitting either of these two variables from the regression could lead to a biased estimate.[14] The theory suggests that both variables could explain the cross-country variations in the tradeoff. Thus, the specification with both of them included is preferred. The regression result presented in column 4.3 suggests that trend inflation matters after accounting for aggregate variability, which provides strong evidence for the New Keynesian nominal rigidity hypothesis.[15]

The baseline cross-country comparison results show that the New Keynesian nominal rigidity hypothesis is robust with the extended sample and an alternative nonlinear specification. The inverse relationship between trend inflation and effectiveness of demand policy persists in the low-inflation great-moderation period.

[13] BMR's quadratic functional form is tested with the data as well and the results are consistent with the BMR's findings (Ball, Mankiw and Romer 1988).

[14] A high correlation coefficient of variables, $1/\pi$ and $1/\sigma_x$, implies that they move together. Thus it is possible that the results in column 4.1 with $1/\sigma_x$ omitted arise not because $1/\pi$ directly affects the tradeoff, but because it co-moves with the $1/\sigma_x$ that is a true determinant of τ. The same caveat exists with the results in column 4.2.

[15] Note that the goodness-of-fit has not been improved much when the inverse of aggregate variability is included in the regression, compared with the regression with only the inverse of trend inflation included. The *F*-test of the hypothesis that the inverse of aggregate variability does not enter the regression when the inverse of trend inflation is included also indicates that aggregate variability does not determine τ in the case of $F(1, 38) = 1.85$.

Table 4: Determinants of the output-inflation tradeoff, 37 countries, selected periods

Independent variable	4.1	4.2	4.3
Constant	-0.08	-0.06	-0.1**
	(0.04)	(0.06)	(0.05)
Inverse of mean inflation	0.02*		0.016*
	(0.002)		(0.003)
Inverse of standard deviation of nominal GDP growth		0.02*	0.005
		(0.003)	(0.004)
Summary statistic			
Adj. R-squared	0.645	0.46	0.653
Standard error	0.153	0.187	0.151

Note: The dependent variable is the output-inflation tradeoff, τ_i (estimated in Table 3) based on the data for the full sample period. Numbers in parentheses are standard errors. * and ** indicate that a null hypothesis of zero is rejected at the 1 percent and 5 percent levels, respectively.

Source: Author's calculations.

4.3 Robustness test: Supply shocks

The key assumption of Equation 1 is that Δx reflects only aggregate demand changes. Short-run output movements are mainly due to demand changes, while supply shocks are incorporated into the residual of Equation 1 as some left-out variable. One can argue, however, that supply shocks – for example, oil price shocks – are correlated with changes in nominal GDP. If it were the case, the estimates of the tradeoff, τ_i, could be biased.

A simple approach to avoid this bias is to add the omitted variable by including the supply shocks in Equation 1. Oil price shocks are major negative supply shocks in consideration. Altogether, there are five oil price shocks over the sample period – 1973, 1978, 1980, 1990 and 2002 (see Hamilton 2011). I discard these five years from the sample, which is equivalent to introducing an oil price shock dummy variable. Equation 1 is re-estimated. The regression results are similar to the ones obtained above. The correlation between the $\tau's$ estimated with and without the oil price shock years is 0.97. And the regression of the tradeoff estimated without oil price shock years on explanatory variables leads to the following result:

$$\tau_i = -0.1 + 0.018 / \pi_i + 0.005 / \sigma_{xi} + u$$

$$\begin{array}{l}(0.05)\ (0.003) \qquad (0.04) \\ \overline{R}^2 = 0.69;\ \text{standard error} = 0.17\end{array}$$

This result is very similar to that presented in Table 4: the coefficient on the inverse of trend inflation is statistically significant and quantitatively slightly larger; the coefficient on the inverse of aggregate variability is insignificant and small. It suggests that the omission of supply shocks in the baseline cross-country analysis does not cause severe bias in the estimates of the tradeoff.

5. International Evidence (2): Two-Stage Cross-Country Panel Results

The nominal rigidity theory argues that a higher average inflation rate (or more volatile aggregate demand) increases nominal flexibility and as a consequence changes in demand are largely transmitted to price changes and leave real variables little changed. In other words, a higher trend inflation is associated with a lower value of the output-inflation tradeoff. In the preceding part it is recognized that the output-inflation tradeoff varies across countries due to the persistent inflation differentials among those countries. Yet, trend inflation and aggregate variability are assumed to be constant for each country throughout the sample period; consequently, the output-inflation tradeoff for each country, τ_i, is treated to be constant over time for each country.

However, it is more likely that trend inflation and aggregate variability are not constant over time in most countries. The descriptive statistics on inflation in Table 2 suggests that this is the case. Inflation in many high-inflation countries is very volatile – the standard deviation of inflation is as high as 0.19 in Mexico, for example. In low-inflation countries, a simple plot of inflation suggests high fluctuation of inflation over the past six decades as well. For example, the trend inflation in the United States (measured with the average rate of 6.6 percent) was much higher in the 1970s, compared to that (around 2.2 percent) in the 1960s and 1990s.

If trend inflation and aggregate variability are not constant over time in most countries, the optimal frequency to adjust prices should also change over time within individual countries. We should thus expect the tradeoff to change over time as well. Table 3 shows that with a simple split of the whole period into two, in many countries the tradeoff estimated with the earlier data appears to be different from the one estimated with the later data. A Wald-test suggests that in about 30 percent of countries[16], the null hypothesis that there is no change between these two $\tau 's$ estimated with the earlier and later data can be rejected at the 5 percent significance level.[17]

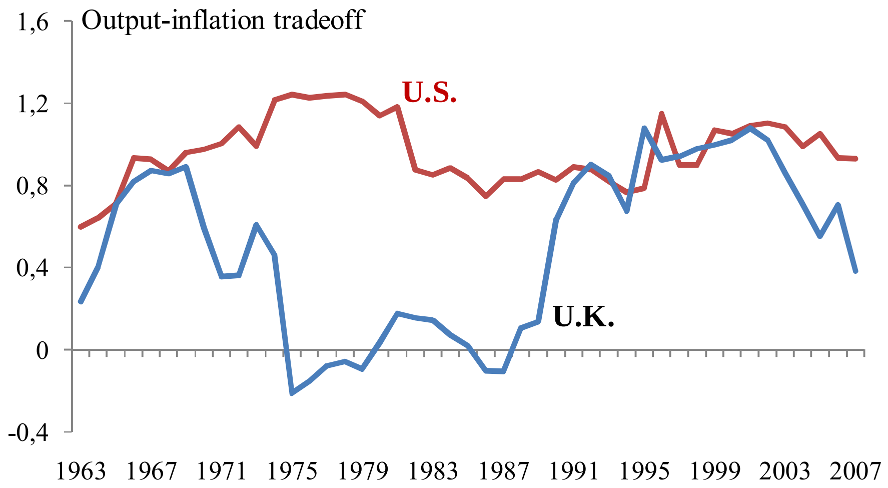
5.1 Estimating the output-inflation tradeoff with rolling regressions

A simple split of the sample period into two sheds lights on the fact that the tradeoff changes over time as well. Hence I relax the assumption that τ is constant over the six decades and re-estimate the first-stage regression. To estimate τ for each country, Equation 1 is estimated for each country using a rolling regression with a rolling window of 15 years.[18] That is, Equation 1 is first estimated using the data from 1949 to 1963, next using the data from 1950 to 1964, …, finally using the data from 1993 to 2007. In this way, for each country the tradeoff estimated with the first rolling regression is allowed to be different from those estimated with other rolling regressions. Thus, a series of τ_t estimates are obtained for each country. The length of such a series depends on the data availability and varies across countries, ranging from 17 to 45.

The rolling regression results show that in most countries, τ_t displays a distinct movement over time. Two series of τ_t estimated for the United Kingdom and the United States are, for example, illustrated in Figure 3. The tradeoff in the United States appears more stable while the tradeoff estimated for the United Kingdom shows more fluctuation; in the 1960s and 1990s, the Phillips curve in the U.K. is much steeper than that in the 1970s.

[16] They are Costa Riga, Dominican Republic, Ecuador, El Salvador, France, Guatemala, Ireland, Panama, Sweden and the United Kingdom.
[17] This null hypothesis is rejected at the 10 percent significance level in 40 percent of the countries.
[18] The rolling window is specified as 15 years to ensure sufficient degrees of freedom for each regression.

Figure 3: The Output-Inflation Tradeoff, the U.K. and the U.S., 1948-2007



Note: The estimates of τ_{it} are obtained from running rolling regressions of Equation 1 with a rolling window of 15 years. The year on the horizontal line marks the end year for each rolling period.

Source: Author's estimates. The data used in the estimation are from IMF, *International Financial Statistics*.

5.2 Determinants of the tradeoff: Cross-country panel results

The series of τ_t for each country are then pooled together such that I obtain a pooled dataset, containing both cross-country and over-time estimates of the tradeoff. Such a pooled dataset is rich in observations – here, altogether 1444 observations – and thus ensures a large gain in degrees of freedom and would in principle result in more precise estimates. For the second-stage regression, trend inflation is now approximated by a fifteen-year average inflation rate for each rolling period; and aggregate variability is approximated by the standard deviation of the nominal growth for the same rolling fifteen-year periods.

Table 5 presents the regression results of cross-country time series of the tradeoff on the inverses of average inflation and standard deviation of nominal GDP growth. Both explanatory variables appear to be statistically significant in the general specification as listed in column 5.3. And the inverse of aggregate variability turns out to be a substantively important determinant, compared to the cross-country regression results presented in Table 4. Like high inflation, uncertainty leads to less nominal rigidity and thus nominal disturbances have less effect on the real economy.

Table 5: Determinants of the tradeoff, panel data, 37 countries, selected periods

Independent variable	5.1	5.2	5.3
Constant	0.34*	0.07*	0.07*
	(0.009)	(0.01)	(0.01)
Inverse of mean inflation	0.0007*		0.0003*
	(0.0001)		(0.00009)
Inverse of standard deviation of nominal GDP growth		0.01*	0.01*
		(0.0003)	(0.0003)
Summary statistic			
Adj. R-squared	0.023	0.390	0.394
Standard error	0.328	0.259	0.258

Note: The dependent variable is the pooled estimates of output-inflation tradeoff, τ_{it}, which is estimated by running rolling regressions based on Equation 1 with a rolling window of 15 years. The regression is based on the pooled dataset. Numbers in parentheses are standard errors. * indicates that a null hypothesis of zero is rejected at the 1 percent level.

Source: Author's calculations.

5.3 Robustness test: Cross-country heterogeneity

In the regression using the pooled dataset, I treat the cross-country variation in τ and intra-country over-time variation in τ indiscriminately. However, such a regression is based on the strong assumption of the absence of cross-country heterogeneity. In reality, it is more likely that heterogeneity exists among countries. For example, countries are different in institutional frameworks, such as the laws governing labor market flexibility, trade union strength, etc., which, like trend inflation, have impacts on the extent of wage and price rigidity and consequently the output-inflation tradeoff. These differences in institutions might lead to country-specific levels of the tradeoff. If it were true, we would expect different intercepts for different countries and thus the assumption that the regression has a single common constant for all countries was improper.

Besides, these differences in institutions might affect the sensitivity of the tradeoff to two focal explanatory variables – trend inflation and aggregate variability – as well. If it were the case, the assumption in the pooled model that the slope coefficients, α and β, are equal across countries would not be suitable, either.

To check the pooling restriction that all countries share a common intercept, the pooled regression is amended to include separate dummy variables for forty-one countries (the constant is thus dropped out). Those country dummies capture individual country-fixed effects. Table 6 presents the regression results of slope coefficients, α and β, and country dummies. Most of the country-fixed effects are statistically significant. The F-test for the restriction that all country dummies are equal to each other yields an $F(36, 1401) = 26.65$. This pooling restriction is thus rejected at the 99 percent level.

If only country-fixed effects mattered, i.e., those institutional differences affected only the level of the output-inflation tradeoff and had no effects on the sensitivity of the tradeoff to the two explanatory variables, the estimation results with the correction of country-fixed effects, presented in Table 6, would be sufficient for a conclusion. Yet, as pointed out above, very likely those country-specific institutions affect the sensitivity of the tradeoff to trend inflation and aggregate variability as well.

To check it, I amend the pooled regression again by including interactions between forty-one country dummies and each of the explanatory variables – $\alpha * Dummy_i$ and $\beta * Dummy_i$ – while a common constant is assumed. The pooling restriction of the equalities of slope coefficients across country is rejected at the 99 percent level with an $F(72, 1361) = 12.6$.

Due to the presence of the cross-country heterogeneity, both pooling restrictions are rejected. It suggests that it is improper to pool the cross-country and over-time changes in the tradeoffs together. An alternative approach is to focus on the over-time changes in the tradeoff within each individual country, which will be done in the ensuing two sections.

Table 6: Determinants of the tradeoff with fixed effects, panel data, 37 countries, selected periods

Country-specific effects	Coefficient	Standard Error
Australia	0.2*	0.037
Austria	0.46*	0.043
Belgium	0.15*	0.037
Canada	0.41*	0.033
Colombia	0.07***	0.040
Costa Riga	-0.16*	0.035
Denmark	0.46*	0.043
Dominican Republic	-0.06***	0.036
Ecuador	0.1*	0.037
El Salvador	0.14*	0.032
Finland	0.44*	0.036
France	0.13*	0.036
Germany	0.54*	0.038
Greece	0.18*	0.031
Guatemala	0.05	0.032
Iceland	0.13*	0.035
Iran	0.38*	0.038
Ireland	0.24*	0.031
Israel	0.1*	0.04
Italy	0.23*	0.043
Jamaica	-0.015	0.035
Japan	0.43*	0.036
Mexico	-0.067**	0.03
Netherlands	0.43*	0.037
Norway	-0.016	0.04
Panama	0.35*	0.032
Philippines	-0.058***	0.035
Portugal	0.12**	0.05
Singapore	0.41*	0.035
South Africa	0.24*	0.033
Spain	0.23*	0.034
Sweden	0.17*	0.035
Switzerland	0.45*	0.033
Tunisia	0.38*	0.037
United Kingdom	0.22*	0.036
United States	0.66*	0.037
Venezuela	-0.023	0.033

Note: The dependent variable is the pooled estimates of output-inflation tradeoff, τ_{it} (see note of Table 5). The regression is run with Equation 2 and the constant is replaced with a set of 37 country dummies. Numbers in the third column are standard errors. *, ** and *** indicate that a null hypothesis of zero is rejected at the 1 percent, 5 percent and 10 percent levels, respectively.

Source: Author's calculations.

6. International Evidence (3): Two-Stage Country-by-Country Time-Series Results

In this section and the one following, I relax the assumption made in the cross-country analysis that countries are homogenous in other factors that affect the extent of nominal rigidity and examine the over-time changes in the tradeoff within each individual country. In so doing, I offer a disaggregate analysis by answering the same question how the output-inflation tradeoff is determined in a country-by-country inter-temporal framework. [19] The regression in such a framework has the advantage of correcting fixed country effects. If the New Keynesian theory holds true, evidence that trend inflation matters should arise in a significant fraction of countries.

The estimates of τ_t obtained from the rolling regressions in the preceding part consist of time series of the tradeoff for each country, displaying over-time changes in the tradeoff in these countries. They will be used in this part.

The determinants of the tradeoff: Country-by-country time-series results. For each country, Equation 2 is regressed with a series of over-time changes in the tradeoff as a regressand over a constant and inverses of average inflation and standard deviation of nominal GDP growth. These regressions test New Keynesian theory by examining intra-country time variations of the tradeoff country by country.

Table 7 presents the regression results of two slope coefficients for each country, together with their estimation standard errors and the adjusted-R-squared.[20] The results suggest that in about 40 percent of the countries under study, there exists a nonlinear significant negative relationship between the tradeoff and average inflation. And in about another 40 percent of the countries, aggregate variability is significant in explaining the over-time changes in the tradeoff. In those countries, aggregate demand policy is less effective on output during the periods with high inflation or/and high uncertainty.

[19] This inter-temporal framework is applied in several studies as well (see, e.g., Defina 1991; Froyen and Waud 1980; Khan 2004).

[20] The estimation results of the constant in each regression are not reported as it is not of our interest.

Table 7: Determinants of over-time variations in the tradeoff, 37 countries, selected periods, two-step procedure

country	Observations	Inverse of mean inflation	Standard error	Inverse of standard deviation of nominal GDP growth	Standard error	Adj. R-squared
Australia	34	0.0066	0.003	-0.006**	0.002	0.18
Austria	29	-0.00001	0.002	0.0002	0.002	-0.08
Belgium	40	-0.007*	0.003	-0.003	0.002	0.44
Canada	45	0.006*	0.002	-0.001	0.004	0.16
Colombia	25	0.09*	0.008	0.007*	0.001	0.86
Costa Riga	33	-0.0004	0.007	0.041*	0.006	0.68
Denmark	27	-0.005	0.005	0.003	0.006	-0.03
Dominican Republic	31	0.045*	0.004	-0.005	0.005	0.83
Ecuador	28	-0.0007*	0.000	0.1*	0.013	0.72
El Salvador	41	-0.0004	0.000	0.016**	0.007	0.27
Finland	33	0.0037*	0.001	-0.01*	0.003	0.38
France	43	0.009*	0.004	0.001	0.003	0.34
Germany	33	-0.001	0.002	0.004	0.003	-0.004
Greece	45	0.003	0.003	0.008**	0.004	0.08
Guatemala	42	0.00007	0.000	0.016*	0.002	0.80
Iceland	33	0.033*	0.011	-0.012	0.012	0.49
Iran	27	0.22*	0.091	0.002	0.034	0.22
Ireland	45	0.015*	0.005	0.015	0.007	0.62
Israel	25	0.009	0.011	0.034*	0.010	0.84
Italy	23	-0.008	0.012	0.008	0.007	0.13
Jamaica	33	-0.05*	0.014	0.026*	0.007	0.29
Japan	38	0.00013	0.000	0.01*	0.003	0.22
Mexico	45	0.05*	0.007	-0.02*	0.006	0.79
Netherlands	37	-0.007	0.005	0.007	0.003	0.06
Norway	27	0.001	0.001	0.011*	0.002	0.55
Panama	43	0.002*	0.000	-0.007**	0.003	0.37
Philippines	33	0.048*	0.017	0.015*	0.003	0.77
Portugal	16	0.022	0.011	0.001	0.009	0.72
Singapore	33	0.002*	0.001	-0.019*	0.007	0.47
South Africa	43	-0.003	0.002	0.009*	0.002	0.27
Spain	39	0.010	0.014	0.016**	0.008	0.35
Sweden	43	0.004**	0.002	-0.001	0.002	0.11
Switzerland	45	0.0005	0.002	0.003	0.004	0.05
Tunisia	32	0.005	0.008	0.014582	0.004	0.68
United Kingdom	45	0.05*	0.012	-0.007**	0.003	0.38
United States	45	-0.004	0.002	0.004*	0.001	0.20
Venezuela	36	-0.004	0.004	0.036**	0.014	0.78
Across-country values						
Mean		0.014	0.008	0.010	0.006	0.43
Standard deviation		0.040	0.015	0.021	0.006	0.302

Note: The dependent variable is the estimates of output-inflation tradeoff, τ_t's, obtained from rolling regressions (see note of Table 5). The regression is run for each country: $\tau_t = c + \alpha / \pi_t + \beta / \sigma_{x,t} + u$, with only slope coefficients reported in the table. * and ** indicate that a null hypothesis of zero is rejected at the 1 percent and 5 percent levels, respectively.
Source: Author's calculations.

Yet in some countries, the estimated effects of average inflation and aggregate variability on the tradeoff are positive, not negative as predicted by theory. In most of those countries with wrong-sign coefficients, these coefficients are not statistically significant. But there are a few exceptions with significant wrong-sign coefficients. This is puzzling and will be addressed in the next section.

7. International Evidence (4): One-Stage Country-by-Country Time-Series Results

Till now, all the analyses in the preceding parts are done in a two-stage procedure. At the first stage, the output-inflation tradeoff, τ_i, was estimated by running regressions on Equation 1 for each country. At the second stage, to explain the differences of the output-inflation tradeoff, τ_i, obtained at the first stage across country or over time, they are regressed on two explanatory factors. Such a procedure was originally applied in Lucas (1973) and Ball, Mankiw and Romer (1988), and many subsequent studies (see also Alberro 1981; Froyen and Waud 1980; Jung 1985; Katsimbris 1990).

However, as Akerlof, Rose and Yellen (1988) pointed out, this two-stage procedure might result in an efficiency loss as the precision with which τ is estimated in the first-stage procedure varies from country to country. The tradeoff, τ, is measured with errors. Especially, as shown in Table 3, some estimates of τ are statistically significant while others are not. However, all these tradeoffs estimated at the first stage are treated equally in the second-stage analysis. "The resulting heteroskedasticity in equation (2) leads to inefficient estimates, and also could lead one to conclude, for example, that (the inflation coefficient) is significant in equation (2), when in fact it is not" (Akerlof, Rose and Yellen 1988:72).

This might shed light on the possible reasons why the puzzling results were obtained in Section 6. There the tradeoff is estimated with the rolling regression at the first stage, which might endanger the accuracy of the estimates of the tradeoff as the rolling window is specified as 15 years and thus the degree of freedom is low. Therefore, the results reported in Section 5 and 6 should be interpreted cautiously.

The determinants of the real effect of changes in aggregate demand: One-stage country-by-country time-series result. In this part, I apply an alternative approach to answer what determines the real effect of changes in aggregate demand in a one-stage analysis. The dependency of the tradeoff on two explanatory variables is nested directly within Equation 1. In so doing, I get:

$$y_{it} = con_i + f(\pi_{it}, \sigma_{x,it})\Delta x_{it} + \theta_i y_{i,t-1} + \gamma_i Time + \omega_{it}, \text{ for } i = 1, 2, \ldots, 41 \tag{3}$$

Most of notations are as given in Equation 1. The residual is measured with ω_{it}. The function, $f(\pi_{it}, \sigma_{x,it})$, specifies the relationship between the magnitude of real effects of nominal disturbances and two explanatory factors – trend inflation and aggregate variability. As shown in the preceding parts, this relationship is negative and nonlinear. Following Equation 2, the f function is thus specified as:

$$f(\pi_{it}, \sigma_{x,it}) = c_i + \alpha_i / \pi_{it} + \beta_i / \sigma_{x,it}. \tag{4}$$

Substituting Equation 4 into Equation 3, we get:

$$y_{it} = con_i + c_i \Delta x_{it} + \alpha_i \Delta x_{it} / \pi_{it} + \beta_i \Delta x_{it} / \sigma_{x,it} + \theta_i y_{i,t-1} + \gamma_i Time + \omega_{it}. \tag{5}$$

With a one-stage regression based on Equation 5, we can directly derive how trend inflation and aggregate variability impact the size of real effects of nominal disturbances (see, e.g., Defina 1991; Khan 2004). The impact effects of nominal demand changes on output in country *i* are thus the first derivative of real output with respect to the nominal demand change. It results in the *f* function: $\partial y_{it} / \partial \Delta x_{it} = c_i + \alpha_i / \pi_{it} + \beta_i / \sigma_{x,it}$. And the effects of the inverse of average inflation and nominal demand volatility on the impact effect are the cross-partials.

$$\frac{\partial^2 y_{it}}{\partial \Delta x_{it} \partial (1/\pi_{it})} = \alpha_i, \tag{6}$$

$$\frac{\partial^2 y_{it}}{\partial \Delta x_{it} \partial (1/\sigma_{x,it})} = \beta_i. \tag{7}$$

The two coefficients, α_i and β_i, measure sensitivity of the slope of Phillips curve to the inverse of average inflation and the inverse of aggregate demand variability, respectively. These coefficients to be estimated appear to be the same as those estimated in the preceding analysis. However, the method to be applied to estimate α_i and β_i is different; they are to be estimated directly from a one-stage procedure. In this way, the loss of efficiency will be avoided.

Another advantage of this one-stage procedure is that it allows more degrees of fluctuation of two explanatory variables and consequently the tradeoff. In the preceding two parts, the estimation using a rolling regression is an attempt to permit some variations of these two variables. However, the permitted degree of variations in the rolling regression is still limited due to the fact that a sufficient degree of freedom is required for running a regression at the first stage. For a rolling window of 15 years, average inflation and nominal demand volatility are assumed to be constant during each of these rolling 15 years. Realistically, inflation and nominal demand volatility have fluctuated more in most countries. As one-stage procedure applied in this part is not constrained with a degree of freedom, the period can be shortened during which these two explanatory variables are assumed to be constant. They are hence allowed to take different values each three years. In this way, average inflation and nominal demand volatility are computed as a three-year moving average of the current and two past values.[21]

Table 8 presents the part of regression results based on Equation 5 for each of these countries. Only the estimates of two coefficients, α_i and β_i, are presented as they are of our interest and they explain how the over-time variations in the real effect of nominal disturbances are influenced by two explanatory factors for each sample country. Together, the number of observations, the estimated standard errors and the adjusted R-squared are reported as well.

The statistics of the adjusted R-squared listed in the last column of Table 8 are high and indicate a goodness-of-fit for the regressions. The standard errors of the estimated coefficients, both α_i and β_i, in the one-stage framework appear to be smaller on average compared to those in the two-stage framework, as listed in Table 7. It suggests that the estimates obtained with a one-stage procedure are more accurate on average. Another comparison with Table 7 reveals that one-stage estimates also result in much fewer wrong-sign coefficients.

Table 8 suggests that in around 60 percent of the countries, a higher-inflation period is accompanied by less effective demand policy, while only in 17 percent of the countries, such a negative relationship between aggregate variability and the tradeoff is significant. These estimation results thus provide further support for the New Keynesian hypothesis – during a period of high inflation, demand policy is found to be less effective in a large fraction of countries.

[21] Defina (1991) uses five-year moving averages. By using three-year moving averages in this paper, I allow more movement in these two explanatory variables. Another advantage is that it ensures more degrees of freedom, particularly for those countries with relatively short time series available. Despite this difference, I obtain qualitatively the same results as he did.

Table 8: Determinants of over-time variations in the tradeoff, 37 countries, selected periods, one-stage procedure

country	Observations	α	Standard error	β	Standard error	Adj. R-squared
Australia	46	0.0023**	0.001	0.00027	0.0002	0.999
Austria	41	-0.002	0.001	-0.00019	0.0004	0.998
Belgium	51	0.001	0.001	0.00005	0.0003	0.999
Canada	57	0.0048*	0.001	0.00117	0.0006	0.9996
Colombia	37	0.029*	0.010	0.00118	0.0006	0.998
Costa Riga	45	0.001	0.003	0.00042	0.0007	0.997
Denmark	39	0.0078*	0.003	0.00031	0.0003	0.996
Dominican Republic	43	0.0063*	0.002	0.0033	0.0031	0.995
Ecuador	40	-0.0035*	0.001	0.0011	0.0012	0.995
El Salvador	53	0.0001	0.000	-0.00035	0.0011	0.99
Finland	45	0.0003	0.000	0.00056	0.0003	0.998
France	55	0.0054*	0.002	0.00004	0.0003	0.999
Germany	45	0.001	0.000	-0.0001	0.0003	0.999
Greece	57	0.011*	0.003	0.0002	0.0003	0.998
Guatemala	54	0.0005	0.000	0.0026**	0.0011	0.999
Iceland	45	0.014**	0.006	0.0016**	0.0007	0.997
Iran	39	0.01	0.008	0.011**	0.0052	0.94
Ireland	57	0.012*	0.002	0.0007	0.0003	0.999
Israel	37	-0.0006	0.002	0.0036	0.0031	0.98
Italy	35	0.019*	0.005	0.0010	0.0007	0.997
Jamaica	45	0.02*	0.005	0.0004	0.0008	0.98
Japan	50	0.0006	0.001	0.0005	0.0003	0.998
Mexico	57	0.011*	0.004	-0.00001	0.0009	0.999
Netherlands	49	0.003*	0.001	0.0003	0.0003	0.999
Norway	39	0.002	0.001	0.0015*	0.0005	0.999
Panama	55	0.0005	0.001	0.0015	0.0010	0.999
Philippines	45	0.03*	0.009	-0.0005	0.0005	0.997
Portugal	28	0.019**	0.009	0.0001	0.0003	0.99
Singapore	45	0.0002	0.000	0.0013**	0.0006	0.9996
South Africa	55	0.006*	0.002	-0.0003	0.0005	0.998
Spain	51	0.01*	0.003	0.0004	0.0005	0.997
Sweden	55	0.0076*	0.002	0.0004	0.0003	0.999
Switzerland	57	0.0009	0.001	0.00078**	0.0004	0.999
Tunisia	44	0.015*	0.005	0.000005	0.0008	0.999
United Kingdom	57	0.016*	0.003	0.0002	0.0004	0.999
United States	57	0.007*	0.001	0.0003	0.0005	0.9996
Venezuela	48	0.002	0.003	-0.0007	0.0027	0.98
Across-country values						
Mean		0.0015	0.0033	0.0005	0.0009	0.99
Standard deviation		0.0029	0.0033	0.0010	0.0010	0.011

Note: The regression is run with Equation 5 for each country. Only the results for the coefficients of interest, α and β, are reported here. * and ** indicate that a null hypothesis of zero is rejected at the 1 percent and 5 percent percent significance level, respectively.

Source: Author's calculations

8. Conclusion

This paper follows BMR (1988) study and examines the variations in the output-inflation tradeoff by discriminating between the two theoretical frameworks – the New Keynesian nominal rigidity hypothesis and the alternative new classical imperfect information hypothesis. The distinction between these two competing theories has important policy implications. The former suggests that the tradeoff arising from nominal rigidities is a fairly stable economic relationship and it thus can be explored by policy makers, while the latter predicts that the tradeoff due to misperception is not stable and policy makers cannot explore this relationship. This paper conducts a series of tests and finds that a higher degree of nominal rigidity[22] leads to a higher output-inflation tradeoff. This relationship is not only a cross-country observation but also an over-time observation.

Methodologically, this paper summarizes and evaluates different estimation approaches that have been applied in the literature to examine the New Keynesian hypothesis. Namely, they are a baseline two-stage BMR cross-country comparison and three approaches that allow the tradeoff to change over time and examine those changes. A time-variant tradeoff is more consistent with what the theory predicts as trend inflation is far from constant over time. For an over-time analysis, the one-stage approach (see Defina 1991) is preferred, as it avoids a potential efficiency loss arising from a two-stage procedure.

Qualitatively, the cross-country comparison based on the extended sample suggests that the New Keynesian theory is still relevant today. In high-inflation countries, the output-inflation tradeoff that policy-makers face is smaller. However, in each individual country, the output-inflation tradeoff is not constant over time. During a high-inflation period, prices are less rigid. It leads to decreasing effectiveness of demand policy. Policy makers thus need to take a dynamic view towards the tradeoff.

[22] In this paper, I focus mainly on nominal price rigidity. Certainly, rigidities arise also from sticky wages or other forms of nominal frictions (see Christiano, Eichenbaum, and Evans 1997; Rotemberg 1984). The species of rigidities are, nevertheless, relatively unimportant for the discussion of the real impacts of nominal disturbances, as the conclusion would not be altered so long as the degree of these rigidities is inflation-dependent.

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