Globalization and Changing Inflation Dynamics in China

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Abstract: This paper investigates the changing impact of economic globalization on inflation in China over the post-reform era. We construct an inflation dynamics model with globalization factors from microeconomic foundations. Empirical results with quarterly data spanning from 1984 to 2012 show that in 1994 there was a significant structural change in the inflation dynamics model, after which China's inflation responded more significantly to foreign economic slack while the slope of the inflation-domestic slack relation reduced substantively. The finding indicates that the prescription that central banks should specifically react to developments in global output is justified for China over the post-1994 era.

Key Words: Globalization**;** Inflation; NKPC; Inflation Dynamics

JEL Classification: E31, E37, E52, E58, C22

1. Introduction

China's integration into the global economy brings a fundamental change to the global economic system and provides the nation historical opportunities benefitting from this globalization process (Mishkin, 2006). Indeed, China's economic growth performance over the last two decades has been spectacular, with the growth rate of gross domestic product (GDP) averaging above 8 percent and an overall economy now ranking second largest in the world (based on market exchange rates). As its economy becomes more open and more integrated in international trade (and finance), China faces an increasingly complex set of policy challenges. Given its important role in the world economy, in terms of population and sheer economic size, addressing these challenges effectively has important economic and political implications for both China and economies beyond its national borders.

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One of the leading challenges for China is the changing nature of inflation dynamics brought upon by the current great globalization. In particular, the past decade saw a marked fall in China's inflation, which was also associated with a distinct increase in economic globalization more generally seen in China than that in the industrial countries. As Figure 1 attested, the level of economic globalization in China has risen from less than 0.3 in the 1980s to around 0.4 in the 1990s and above 0.5 in the most recent decade[3]. The rising globalization brings a new challenge for the Chinese central bank, the People's Bank of China (PBOC). If the PBOC fails to grasp profound global changes at play and their implications for domestic inflation developments, it could cost the nation a dangerous lurch into secular deflation or unexpected high inflation.

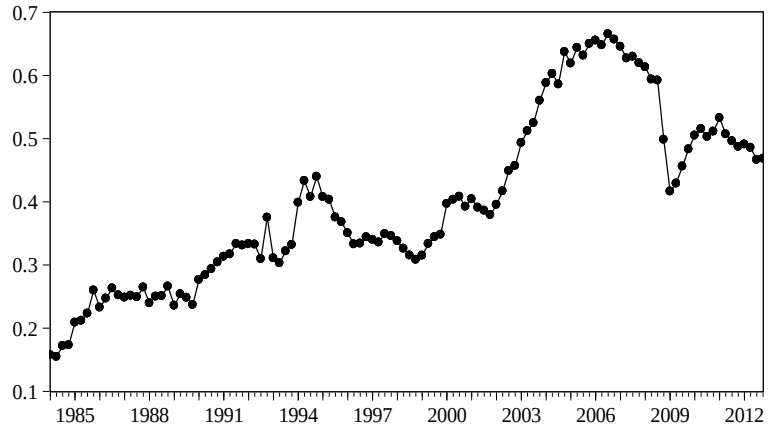

Figure 1 China's economic globalization (total trade divided by nominal GDP; SA): 1984Q1—2012Q4

Source: Central Administration of Customs, National Bureau of Statistics of China, and the author's calculations.

Despite conspicuous importance of the effects of globalization on inflation dynamics in China, much of the existing studies have focused on the relevant issue for industrial economies. One motivation for concentrating on industrial economies is that the increasing integration of China and other lower-cost producers into world production networks may have induced downward pressure on wages and import prices in industrial countries (BIS,

[3] Economic globalization is measured as the sum of exports and imports as a percentage of nominal GDP.

2005). While early studies such as Kamin *et al*. (2006) have not found much evidence for the downward price effect, there now exists a substantial body of research documenting that there is a pronounced effect (e.g. Auer and Fischer, 2010; Auer *et al*, 2010; Holz and Mehrotra, 2013). This cross-border price spillover effect may also materialize through global value chains (see Aurer and Mehrotra, 2014; Hirakata *et al*., 2014).

In addition, excess capacity abroad may have helped manufactures in the industrial countries meet the domestic demand without straining domestic resources and pushing up inflationary pressures. Recent researches of BIS (2005), Helbling *et al*. (2006), Borio and Filardo (2007), Sbordone (2009), Auer *et al*. (2010), and Milani (2010) appear to support this argument. In particular, Borio and Filardo (2007) estimate traditional Phillips curves for fifteen industrialized countries and find that foreign output gap drives domestic inflation significantly in most of these economies. However, this finding has been challenged by Ball (2006), Badinger (2009), and Ihrig *et al*. (2010), who conduct similar empirical analyses for a narrower sample of countries, by Pain *et al*. (2006) using a system of error correction mechanism for a sample of 21 OECD countries, and by Calza (2009) using alternative specifications of traditional Phillips curve augmented by the contemporaneous foreign output gap for 26 advanced and developing economies.

These different findings for the industrial economies may be unsurprising because the integration of emerging countries into the global economy can bring interconnecting and two-way impacts on the inflation process of advanced economies. On the one hand, higher demand may drive up prices for energy, raw materials, and general commodities, which eventually reflects in overall price inflation. On the other hand, an influx of lower cost labor, products and services into the world market can drive prices downward. This two-way impact may also explain why globalization-inflation relationship remains a "puzzle" (Temple, 2002) when different pools of countries are considered as in Romer (1993), Terra (1998), and Gruben and McLeod (2004).

However, the impact of globalization on China's inflation process, being that it is the

world's largest developing and emerging economy, may be less ambiguous. Indeed, inflation in China is more likely to be affected than that of an industrial economy by foreign demand and supply via the international goods market, since China's economic development has higher dependence on global trade than industrial economies. In addition, China is the exporter of lower cost labor, products and services, and hence less affected by world factor market.

Therefore, this paper focuses on the link between globalization and inflation dynamics in China. While institutional circumstances and economic conditions in China are different from the developed economies, which may matter a great deal in formulating a suitable framework for inflation dynamics, are there clear general principles in the changing nature of inflation dynamics for China that can serve as a guide in the process of the current great globalization? In the present paper, we attempt to fill the existing void and provide a complementary explanation towards the changing inflation performances in China, linking them to broader debates in academic literature as well as policy implications.

To this end, we will develop an extended New Keynesian Phillips curve from an open economy version of an extended Calvo's (1983) sticky price model with microeconomic foundations relating to the dynamic stochastic general equilibrium model. The commonly used framework in the literature of globalization and inflation is the traditional backward-looking Phillips curve model (e.g. Borio and Filardo, 2007; Ihrig *et al*., 2010), which maintains the virtue of simplicity but neglects the important micro foundation of staggered price setting mechanism. To preview our results, we find that there is a significant structural break in China's inflation dynamics in 1994 after which an increase in globalization generates a significantly large increase in the response of inflation to the global demand and reduces the slope of inflation-domestic demand relation.

The rest of the paper is organized as follows: Section 2 presents the baseline model and briefly describes its connection with the micro foundation of sticky prices; Section 3 describes the data used in empirical work and some stylized facts about globalization and

inflation in China; Section 4 discusses the econometric issues related to the empirical estimations and provides empirical results of the underlying model, followed by relevant implications explored in Section 5; Section 6 concludes the paper.

2. The model

In this paper, we construct a dynamic, micro-founded inflation dynamics model for an open economy, like China, with sticky prices. Our model is a small but important extension of recent developments in the open economy dynamic stochastic general equilibrium (DSGE) literature pioneered by Obstfeld and Rogoff (2000), Clarida *et al*. (2002), Smets and Wouters (2002), and Gali and Monacelli (2005). The households' consumption and savings decisions are in the spirit of Gali and Monacelli (2005) in which a representative household seeks to maximize a utility function with a composite consumption composed of both domestic goods and imported goods.

For the domestic monopolistically competitive goods market, we lay out an extended framework of Calvo (1983), which can be easily rationalized in terms of sticky price setting of backward-looking firms in the closed-economy models. In particular, for the pricing behavior of the domestic firms, we assume an economic environment similar to the one in Calvo's (1983) model, in which firms are able to revise their prices in any given period with a fixed probability $(1-\theta)$. In addition, we assume both "forward-" and "backward-looking" firms co-exist in the economy with a proportion of ω and $(1-\omega)$, respectively. Further, we extend the rule of the recent pricing behavior of the backward-looking firms to incorporate a weighted process of past inflation, instead of stylized one lag of inflation inertia.

Specifically, based on the regular assumptions in Calvo's model and log-linear approximations, it is possible to obtain the (log) aggregate price level by

$$p_t = \theta p_{t-1} + (1-\theta) p_t^{new}$$

(1)

where p_t^{new} is the new price set in period *t*. Let p_t^f be the price set by forward-looking firms and p_t^b be the price set by backward-looking firms at time *t*. The new price (relative to the aggregate price) can be expressed as a convex combination of p_t^f and p_t^b, viz.

$$p_t^{new} - p_t = \omega(p_t^f - p_t) + (1-\omega)(p_t^b - p_t) \quad .$$

(2)

Next, following Woodford (2003), the pricing behavior of the forward-looking firms can be written as

$$p_t^f - p_t = \theta\varsigma\sum_{s=0}^{\infty}(\theta\varsigma)^s E_t\pi_{t+s+1} + (1-\theta\varsigma)\sum_{s=0}^{\infty}(\theta\varsigma)^s E_t mc_{t+s}$$

(3)

where ς denotes a subjective discount factor, π_t denotes inflation rate, and mc_t is the real marginal cost of a typical domestic firm producing differentiated goods with a linear technology. Iterating (3) gives

$$p_t^f - p_t = \theta\varsigma E_t\pi_{t+1} + (1-\theta\varsigma)mc_t + \theta\varsigma E_t(p_{t+1}^f - p_{t+1}) \quad .$$

(4)

Assume a rule of thumb in the pricing setting, viz.

$$p_t^b - p_t = p_{t-1}^{new} - p_t + \pi_{t-1} \quad .$$

(5)

As emphasized in the literature, this is an elegant innovation in that the backward-looking firms can now set their prices to the average price determined in the most recent price adjustments with a correction for inflation.

However, inflation inertia in (5) is confined to one single lag, which may neglect the importance of other historical inflation in predicting current inflation. In particular, if we interpret one period as being short, the backward-looking agents are likely to take more than one period to fully respond to changes in actual inflation (Zhang and Clovis, 2010). Therefore,

it would appear reasonable to replace π_{t-1} in (5) with a weighted average of inflation over several periods in the past. Importantly, this replacement can effectively mitigate a serial correlation problem in empirical analysis. As such, we extend (5) in the following process:

$$p_t^b - p_t = (p_{t-1}^{new} - p_t) + \pi_{t-1} + \rho(L)\Delta\pi_{t-1} \quad (6)$$

where $\rho(L) = \rho_1 + \rho_2 L + \cdots + \rho_m L^{m-1}$ is a polynomial in lag operator. In practice, *m* may be specified by utilizing appropriate diagnostic tests (e.g. standard information criteria).

Combining (1)-(6), it can be shown that the dynamics of domestic inflation in terms of real marginal cost are described by an equation analogous to the one associated with a closed economy, viz.

$$\pi_t = \gamma_e E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \sum_{i=1}^{m-1} \alpha_i \Delta\pi_{t-i} + \lambda mc_t \quad (7)$$

where coefficients of (7) are functions of the deeper parameters in (1)-(6).

It can be verified that, by combining equation (7) with the equations that depict the representative household seeking to maximize a utility function with a composite consumption composed of both domestic goods and imported goods, we can obtain an open-economy generalization of the extended New Keynesian Phillips Curve (NKPC) which incorporates an extended inflation dynamics and world excess demand, viz.

$$\pi_t = c + \gamma_e E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \sum_{i=1}^{m-1} \alpha_i \Delta\pi_{t-i} + \delta_d \hat{y}_t + \delta_f \hat{y}_t^* + \lambda_t \quad (8)$$

where $\hat{y}_t$ and $\hat{y}_t^*$ denote domestic and foreign real output gaps , λ_t is an error term, and other coefficients are functions of structural parameters in the DSGE system.

Note that model (8) introduces the globalization factor and more inflation dynamics (i.e. $\sum_{i=1}^{m-1} \alpha_i \Delta\pi_{t-i}$) into an extended NKPC model and provides a channel through which

globalization may alter the dynamic response of inflation to domestic demand. If the impact of the world excess demand on inflation is trivial, the model then reduces to a closed economy version of NKPC. The inclusion of additional lag terms in the model is particularly important for obtaining valid results in empirical estimations since the stylized specification of the conventional NKPC model generally has serial correlation problem (Zhang *et al*., 2008). The possible presence of serial correlation is crucial for the choice of valid instruments for GMM estimations of the NKPC models, since all lags of the dependent variable are invalid instruments in the presence of autoregressive serial correlation. Since lags of inflation are typically employed as instruments for estimation of the NKPC, the consistency of these estimates depends on the lack of such serial correlation.

3. The data

This section describes the data series used in the empirical work and provides some stylized facts pertaining to the underlying variables. In all, the baseline estimation of model (8) involves series for overall inflation π_t; inflation expectations $E_t\pi_{t+1}$; a measure of the domestic real output gap $\hat{y}_t$; and a measure of the foreign real output gap $\hat{y}_t^*$. As will be explained in the next section, the estimation of model (8) also involves taking growth rate of monetary aggregate (i.e. M2) as an instrumental variable. A robustness analysis further involves effective exchange rates. Most of the data series were obtained from China Economic Information Center (CEIC) database, except for China's nominal and real GDP series, which were obtained from Datastream. The raw level data for all quarterly series were seasonally adjusted prior to any further application. The final series used in empirical estimations are stationary (confirmed by conventional unit root tests). The sample size in our empirical estimations spans the first quarter of 1984 to the last quarter of 2012 (i.e.

1984Q1-2012Q4) dictated by availability of trade data.

First, China's overall inflation is measured by quarterly year-on-year growth rate of the GDP deflator. The raw data for GDP deflator is derived by dividing real GDP by nominal GDP. Figure 2 plots the time series of quarterly data for GDP deflator inflation. It shows that the dynamic evolution of overall inflation in China has witnessed remarkable cyclical behavior of booms and busts over time. In particular, Chinese inflation witnessed the first distinct increase in 1985, followed by a second peak in 1989, and the most striking peak in the middle 1990s. Since the late 1990s, however, inflation in China has been relatively low and stable, with a few periods of deflation. Despite several local peaks of inflation occurred in 2004, 2008, and 2011 due to transitory demand shock (e.g. shock to real estate market), supply shock (e.g. shock to food and energy prices), and policy shock (e.g. the 4-trillion stimulus package implemented in 2007-2008), respectively, the most recent decade can be characterized as a lower and less volatile inflation era than the 1980s-1990s.

Second, inflation expectations are unobservable and have to be approximated via an appropriate method. A commonly used method in the literature (e.g. Gali and Gertler, 1999) is to approximate the unobserved inflation expectations in (8) by the corresponding realized future inflation, i.e. $E_t\pi_{t+1} = \pi_{t+1} - e_{t+1}$, where e_{t+1} denotes the rational prediction error. This approach however, induces an extra disturbance to the underlying model which is likely to affect the accuracy of the estimation of the variance of the error term associated with the NKPC model and complicate diagnostic tests (in particular serial correlation test) in the empirical estimations. To avoid these problems, we follow Pagan (1984) and approximate inflation expectations by projecting realized future inflation (i.e. π_{t+1}) on the instrumental variable (IV) set Z that is used in our empirical estimations (i.e. $E_t\pi_{t+1} = P_Z\pi_{t+1}$ where $P_Z = Z(Z'Z)^{-1}Z'$ is the projection matrix in terms of the IV set). It follows that this procedure will yield precisely the same coefficient estimates as those obtained by the IV estimation with the rational expectation approximation, while the standard errors will be different since the

former ignores uncertainty in the estimation of the projection matrix (Pagan, 1984).

Third, the real domestic output gap in the baseline estimations was obtained from Hodrick-Prescott (HP) filter on the corresponding real GDP series (with the smoothing parameter 1600 for quarterly data). In robustness assessments, we also use growth rate of real GDP and deterministic, quadratically detrended log real GDP to approximate the real output gap in model (8).

Fourth, the foreign output gap is calculated as a weighted sum of the real GDP gap measure of China's top eighteen major trading partners[4]. The weight for each trade partner in each year is determined by the percentage of the partner's trade (both exports and imports) with China over the total trade between China and the eighteen partners for that year.

Table 1 presents the corresponding statistics for the trade weights of each country/region to China over 1984-2012. It shows that the trade weights of different countries/regions to China change over time. For example, the trade percentage of the U.S. to China witnessed a dramatic jump in the mid-1990s, rising from less than 12 percent before 1993 to above 16 percent afterwards. Interestingly however, the trade percentage of Hong Kong to Mainland China has experienced a steady decline from the 1990s to the 2000s. A similar pattern of decline in trade percentage with China can also be observed for Japan, which was China's largest trading partner during the 1980s and 1990s. Nevertheless, the U.S. took over Japan as China's largest trading partner after 2004.

The variations of the trade percentage are accommodated in the calculation of the foreign real GDP gap, i.e. $\hat{y}_t^* = \sum_{j=1}^{18} w_{j,t}\hat{y}_{j,t}$, where $w_{j,t}$ denotes the defined weight (i.e. trade percentage) at time t (quarterly observations within one year use the same weight of the year) and $\hat{y}_{j,t}$ is the real output gap measure for country/region j.

[4] China's top eighteen major trading partners include Australia, Canada, France, Germany, Hong Kong, Indonesia, Italy, Japan, Korea, Malaysia, Netherlands, Russia, Singapore, Thailand, Tai Wan, The United Kingdom, The United States and Latin America. Note that the trade data for Latin America aggregates the corresponding data of Argentina, Brazil, and Chile. The trade data and real GDP series for the eighteen countries/regions were obtained from CEIC database.

Figure 2 plots the resulting foreign real output gap series in conjunction with China's domestic real GDP gap and overall inflation series. Figure 2 shows that the cyclical behavior of domestic and foreign output gaps is similar in general, but differs in detail. In particular, the domestic GDP gap is more volatile than the foreign GDP gap before the late 1990s and vice versa during the most recent decade. This difference is reflected in the comparison of the dynamic evolution between inflation and the two output gaps: China's overall inflation moves more closely with the domestic output gap than the foreign output gap before the late 1990s and the scenario reverses afterwards. Whether this difference envisions structural changes in inflation dynamics modeling, remains an empirical issue.

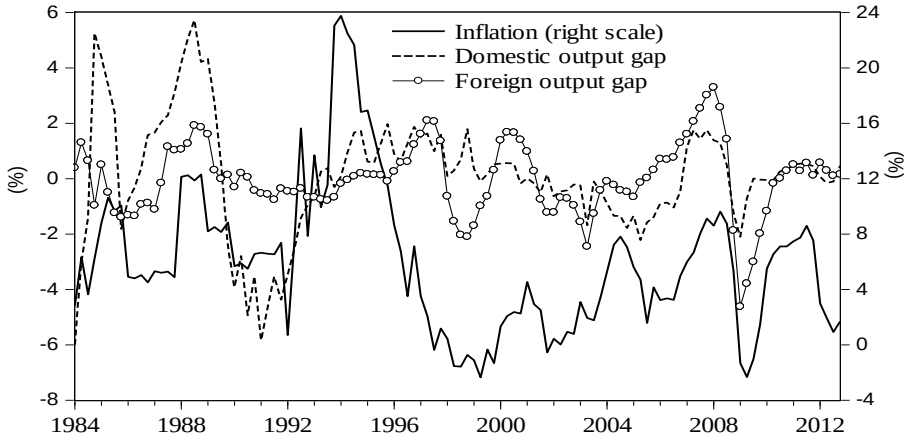

Figure 2 China's inflation, domestic real GDP gap, and foreign real GDP gap: 1984Q1—2012Q4

Source: CEIC database and the author's calculations.

Table 1 Trade percentage of China's major trade partners (%)

	AUS	CAN	FRA	GEM	HK	IDO	ITA	JAP	KOR	MAL	NETH	RUS	SIN	THA	TW	UK	US	LAT
1984	2.6	3.2	1.4	5.0	22.8	0.7	1.8	32.2	--	1.0	1.2	3.1	3.3	1.0	--	2.0	14.8	3.8
1985	2.3	2.4	1.6	5.4	20.7	0.8	2.1	36.5	--	0.7	1.0	3.4	4.0	0.7	--	1.9	12.8	3.8
1986	2.6	2.2	1.7	7.5	25.2	0.8	2.5	28.2	--	0.6	1.2	4.3	2.9	0.7	--	4.0	12.1	3.4
1987	2.4	2.7	2.0	6.4	32.7	1.1	2.6	24.2	--	0.8	1.2	3.7	2.9	1.0	--	2.1	11.6	2.5
1988	1.7	2.6	1.8	5.7	35.3	1.1	2.7	22.1	--	1.0	1.3	3.8	2.9	1.3	--	1.8	11.7	3.0
1989	2.0	1.6	2.1	5.3	36.4	0.9	2.7	20.0	--	1.1	1.3	4.2	3.4	1.3	--	1.8	13.0	3.1
1990	1.8	1.9	2.2	4.8	39.7	1.1	1.8	16.1	1.9	1.1	1.3	4.2	2.7	1.2	2.5	2.0	11.4	2.2
1991	1.7	1.8	1.8	4.4	40.3	1.5	1.9	16.5	2.6	1.1	1.3	3.2	2.5	1.0	3.4	1.4	11.5	1.9
1992	1.6	1.7	1.5	4.3	38.8	1.4	1.9	16.9	3.4	1.0	1.1	3.9	2.2	0.9	4.4	1.3	11.7	2.0
1993	1.8	1.5	1.7	5.8	18.9	1.3	2.4	22.7	4.8	1.0	1.4	4.5	2.8	0.8	8.4	2.1	16.1	2.2
1994	1.9	1.5	1.6	5.7	19.9	1.3	2.2	22.9	5.6	1.3	1.4	2.4	2.4	1.0	7.8	2.0	16.9	2.2
1995	1.7	1.7	1.8	5.5	18.0	1.4	2.1	23.3	6.9	1.4	1.6	2.2	2.8	1.4	7.2	1.9	16.5	2.5
1996	2.0	1.6	1.6	5.2	16.0	1.5	2.0	23.5	7.8	1.4	1.7	2.7	2.9	1.2	7.4	2.0	16.8	2.6
1997	1.9	1.4	2.0	4.5	17.9	1.6	1.7	21.4	8.5	1.6	1.9	2.2	3.1	1.2	7.0	2.0	17.3	3.0
1998	1.8	1.6	2.1	5.1	16.2	1.3	1.7	20.6	7.6	1.5	2.1	2.0	2.9	1.3	7.3	2.3	19.5	3.0
1999	2.0	1.5	2.2	5.2	14.1	1.6	1.8	21.3	8.1	1.7	2.1	1.8	2.8	1.4	7.6	2.5	19.8	2.7
2000	2.1	1.7	1.9	5.0	13.6	1.9	1.7	20.9	8.7	2.0	2.0	2.0	2.7	1.7	7.7	2.5	18.7	3.2
2001	2.1	1.7	1.8	5.5	13.1	1.6	1.8	20.6	8.4	2.2	2.0	2.5	2.6	1.7	7.6	2.4	18.9	3.5
2002	2.0	1.5	1.6	5.4	13.4	1.5	1.8	19.7	8.5	2.8	2.1	2.3	2.7	1.7	8.6	2.2	18.8	3.4
2003	2.0	1.4	1.9	6.0	12.6	1.5	1.7	19.2	9.1	2.9	2.2	2.3	2.8	1.8	8.4	2.1	18.2	3.9
2004	2.2	1.7	1.9	5.8	12.1	1.5	1.7	18.1	9.7	2.8	2.3	2.3	2.9	1.9	8.4	2.1	18.3	4.3
2005	2.4	1.7	1.8	5.6	12.2	1.5	1.7	16.5	10.0	2.7	2.6	2.6	3.0	1.9	8.1	2.2	18.9	4.5
2006	2.4	1.7	1.9	5.8	12.3	1.4	1.8	15.3	9.9	2.7	2.5	2.5	3.0	2.0	8.0	2.3	19.4	5.2
2007	2.7	1.8	2.0	5.7	12.0	1.5	1.9	14.4	9.7	2.8	2.8	2.9	2.9	2.1	7.6	2.4	18.4	6.2
2008	3.2	1.8	2.1	6.1	10.8	1.7	2.0	14.2	9.9	2.8	2.7	3.0	2.8	2.2	6.9	2.4	17.7	7.6
2009	3.7	1.8	2.1	6.5	10.7	1.7	1.9	14.0	9.6	3.2	2.6	2.4	2.9	2.3	6.5	2.4	18.3	7.5
2010	4.0	1.7	2.0	6.5	10.5	1.9	2.1	13.6	9.4	3.4	2.6	2.5	2.6	2.4	6.6	2.3	17.5	8.4
2011	4.4	1.8	2.0	6.4	10.7	2.3	1.9	13.0	9.3	3.4	2.6	3.0	2.4	2.5	6.1	2.2	16.9	9.1
2012	4.4	1.8	1.8	5.8	12.2	2.4	1.5	11.8	9.2	3.4	2.4	3.2	2.5	2.5	6.1	2.3	17.4	9.4

Notes: The statistic is calculated as the ratio of China's trade to each country (or region) as a percentage of total trade of China to all countries (regions) listed in the table (the data for Korea and Taiwan are not available until 1990); initial letters of each country/region's name are used as an acronym to represent the country/region.

4. Empirical results

4.1 Econometric issues

As already noted in Section 1 of this paper, China's economic globalization level has increased dramatically since the 1990s and this change may shift the mechanism of the impact of globalization on inflation dynamics in China. In particular, the empirical sample in our analysis covers a relatively long period from the early 1980s to 2012, which witnesses profound changes in China's integration to the world economy and its macroeconomic dynamics. While the link between economic globalization and inflation dynamics makes it plausible that such changes may lead to structural breaks in the parameters of the NKPC model (8), any such effect and its timing depend on the behavior of economic agents. Since the dates of potential change points are therefore unknown, we perform break tests using the methodology proposed by Andrews (1993).

Prior to examining the structural break tests, several econometric issues in estimating the baseline model should be noted. First, inflation expectations in model (8) may be influenced by information relating to the current period. In addition, the real variables are also likely to be correlated with the contemporaneous noise, since demand shocks may influence both variables. Therefore, we use IV, or more specifically the Generalized Method of Moments (GMM) estimator to estimate model (8) and pin down the endogeneity problem.

The baseline IV set used in estimating (8) consists of two lags of each of the domestic and foreign output gaps, and M2 growth rate, plus the lags of inflation included in the model (and a constant). Since the NKPC in (8) is specified with sufficient dynamics (by Akaike Information Criteria (AIC)) and is generally free of significant serial correlation in empirical estimations, lagged inflation values on the right-hand-side of (8) are used as valid instruments for themselves. In addition, the baseline estimations are verified through Godfrey's (1994) IV serial correlation test, Hansen's (1982) *J*-test for over-identifying restrictions, and the Stock and Yogo (2003)'s generalized *F*-test for weak IV.

Note that the Godfrey IV serial correlation test is implemented by adding appropriate lagged residuals from the initial estimation to the regressors from the initial model and checking their joint significance by the Lagrange Multiplier (LM) principle. This test is used to check the possibility of disturbance serial correlation in the IV estimations with null hypothesis of no serial correlation. Therefore, a large p-value indicates no significant serial correlation in the regression and vice versa. The Stock–Yogo weak instrument test provides diagnostic information on to what extent the underlying instruments are weak in the estimation. The statistics reported (in Table 3) are the Cragg-Donald statistics, with larger values indicating stronger IV sets.

Based on the preceding design, we carry out formal unknown structural break tests. Specifically, we employ the Supreme Likelihood Ratio (LR) test of Andrews (1993) to test for unknown structural breaks in model (8). The test is designed to test for the null hypothesis of no structural break in the underlying parameters of interest. The corresponding *p*-values of the tests are computed using the method of Hansen (1997). By construction, the Andrews' (1993) Supreme LR statistic is the maximum LR-statistic for testing a break through all possible break points over a specified searching range, say τ, which is given by

$$SupLR = \sup LR_T(\tau_i) \big| \tau_i \in [\tau_{\min}, \tau_{\max}] \tag{9}$$

where $LR_T(\tau_i)$ denotes sequential LR-statistic testing for the null hypothesis of no structural break in the underlying parameter. We set a searching interval $\tau_i \in [0.20,\ 0.80]$ of the full sample T to allow a minimum of 20 percent of effective observations contained in both pre- and post-break periods to avoid extreme statistic results.

4.2 Baseline results

Table 2 summarizes the results of the Andrews (1993) unknown structural break tests for the inflation dynamics model (8). Note that the optimal lag order in the model is jointly specified by AIC and Godfrey's (1994) IV serial correlation test (with maximum eight lags). The break tests are performed on all the coefficients overall and then on the individual coefficients. Specifically,

the first row in Table 2 provides notational information for the coefficients in the break tests, with the first statistic (denoted *all*) testing for stability of all the coefficients in (8) while the other results referring to individual tests for the indicated coefficients. The second row reports *p*-values associated with the corresponding break test statistics for the null hypothesis of no structural change, while the third row labeled *break date* represents the estimated break date corresponding to the *Sup*-LR statistic.

As can be seen from the results in Table 2, *p*-values for the break test statistics test overall model stability. The autoregressive coefficients (α_i), and the coefficient on the foreign output gap (δ_f) are highly significant, with the *break date* statistics providing the uniform break point in the first quarter of 1994. These results suggest that the inflation dynamics model (8) for China indeed experiences a significant structural break early in 1994, and the strongest evidence of change relates to autoregressive coefficients and the foreign output gap.

Table 2 Results of Andrews unknown breakpoint tests for model (8)

	all	*c*	γ_e	γ_b	α_i	δ_d	δ_f
p-Sup	0.001	0.696	0.206	0.499	0.000	0.558	0.001
break date	1994Q1	1995Q1	1993Q3	1993Q3	1994Q1	2007Q1	1994Q1

Notes: The estimated equation is given by model (8) with sample spanning 1984Q1-2012Q4 prior to lag adjustment. Optimal autoregressive lag order in the NKPC is specified by AIC and IV serial correlation test (with maximum eight lags). The baseline IV set for the NKPC includes two lags of each of the domestic real GDP gap, the foreign real GDP gap, and M2 growth rate, plus the lags of inflation included in the model (and a constant). *p*-Sup denote *p*-values of the Sup-LR *F*-test for the null of stability; *break date* corresponds to the break point at which the maximum LR *F*-statistic is achieved; the structural break tests are implemented over central 60 percent of the underlying sample (to avoid possible extreme results).

We have now obtained a structural break point based on which we can investigate the nature of changes in China's inflation dynamics model and compare the impact of globalization on inflation dynamics over different sample periods when breaks in the coefficients are recognized at the beginning of 1994. Table 3 reports GMM estimates of model (8) over the whole sample and pre- and post-1994 periods for forward- and backward-looking inflation coefficients and the domestic and foreign output gap measures, in conjunction with relevant diagnostic statistics.

The diagnostic test statistics in Table 3 indicates that the specification of model (8) is free from significant serial correlation and the IV choice is valid and relatively strong in most cases. The *p*-values of the joint significance tests on the extra lagged inflation (from order two onwards) are very small in all regressions, indicating the statistically significant role of the extra lagged inflation in the empirical NKPC model.

Table 3 (GMM) Estimation results of the inflation dynamics for China

	Baseline estimates				Diagnostic tests			
Sample	γ_e	γ_b	δ_d	δ_f	$p(\alpha_i)$	*p*-auto	*p*-J	weakIV
A. 1984Q1-2012Q4	0.593***	0.415***	0.146***	0.078	0.000***	0.495	0.622	32.1****
	(0.108)	(0.083)	(0.040)	(0.152)				
$\gamma_e+\gamma_b=1$	0.586***	0.414***	0.147	0.081	0.001***	0.542	0.775	32.1****
	(0.084)	(0.084)	(0.094)	(0.174)				
B. 1984Q1-1994Q1	0.731**	0.471***	0.227	-0.300	0.000***	0.111	0.500	4.87*
	(0.128)	(0.166)	(0.151)	(0.495)				
$\gamma_e+\gamma_b=1$	0.673***	0.327***	0.134	-0.089	0.000***	0.330	0.572	4.87*
	(0.118)	(0.118)	(0.156)	(0.388)				
C. 1994Q2-2012Q4	0.529***	0.453***	0.080	0.164***	0.000***	0.318	0.230	6.78**
	(0.042)	(0.033)	(0.107)	(0.056)				
$\gamma_e+\gamma_b=1$	0.545***	0.455***	0.091	0.144	0.000***	0.306	0.360	6.78**
	(0.044)	(0.044)	(0.122)	(0.104)				

Notes: Autoregressive lag order in the NKPC is specified by AIC and IV serial correlation test (with maximum of eight lags). Inflation expectations are measured by fitted values of regressing the realized future inflation on the baseline IV set (IV is the same as in Table 2). The Bartlett kernel with Newey-West (fixed bandwidth) HAC-robust standard errors are reported in parentheses. $p(\alpha_i)$ is the *p*-value of joint significance test on lagged inflation beyond order one; *p*-auto, *p*-J, and weakIV refer to *p*-values of Godfrey's (1994) first order IV serial correlation test, Hansen's (1982) *J*-test, and Stock and Yogo's (2003) weak instrumental variables test (Critical values for the weak IV test are provided in Stock and Yogo (2003), table I, with ****, ***, **, and * denoting statistically significantly strong IV (5% significance level) when the desired maximal bias of the IV estimator relative to OLS is specified to be 5, 10, 20 and 30 percent respectively; the null hypothesis is that the underlying IV set is weak). *, ** and *** denote statistical significance at the 10, 5 and 1 percentiles respectively. All series involved in the estimations are stationary (confirmed by ADF unit root tests).

More importantly, the baseline results reported in Panels A, B, and C in Table 3 reveal significant changes of the impact of the domestic and foreign output gap measures on China's inflation over different sample periods. Specifically, Panel A shows that over the whole sample

period of 1984-2012 the domestic output gap drives inflation significantly with the coefficient estimate around 0.15. In contrast, the coefficient estimate on the foreign output gap is statically insignificant with the point estimate about a half of the domestic output gap. Although the significance of the coefficient on the domestic output gap is less striking when the convex restriction $\gamma_e + \gamma_b = 1$ is imposed, the magnitude of the point estimates on the real variables and their comparisons with each other resemble the scenario without the convex restriction.

Panel B and Panel C provide evidence that the impact of the domestic and foreign output gaps on inflation has changed (switched) significantly. The coefficient estimate of the domestic output gap falls substantially from 0.23 pre-1994 to 0.08 post-1994. Conversely, the coefficient estimate of the foreign output gap has risen from an insignificant and negative value to a significant and positive value (0.16). These results indicate that foreign output gap plays a more important role than domestic output gap in the NKPC of China after 1994, with this effect statistically significant in the case of no convex restriction[5].

Although not the principal focus of our study, the results of Table 3 should be noted as they indicate the forward-looking behavior is in general predominant while the backward-looking component appears quantitatively less important in all sample periods, with this effect being more striking pre-1994. This finding may be unsurprising because inflation expectations in China during the 1980s and early 1990s were very high and played a predominant role in Chinese inflation behavior, presumably due to the ongoing economic reform and development, as well as an insufficient supply of consumer goods.

To summarize, the coefficient estimates of the domestic and foreign output gap measures provide our main finding from Table 3, namely that the impact of the foreign output gap on China's inflation has changed significantly its role from less important to more important compared with the domestic output gap. This finding indicates that inflation dynamics in China has shifted significantly since the mid-1990s and the impact of globalization via the foreign

[5] It may be noted that the estimates of the standard errors are likely to be inflated when the convex restriction is imposed so that it is unsurprising for the significance of the corresponding statistics to be less striking.

excess demand has indeed risen accordingly.

The next section assesses the robustness of this finding.

4.3 Robustness assessments

To assess the robustness of the baseline finding that the impact of globalization on inflation dynamics has risen after the mid-1990s in China, we carry out two sets of sensitivity exercises. First, we investigate whether the finding is robust to alternative output gap measures. That is, we estimate the model (8) by using growth rate of real GDP and deterministic, quadratically detrended log real GDP to approximate real output gap. Second, we augment the baseline model (8) by taking into account the possible impact of exchange rate on inflation, viz.

$$\pi_t = c + \gamma_e E_t \pi_{t+1} + \gamma_b \pi_{t-1} + \sum_{i=1}^{q-1} \alpha_i \Delta \pi_{t-i} + \delta_d y_t^d + \delta_f y_t^f + \delta_s \Delta eer_t + \eta_t \qquad (10)$$

where Δeer denotes growth rate of effective exchange rate and all other notations follow those in (8). By construction, model (10) considers explicitly possible pass-through of exchange rate on inflation. It may also mitigate a concern that the pass-through effect might be squeezed into the foreign output gap when exchange rate variable is omitted.

Table 4 reports the corresponding results, which show that the baseline finding pertaining to the post-1994 period has no substantial change when alternative real variables are used. In addition, the estimation results pertaining to the augmented model (10) (the lower two panels in Table 4) with both real and nominal effective exchange rates provide a similar conclusion. In all regressions of the robustness analysis, the coefficient estimates on the foreign real economic activity outweigh the domestic counterparts, with the coefficient estimates on the foreign output variables ranging from 0.147 to 0.195 *versus from* 0.05 to 0.06 for the domestic output variables. Another interesting finding is that the pass-through effect of exchange rate on inflation is trivial and statistically insignificant. These results reinforce the conclusion that the foreign economic activity plays a quantitatively and statistically significant role in affecting China's inflation over the post-1994 era.

Table 4 Robustness estimation results of the inflation dynamics model for China: 1994Q2-2012Q4

	Baseline estimates					Diagnostic tests			
	γ_e	γ_b	δ_d	δ_f	δ_s	$p(\alpha_i)$	*p*-auto	*p*-J	weakIV
(1) *y=qdgap*	0.531***	0.433***	-0.012	0.147*		0.000***	0.107	0.217	8.97***
	(0.070)	(0.042)	(0.045)	(0.087)					
(2) *y=gdpgr*	0.427***	0.517***	0.050	0.151*		0.004***	0.119	0.400	4.68*
	(0.140)	(0.078)	(0.132)	(0.085)					
(3) add *reergr*	0.531***	0.450***	0.059	0.170***	0.002	0.002***	0.250	0.224	3.46
	(0.030)	(0.030)	(0.070)	(0.027)	(0.011)				
(4) add *neergr*	0.504***	0.469***	0.060	0.195***	-0.015	0.002***	0.369	0.203	2.85
	(0.059)	(0.040)	(0.084)	(0.016)	(0.016)				

Notes: Sample spans 1994Q2 to 2012Q4 prior to lag adjustment (Andrews' structural break tests were used to test for a structural break point for each regression and the results showed that 1994 is a significant break point in all regressions). *qdgap* denote quadratically detrended real GDP gap, while *gdpgr*, *reergr*, and *neergr* denote growth rates of real GDP, real and nominal effective exchange rates, respectively. The IV set for the last two regressions is augmented by adding two lags of exchange rate.

5. Discussion

The empirical results in Section 4 provide evidence of a significant structural break in the impact of globalization on China's inflation dynamics in 1994. Omitting such a structural break, as the results pertaining to the whole sample estimation indicate, can blur and inadequately measure the role of global demand in domestic inflation dynamics. In addition, the world economic slack exerts less significant impact before 1994 than after on overall domestic inflation in China. These findings have several important implications.

5.1 The structural break in 1994

The structural break in 1994 coincides with the distinct increase in the level of globalization of China in the mid-1990s (recall Figure 1). This break time also reflects the important progress of China's integration into the world economy enhanced by several financial and economic policy

regime shifts in China in the early 1990s.

First, in the spring of 1992, a speech on the subject of "promoting Chinese economic development with all efforts" by the Chinese leader Deng Xiaoping (known as the "South China Tour Speech") marked a new round of fast economic development in China. To promote opening-up policy and encourage international trade and investment, China carried out a set of comprehensive economic reforms. In January 1994, the Chinese central government called off all subsidies to export and import firms with the intention to increase competition among those firms and generate reforming incentives for the firms doing business in foreign trade. In the meantime, Export-Import Bank of China (EIBC) was established with the main mandate to facilitate and promote international economic cooperation and trade. The establishment of the EIBC not only physically promoted Chinese foreign trade and investment with the world, but also philosophically sent a signal to the world that China would pursue an open economy model of economic development in the long-run.

Second, China reformed its exchange rate system from the "dual" exchange rate regime (a market rate and an official rate that coexisted) to a unified single exchange rate system. Prior to 1994, 80 percent of foreign exchange trading volume was at the market rate and 20 percent at the official rate (Yi, 2008). In 1994, however, China reformed the "dual" exchange rate resulting in a large depreciation of RMB Yuan against US dollar (USD) after 1994. The exchange rate of RMB/USD was below 6.0 before 1994 but it depreciated markedly to above 8.2 after 1994. This depreciation of RMB in 1994 increased Chinese export in the ensuing years. More importantly, the exchange rate regime shift effectively enhanced the stability of Chinese foreign trade policy and promoted reciprocal interaction of Chinese economy with the rest of the world.

Another important change related to China's economic globalization in the mid 1990s was Chinese banking reform, after which small business firms, especially foreign trade-related firms, could obtain more financial loans than before from financial intermediaries. Indeed, the banking reforms starting from 1994 entailed a progressive move toward less administrative and more

independent banking operations. In addition to the EIBC, another two policy banks were also established in 1994, namely China Development Bank and China Agricultural Development Bank, which took over policy lending from the big-four state-owned commercial banks. Meanwhile, a small but growing number of new banks were established and the restriction on foreign bank entries was relaxed in the mid-1990s in China. These reforms in banking industry provided more finance channels for foreign trade firms and increased the presence of Chinese multinationals, small businesses, traders, and migrants to the world.

Other relevant changes in the mid-1990s include the enactment of Foreign Trade Law, the reduction of trade tariff, and the liberalization of RMB in current account (in 1996). All of these reforms and changes in the 1990s in China promoted greatly the integration of Chinese economy to the world economy. The underlying shifts also provide support and explanation for the structural break of year 1994 identified in our empirical work. The empirical results in the current study nonetheless, provide a scientific benchmark and an accurate break time for subsample analysis in the context of rising economic globalization and changing inflation dynamics in China.

5.2 Policy implications

The finding for the significant role of global demand in China's domestic inflation dynamics since 1994 entails a further discussion on policy implications. First, Chinese monetary authority or central bank has been amused by the celebrated high-growth and low-inflation Eden in China since the late 1990s. In particular, the People's Bank of China seems to be able to avoid being on the horns of one dilemma or another over the past decade and claims in most issues of their monetary policy report that it can control inflation without negative implications for economic growth and unemployment.

Our finding in this paper suggests, however, that the Chinese central bank was not as effective as it may have claimed, and the high-growth and low-inflation Eden in China since the late

1990s is likely to be attributed to favorable global economic environment rather than to the sound and healthy policies of the central bank. This raises a realistic concern that the problems the Chinese central bank faced with are likely to be complicated by the rising economic globalization of Chinese economy, which will make the central bank's job of controlling inflation more difficult than before.

More specifically, because the Phillips curve is an indispensible component in monetary policy analysis, it is natural that the impact of globalization factor on inflation can also be transmitted to other macroeconomic variables in policy analysis frameworks. Suppose we analyze the issue in a standard three-equation model with an IS curve, a Phillips curve, and a policy reaction function. The impact of globalization on inflation will be transmitted to domestic real output through the IS curve and to monetary policy via the policy reaction function. Interestingly, however, Woodford (2007) carries out a formal theoretical analysis on the possible impact of globalization on this traditional monetary policy transmission process and his simulation results appear to suggest that increased globalization engenders no substantial reduction of the effects of domestic monetary policy on domestic economy. Through the theoretical designs, Woodford provides a comprehensive and valuable discussion on a wide range of ways that globalization might weaken the central bank's ability to influence the economy.

Our results in this paper are consistent with, rather than contrary to, Woodford's (2007) analysis. As Woodford carefully interprets in his conclusion that his results mainly suggest that increased globalization should not eliminate the influence of domestic monetary policy over domestic inflation, but the degree of openness of an economy is no significance for the implementation of monetary policy. Indeed, increased international trade in financial assets, consumer goods and factors of production should lead to changes in the magnitudes of various key response elasticities relevant to the transmission mechanism for monetary policy (Woodford, 2007). In particular, changes in the degree of goods market integration affect the quantitative

specification of both the aggregate-demand and aggregate-supply blocks in Woodford's analysis.

Consistent with the existing literature, our results do not mean that the rising globalization of China will eliminate the capacity of the central bank of China in stabilizing domestic inflation; neither do we regard the rising globalization as a fatal fear to the national economy. We argue that the central bank can gear up its capacity in controlling inflation by appropriate coordination with other central banks. Even without material-coordinated actions, the central bank can still increase the precision of its relevant forecasts and thereby improve the effects of its policies on domestic economy by taking into account global development as a part of its forecasting information set or augmenting its policy analysis framework with globalization factor.

Our baseline finding, however, does call attention to the rising globalization that may generate material forces for central bankers to confront more practical issues than the traditional issues in a closed economy. The changing degree of globalization also makes the issue of change over time in the correct quantitative specification of the models used in a central bank a more pressing one to consider (Woodford, 2007).

6. Conclusions

Over the past decades, China has markedly opened its economy and dramatically improved its connectedness with the world trade networks. In conjunction with the rising globalization, China has also witnessed marked change in the nature of inflation dynamics. Therefore, this paper has focused on the impact of rising globalization on inflation dynamics in the world largest developing economy. In particular, we have constructed an extended New Keynesian Phillips curve model from microeconomic foundations and showed that globalization factor (i.e. foreign output gap) can be incorporated in such a model. We proposed that this model for Chinese inflation might have experienced a structural break, given the fact that the level of globalization

of Chinese economy has changed substantively over the period from the early 1980s to 2012.

Our empirical investigations justified this conjecture and showed that there is a significant structural change in 1994 in China's inflation dynamics model after which inflation in China responds significantly to the foreign excess demand while the slope of the inflation-domestic demand relation is reduced substantively. This finding indicates that the prescription that central banks should specifically react to developments in global economic performance is justified for China. The finding also indicates that the low and stable inflation period in China over the past decade may be attributed to the rising globalization of Chinese economy through which China benefited from the stable economic slack in its trading partners.

While the higher level of globalization may help subdue and stabilize domestic inflation by, for example, stable global economic slack, during world tranquil time, negative global economic environment can also exert extra challenges for the domestic policy-makers. A notable case is the recent world financial crisis in 2007-2008, where China was affected by weaker demand from its trading partners. In addition, as recent experience of rising commodity prices suggests, globalization may sometimes be associated with rising import prices. And even when import prices were falling, the consequences for domestic inflation depended on how foreign real incomes changed and how domestic monetary policy reacted. Therefore, studies that neglect the role of foreign demand are likely to underestimate the impact of globalization on domestic inflation dynamics.

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