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Does the Exchange Rate Pass-Through into Prices Change when Inflation Targeting is Adopted? The Peruvian Case Study between 1994 and 2007

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Abstract

This paper analyzes whether the exchange rate pass-through into prices changed when the inflation targeting scheme was adopted in Peru. Firstly, a small dynamic stochastic general equilibrium model is simulated, which shows that adopting this scheme induces an increase in exchange rate volatility. Furthermore, applying the theory of the currency denomination of international trade, it is demonstrated that increased exchange rate volatility reduces the share of firms that set their prices in foreign currency (dollars). Given that the pass-though has a direct relationship with this share, it is shown that adopting inflation targeting generates a pass-through contraction. Secondly, we empirically test whether the Peruvian Central Bank's decision to adopt inflation targeting in January 2002 actually had an effect on the pass-through estimating a time-varying vector autoregressive model which allows for an asymmetrical estimation of the pass-through. It provides parameters for both the pre and post inflation targeting regimes based on the assumption that the transition from one regime to the other is smooth. An analysis of the generalized impulse response functions reveals that the decision to adopt inflation targeting significantly decreased the exchange rate pass-throughs into import, producer, and consumer prices. The results are consistent with economic theory and are robust to the specification of parameters of the model.

Keywords: Inflation targeting; exchange rate pass-through into prices; TV-VAR models
JEL Classification: E52; E58; F31

Resumen

Este documento analiza si el traspaso del tipo de cambio a precios cambió tras la adopción del esquema de metas de inflación. En primer lugar, un pequeño modelo de equilibrio general dinámico y estocástico es simulado y se muestra que la adopción del régimen de metas de inflación induce un incremento en la volatilidad del tipo de cambio. Además, recurriendo a la teoría de la denominación de la moneda en el comercio internacional, se muestra que el aumento de la varianza del tipo de cambio reduce la proporción de firmas que fijan sus precios en moneda extranjera (dólares). Dado que el traspaso depende de manera directa de dicha proporción, se evidencia que la adopción de metas de inflación conlleva a una reducción del mismo. En segundo, lugar se procede a verificar empíricamente si la adopción del esquema de metas de inflación en enero 2002 produjo un cambio en el traspaso. Esto se realiza estimando un modelo vectorial autorregresivo de transición suave que permite la incorporación de asimetrías. Los resultados indican cambios en los parámetros para los periodos antes y después de la adopción del esquema de metas de inflación. El análisis de las funciones impulso respuesta generalizadas evidencia que la adopción de metas de inflación redujo de manera significativa los traspasos del tipo de cambio a precios de productos importados, insumos y al consumidor. Los resultados son consistentes con la teoría económica, y son robustos a la especificación de los parámetros del modelo.

Palabras clave: Metas de inflación; traspaso del tipo de cambio a precios; modelos TV-VAR
Clasificación JEL: E52; E58; F31

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1. Introduction

Since New Zealand first adopted inflation targeting (IT) in 1990, a set of countries, both industrialized and developing, has adhered to the same regime. In recent years, several empirical papers have demonstrated that the adoption of IT is linked to better macroeconomic performance (Petursson, 2004; IMF, 2005; Vega and Winkelried, 2005; Mishkin, 2007), while there are only a few that propose that the effects have been null (Ball and Sheridan, 2005). In order to determine whether the adoption of IT improved macroeconomic performance, most papers analyze the level and persistence of inflation, the effects on economic growth, and exchange rate volatility. However, determining whether the exchange rate pass-through into prices[1] changes when IT is adopted is also crucial to defining this regime's performance. This is particularly relevant in small open economies – such as Peru's – given that changes in the pass-through can affect both inflation forecasts and the effectiveness of monetary policy.

Throughout this paper, the pass-through is regarded as a nonlinear phenomenon that depends, in particular, on the monetary policy scheme. Although, to the authors' knowledge, a comprehensive theory explaining how the monetary policy scheme conditions the magnitude of the pass-through does not exist, several papers are reviewed to shed light on this relationship. For this purpose, a dynamic stochastic general equilibrium model (DSGEM) – calibrated for a small open economy – is simulated. It is shown that when the central bank adopts IT, it becomes less responsive to exchange rate fluctuations, thus allowing for increased exchange rate volatility. This result is particularly relevant given that the theory of

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1 Throughout this paper the concept of exchange rate pass-through into prices (import, producer or consumer prices) makes reference to the exchange rate variations' effect over the variations of the respective price index, provided that the former is due to an exchange rate shock. When the price index is not specified, it must be understood that the paper is referring to the exchange rate pass-through into the consumer prices.

the currency denomination of international trade predicts that an increase in the exchange rate variance induces a decrease of the share of firms that set their prices in foreign currency. Finally, by using a formal definition for the pass-through, it is shown that the latter is directly dependent on this share. Consequently, it is concluded that adopting IT reduces the pass-through.

In the empirical literature, Gagnon and Irhig (2004) are amongst the first to suggest that decreased pass-throughs, observed in several countries, can be attributed to a greater commitment and credibility of central banks in maintaining low levels of inflation. Although they do not make an explicit connection between the greater commitment and credibility of central banks and IT, it is clear that these characteristics are fundamental to the implementation of this scheme. In their paper, they estimate the pass-through for 20 countries (7 of which adopted IT) for two subsamples: one with high inflation and another with low inflation. It is worth mentioning that the cut date that separates both sub-samples does not coincide with the adoption date of IT (in the case of the countries that adopted this regime). The results of Gagnon and Irhig (2004), which are drawn from a uni-equational linear model, show that the pass-through decreased in most countries. Furthermore, although IT countries had, on average, a greater pass-through in the high inflation subsample, the result is reversed in the low inflation scenario. Finally, by means of instrumental variables, they estimate Taylor rules for all the countries considered and show that pass-through decreases are associated with a more energetic response by central banks to inflationary pressures.

Mishkin and Schmidt-Hebbel (2007) analyze if the adoption of IT allowed for inflation to be less responsive to foreign shocks (i.e. oil price or exchange rate shocks). This study uses a sample of 21 countries that adopted IT and 13 others that followed a different monetary policy scheme. An important characteristic of their analysis is that they use two possible dates for the adoption of IT: the first one refers to the beginning of the disinflation process in which inflation targets are periodically adjusted downwards (DD hereafter) while the second refers to the implementation of full-fledged IT (FD hereafter). The authors compare the differences in the pass-through before and after IT, as well as the differences between the countries that adopted IT and those that did not. For this purpose, they analyze the impulse response functions obtained from a VAR panel model for the two sub-samples. Their results show that there is no significant difference in the pass-through before and after IT is adopted when DD is considered. This result, however, changes if FD is taken into consideration. Nonetheless, when comparing the countries that adopted IT (using either DD or FD) with those that did not, it is shown that the pass-through is always smaller in the latter group.

Recent research on the pass-through in Peru includes Miller (2003) and Winkelried (2003). The former makes use of a linear VAR model to estimate the pass-through for the period from

1994-2002 while the latter analyses the pass-through's nonlinearities in a set of variables applying a VSTAR model to the same sample.

In this paper a time varying vector autoregressive model (TV-VAR, which belongs to the VSTAR family), is utilized. This model sets itself apart from standard VAR models in that it allows for parameters to be state-dependent. In particular, it allows for the pass-through in the pre-IT period to be different from that in the post-IT period. In addition, the model assumes that the transition from one state (regime) to the other is smooth.

Unlike Gagnon and Irhig (2004) but similar to the papers that utilize the VAR framework (Miller, 2003; Mishkin and Schmidt-Hebbel, 2007; Winkelried, 2003), the proposed methodology has the advantage of being able to predict and evaluate the pass-through's path after an exchange rate shock. Like Winkelried (2003), this paper has chosen a nonlinear VAR model over a linear specification, on the grounds that the pass-through is recognized as a state-dependent phenomenon. Nonetheless, this paper expands on Winkelried's work (2003) by modeling the dependency of the pass-through in an additional variable, which in this case is the monetary policy scheme. Finally, unlike studies that split the sample, the suggested methodology allows for the pass-through to be estimated in countries for which few post-IT observations are available.

The analysis of the generalized impulse response functions calculated shows that the Peruvian Central Bank's decision to adopt IT (PCB) in January 2002 led to a decrease in the exchange rate pass-throughs into import, producer, and consumer prices. In particular, there was a significant reduction of 86% in the long-run (36 months after the initial shock) exchange rate pass-through into consumer prices. The results are consistent with economic theory and are robust to the specification of the model's parameters. Furthermore, the evidence provided is relevant from a policymaker's perspective, in that it shows that IT not only contributes to price stability by pegging inflationary expectations to the target but also by reducing the effects of exchange rate shocks on inflation.

The remainder of the paper is organized as follows: section 2 explores the relationship between IT, exchange rate volatility and the pass-through, demonstrating the latter's dependency on the monetary policy scheme; section 3 presents the methodology utilized, an analysis of the series, and the result obtained; finally, section 4 provides conclusions.

2. Theoretical framework

2.1 Inflation targeting

The use of nominal anchors – that is, restrictions on domestic money's value – is an essential element of a successful monetary policy (Mishkin, 2007b). These help peg inflation expectations, thus contributing to price stability. Furthermore, from a technical perspective, without nominal anchors it is impossible to determine a unique price level, which is a necessary condition for price stability. Not so long ago, the most popular nominal anchors fixed the growth rate of the quantity of money or pegged the domestic currency price to a "strong" foreign currency. In the nineties, the failure of fixed exchange rate regimes and the concomitant inflationary processes led both industrialized and developing countries to look for an alternative nominal anchor.

The result was the implementation of IT, a scheme that can be characterized by the following elements (Mishkin, 2007b): (1) the announcement of medium-term numerical inflation targets; (2) an institutional commitment to price stability; (3) a strategy that considers all the available information in the decision making process – not limiting to the quantity of money or the exchange rate; (4) increased transparency in the conduction of monetary policy through a better communication with the public; and (5) greater accountability of the central bank for reaching its target. Bernanke and Mishkin (2007) emphasize that this monetary policy framework should be viewed as a hybrid between a rules scheme and discretionality. Although the main objective is medium-term price stability, under this scheme of "restricted discretionality," the central bank can react to external or internal transitory shocks to stabilize other variables.

Mishkin (2007a) argues that IT has some significant advantages over alternative nominal anchors. Unlike the fixed exchange rate regime yet similar to monetary targeting, IT allows central banks to counter adverse domestic shocks. Furthermore, unlike monetary targeting, the effectiveness of IT does not rely on the stability of money velocity and is more easily understood by the general public. Finally, if a central bank has credibility, the announcement of numerical targets enhances prices stability by pegging inflationary expectations to the target.

How does IT affect the pass-through? The next two sections will answer this question. Section 2.2 addresses the relationship between IT and the exchange rate volatility, while Section 2.3 explores the causal effect of a change in the latter variable on the pass-through.

2.2 Exchange rate volatility and inflation targeting

In order to determine how adopting IT affects exchange rate volatility, a DSGEM is simulated for a small open economy (see appendix A for the model specification). The system is constituted by a dynamic IS curve, a neokeynesian Phillip's curve, a Taylor rule, and three equations: inflation's decomposition, terms of trade, and the uncovered interest rate parity.

The Taylor rule, unlike the closed economy scenario, includes exchange rate variations[2] as one of its arguments; this would indicate that the central bank has incentives to minimize this variable.[3] Reinhart (2000) finds that a great number of countries that claim to have a floating exchange rate actually utilize policy instruments to avoid excessive volatility. Some reasons that would explain this behavior are the fear that an exchange rate appreciation will reduce trade competitiveness or that depreciation will generate inflationary pressures. In the case of economies with a high degree of dollarization, exchange rate depreciation leads to an additional complication in the sense that it deteriorates the balance sheets of both financial and non-financial companies.

Although monetary authorities use policy instruments (e.g. interest rate) to ensure that the output does not deviate significantly from its potential level and inflation and exchange rate variations remain low, the decision to adopt IT implies a relative increase in the weight that is given to inflation in the policy rule, which leads to a relative decrease in the weight that is given to the other policy rule arguments. If the monetary authority becomes less responsive to exchange rate variations and more responsive to inflation, one should expect to see an increase in the former variable's variance and a decrease in the latter variable's variance. Using the DSGEM described in this section, the adoption of IT is simulated by means of two exercises (a and b) that expose the system to exchange rate shocks. The exercise (a) considers a decrease of the exchange rate variations[4] coefficient in the Taylor rule. The exercise (b) considers a simultaneous increase in the inflation coefficient and a decrease in the exchange rate variations coefficient in the Taylor rule.

Figures 1 and 2 (exercises (a) and (b), respectively) suggest that the adoption of IT leads to a decrease in the inflation variance and an increase in the exchange rate variance. However, this conclusion requires careful consideration given that in the DSGEM utilized, the monetary authority only had a single policy instrument: the interest rate. Nonetheless, some central banks, including Peru's, utilize sterilized interventions in the foreign exchange market to reduce exchange rate volatility or to prevent the exchange rate level from deviating significantly from its trend (Humala and Rodríguez, 2010). The more effective these

[2] In the context of optimal monetary policy rules, the exchange rate variations refer to exchange rate deviations from its steady state. Nonetheless, in the context of simple rules it refers to the exchange rate changes between periods t and t-1. The distinction between both interpretations is beyond the scope of this paper. In any case, there is no loss of generality.
[3] De Paoli (2008) shows that in an economy characterized by price rigidities, market power, terms of trade externality, and a high degree of substitution between foreign and domestic goods, central banks can increase the residents' welfare by stabilizing the exchange rate volatility. Additionally, Benigno et al. (2003) and Bask (2006) demonstrate that, in certain cases, it is necessary to include an exchange rate term in the Tayor rule in order for there to be a rational expectations equilibrium in the economy.
[4] In the context of the DSGEM utilized in this section, the exchange rate variations refer to the deviations from its steady state.

interventions are, the smaller one should expect the increase in the exchange rate volatility to be after IT is adopted.

The relationship between exchange rate volatility and the pass-through is explored next.

2.3 Determinants of the pass-through

The magnitude of the pass-through depends primarily on the extent to which the exchange rate is able to affect import prices. In a neokeynesian context – in which firms cannot choose which prices to charge at every point in time because of menu costs – with a flexible exchange rate, the pass-through depends on which currency denomination foreign exporting firms choose (domestic or foreign) when setting prices. If all firms choose to bill in the currency of the importer country (local currency pricing or LCP), then exchange rate variations will not affect the importer country's prices. On the contrary, if firms decide to set prices in their currency (producer currency pricing or PCP), a full pass-through is generated.

Bacchetta and van Wincoop (2002) synthesize the microeconomic literature on the currency denomination of international trade. In the partial equilibrium models that they develop, firms set their prices – either in domestic or foreign currency – before the exchange rate is known. Therefore, they will choose to invoice in the currency that maximizes their expected profits – or alternatively, in the currency that minimizes the uncertainty of these profits. Let $D(p)$ be an import demand function; $C(q)$ a cost function; q the quantity of certain import good (or bundle of goods); p the price paid by the importer for the mentioned good (or bundle of goods); p^I the price (p) set in the importer's currency; p^E the price (p) set in the exporter's currency; and S the nominal exchange rate (defined as the price of foreign exchange in terms of domestic currency). Then, the exporter's profits when it sets its prices in the importer's currency and its own are given, respectively, by:

$$\Pi^I = \left(\frac{p^I}{S}\right) D(p^I) - C\left(D(p^I)\right) \qquad (1)$$

$$\Pi^E = p^E D(p^E S) - C\left(D(p^E S)\right) \qquad (2)$$

If the exporting firm follows LCP, then there would be uncertainty about the price of the good in the exporter's currency; however, if it follows PCP, there would be uncertainty about the demand for the good. The optimal decision depends on the functional forms of the demand and cost functions. Nevertheless, it can be shown that the exporter will choose to set its prices in the currency that is associated with the profit function that is the most convex in the exchange rate. Devereux et al. (2003), assuming specific demand and cost functions, assert that foreign exporting firms will only take the exchange rate variance and the covariance between itself and the marginal cost (w^*) into account when making a decision regarding currency denomination. Hereafter the asterisk super index indicates "foreign".

Assuming a demand function of the form $D(p) = p^{-\mu}$ and a cost function of the form $C(q^*) = w^*q^*$, where μ is the price elasticity of demand (usually greater that one), it can be demonstrated that the exporting firm will set its prices in its own currency as long as the following condition holds (see demonstration in appendix B); the variables in bold indicate equilibrium levels:

$$\left[\frac{(\mu+1)(p^E-\boldsymbol{w}^*)}{2} - \frac{(p^I)^{1-\mu}(p^E)^{\mu}}{\mu}\right] var(S) + cov(S, w^*) > 0 \qquad (3)$$

Note that condition (3) does not depend on price volatility since the model assumes that menu costs exist. Additionally, assuming the existence of monopolistic competition – where, in the limit, p^E converges to $\boldsymbol{w}^*$– condition (3) can be rewritten as follows:

$$-\frac{(p^I)^{1-\mu}(p^E)^{\mu}}{\mu} var(S) + cov(S, w^*) > 0 \qquad (4)$$

In condition (4), the first element of the inequality has a negative relationship with the exporting firm's decision to invoice in its own currency; in particular, as the exchange rate variance increases, the share of firms that choose to use LCP also increases. This result is explained by the fact that the profit function would be more convex in the exchange rate under LCP than under PCP. On the other hand, if the covariance between the exchange rate and marginal cost is positive, firms would have an incentive to use PCP. This is attributable to the fact that a simultaneous increase in the exchange rate and marginal costs would reduce the expected profits more under LCP that under PCP.

Bacchetta and van Wincoop (2002) then extend their initial model to allow for domestic production to compete with imports. They show that when the proportion of exports in the total demand is large and firms can coordinate their decision about the currency denomination of their invoices, they will set their prices in their own currency. The same would occur as the degree differentiation of import products increases. Both situations are closely related to market power, which reduces demand uncertainty under PCP. If market power is large enough, exchange rate volatility – which generates uncertainty about the price under LCP – could give firms an incentive to set their prices in foreign currency. Condition (3) allows for a formal explanation of this behavior; if there is a large enough markup – that is p^E sufficiently greater than $\boldsymbol{w}^*$ – which is a common feature in industries characterized by market power, then the exchange rate variance coefficient could be positive.

Although partial equilibrium models can help shed light on the firms' rationality when deciding which currency will be used to set prices, incorporating an analysis of this kind in a general equilibrium framework allows for a better understanding of the relationships between the firms' decision and the macroeconomic setting. Bacchetta and van Wincoop (2002), as well as Devereux et al. (2003), develop general equilibrium models and extend the rules that guide the firms' decision about which currency will be used for billing purposes. The main change with regard to the previous models is that the exchange rate variance is no longer exogenous and instead depends on monetary shocks – both domestic and foreign.

In section 2.2, theoretical evidence was provided, through simulation exercises, showing that the adoption of IT leads to an exchange rate variance increase. By means of condition (4), it follows that said increase reduces the share of firms that set their prices in foreign currency. Finally, due to the fact that the pass-though magnitude depends on the exchange rate's ability to affect imported goods prices, and said ability is reduced by LCP, one should expect to see a pass-through decrease.[5]

2.4 Exchange rate pass-through into prices: a nonlinear phenomenon

Winkelried (2003) points out that it is a common mistake to assume that the exchange rate pass-through into prices is a stable parameter and that, in reality, it is contingent on the state of the economy. "Although it is a microeconomic phenomenon, the macroeconomic setting can alter the effect of the exchange rate on inflation through the distributional chain. Firms can face a macroeconomic shock of such a magnitude or nature that could cause a permanent change in the volume of traded goods, markups and, therefore, in the magnitude and persistence of the PT [pass-through]."[6] (Winkelried, 2003) In particular, he analyzes five macroeconomic variables that condition the magnitude of the pass-through: the exchange rate dynamic, the output cycle, the real exchange rate misalignment, the inflationary setting, and dollarization.

Nonetheless, it can be demonstrated that the pass-through is also a nonlinear phenomenon in the monetary policy scheme. Let PT_τ be the pass-through at time τ:

$$PT_\tau = \frac{\sum_{j=0}^{\tau} \frac{\partial \pi_{t+j}^{CPI}}{\partial u_t^e}}{\sum_{j=0}^{\tau} \frac{\partial \Delta S_{t+j}}{\partial u_t^e}} \qquad (5)$$

Where π^{CPI} is the percent variation of the consumer price index (CPI) and u^e is an exchange rate shock. Equation (5) can be rewritten as follows (see demonstration in appendix C):

$$PT_\tau = \frac{I\lambda + \sum_{j=1}^{\tau} \frac{\partial \pi_{t+j}^{CPI}}{\partial u_t^e}}{\sum_{j=0}^{\tau} \frac{\partial \Delta S_{t+j}}{\partial u_t^e}} \qquad (6)$$

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[5] Refer to Gopinath et al. (2010) for a discussion on endogenous currency choice and exchange rate pass-through in a dynamic setting.
[6] Authors' translation.

Where I is the imported goods proportion in the consumption basket and λ is the share of foreign exporting firms that set their prices in foreign currency. Equation (6) shows that as long as λ is not a stable parameter, the pass-through will not be linear. Furthermore, there is no theoretical evidence supporting the stability of λ; on the contrary, it depends on the price elasticity of demand for the imported good, the firms' markups, the exchange rate variance, and its covariance with the marginal costs (see condition (3)). In particular, as was shown in section 2.4, the adoption of IT incentivizes a greater number of firms to follow LCP – or, accordingly, a reduction of λ – which translates into a pass-through decrease.

3. Methodology

3.1 A nonlinear model for the pass-through

Based on Winkelried (2003), a vector smooth transition autoregressive model (VSTAR) is utilized to estimate the pass-through. This methodology is chosen because it helps identify the effects of various shocks on variables of interest. In particular, it facilitates the identification of the effects of exchange rate exogenous shocks on the exchange rate itself and on import, producer, and consumer price inflations. Additionally, it allows for the explicit modeling of the pass-through's nonlinearity in the monetary policy scheme. Both characteristics make it possible to estimate exchange rate pass-throughs into different price indexes, both for the pre-IT and post-IT periods.

The model to be estimated is a multivariate generalization of the STAR model proposed in Terasvirta (1994), and represents a particular case of the VSTAR base model proposed in He et al. (2009):

$$\boldsymbol{Y_t} = \left(\boldsymbol{v_1} + \textstyle\sum_{i=1}^{p} \boldsymbol{\alpha_{1i} Y_{t-i}}\right)\left(1 - \boldsymbol{G}(\boldsymbol{s_t}; \boldsymbol{\gamma}, \boldsymbol{c})\right) + \left(\boldsymbol{v_2} + \textstyle\sum_{i=1}^{p} \boldsymbol{\alpha_{2i} Y_{t-i}}\right)\boldsymbol{G}(\boldsymbol{s_t}; \boldsymbol{\gamma}, \boldsymbol{c}) + \boldsymbol{\varepsilon_t} \qquad (7)$$

with $\boldsymbol{Y_t'} = [s_t \quad y_t \quad \Delta e_t \quad \pi_t^m \quad \pi_t^w \quad \pi_t^c]$

$$\boldsymbol{G}(\boldsymbol{s_t}; \boldsymbol{\gamma}, \boldsymbol{c}) = diag\{G(s_t; \gamma, c), \dots, G(s_t; \gamma, c)\}$$

$$G(s_t; \gamma, c) = \frac{1}{1 + exp\{-\gamma(s_t - c)\}} \qquad (8)$$

The variables in vector $\boldsymbol{Y_t'}$ are the non-core inflation (supply shocks), the output gap (demand shocks), the percent variation of the nominal exchange rate as well as import, producer, and consumer price inflations respectively.[7] Function $G(s_t; \gamma, c)$ is a logistic function that takes values between 0 and 1, s_t is the variable that guides the transition from one state of nature

[7] The specification of the endogenous variables vector is based on McCarthy (1999). The series of non-core inflation, output gap, percent variation of the nominal exchange rate, and consumer price inflation were taken from the Peruvian Central Bank statistics. The series of import and producer price inflations were taken from the Peruvian National Institute for Statistics and Informatics (INEI). All these variables were constructed in monthly log-differences.

to another, c is a threshold that allows for the distinction between the states of nature and γ is a smoothing parameter. As s_t increases, the transition function changes monotonically from 0 to 1. If $\gamma \rightarrow \infty$, then the logistic function becomes an indicator function and the transition from one regime to another is almost instantaneous. On the other hand, if $\gamma = 0$ the model collapses to the linear case. According to Lundbergh et al. (2000), the system constituted by equations (7) and (8) can be interpreted as a model with two regimes associated with the extreme values of the transition function, $G(s_t; \gamma, c) = 0$ and $G(s_t; \gamma, c) = 1$, where the parameters transition from one regime to the other smoothly.

Van Dijk et al. (2000), based on Terasvirta (1994), propose 6 steps to estimate STAR (VSTAR) models:

1. Specify the linear VAR model of order p.
2. Test the null hypothesis of linearity against the alternative of VSTAR nonlinearity. If linearity is rejected, select s_t and the form of the transition function $G(s_t; \gamma, c)$.
3. Estimate the parameters of the VSTAR model.
4. Evaluate the model using diagnostic tests and impulse response analysis.
5. Modify the model if necessary.
6. Use the model for descriptive or forecasting purposes.

3.2 Time series analysis

Figure 3 shows the time series used in the empirical analysis. The model described by equations (7) and (8) requires all series to be integrated of order zero. In order to verify it, the augmented Dickey-Fuller GLS test (ADF-GLS) proposed by Elliott, Rothenberg and Stock (1996) is performed on all variables. Additionally, the Zivot and Andrews (1992) test is conducted for the consumer price index series, given that in Figure 3 it appears that this series experienced a trend shift.

The results are shown in Table 1. The ADF-GLS test rejects the null hypothesis that the non-core inflation, output gap, percent change in the exchange rate, and import and producer price inflations have a unit root, and as such they are stationary. Nonetheless, the test is not able to reject the null hypothesis that the consumer price inflation series is integrated of order one. This comes as no surprise, given that there is ample evidence that this test has a low power to differentiate unit root paths from stationary paths with a structural break. Certainly, the adoption of the IT regime with targets expressed in terms of consumer price inflation should represent a structural break for that variable. For these reasons, the test of Zivot and Andrews (1992) is performed, which not only overcomes the low power problem, but endogenously determines the break date in the series. The test indicates rejection of the presence of a unit root.

Next, the optimal order of the linear VAR is specified. As is shown in Table 2, the Schwarz and final prediction error information criteria indicate that the optimal number of lags is one and two, respectively. In favor of a more general model, the order of the linear VAR is set at two. Following Terasvirta's methodology, the next step is to conduct a nonlinearity test.

3.3 Nonlinearity test for the pass-through

While there is theoretical evidence showing that the pass-through is a nonlinear phenomenon in the monetary policy scheme, it is recommendable to take this evidence as a hypothesis and test it empirically. For that purpose, a formal nonlinearity test for the model presented in section 3.2 is performed.[8] In order to conduct this test, one needs to first define the variable that guides the transition in the model (s_t). A priori, there are three theoretical candidates: time, the exchange rate variance, and the share of firms that set their prices in foreign currency. In this context, the rationale is that the adoption of IT is associated with a particular date in time (the adoption date of the regime), to an exchange rate variance increase, and to a decrease in the share of firms that follow PCP. In this paper, time is taken as the transition variable ($s_t = t$) and the adoption date of IT is taken as the threshold ($c = January$ 2002). Time is chosen over the exchange rate variance because of its closer relationship with the adoption of IT. Although an exchange rate variance increase is associated with the adoption of IT, financial stress or foreign exchange market interventions can also have an effect without implying a change in the policy scheme. The share of firms that set their prices in foreign currency is not considered a feasible transition variable due to the lack of data.

Following the methodology proposed in He et al. (2009), a likelihood ratio test is performed in order to contrast the null hypothesis of linearity – the parameters are constant in time – against the alternative hypothesis of VSTAR nonlinearity with $s_t = t$ – the parameters change smoothly in time.

The results are presented in Table 2. The test rejects the null hypothesis of linearity for all the VAR specifications considered. Based on Terasvirta (1994), the next section deals with the VSTAR model estimation.

3.4 Estimation

[8] Recursive estimations were also conducted to shed light on the nonlinearity of the pass-through. Accordingly, the pass-through into the three price indexes in the model were first estimated, for the period between the April 1994 and January 2001, and later for samples including an additional month until December 2003. Graphical evidence rejects the hypothesis of linearity.

In order to estimate the model described in section 3.1 one needs to specify the order of the VSTAR and the arguments of equation (8). To specify the VSTAR order, the optimal number of lags under the linear model (p = 2), is selected. The smoothing parameter is chosen arbitrarily; as such, it must be subjected to a subsequent robustness analysis. As was explained in section 3.3, the transition variable and the threshold are time and the adoption date of inflation targeting (January 2002), respectively. It is worth mentioning that studies on VSTAR models that use time as the transition variable refer to said models as time-varying vector autoregressive models (TV-VAR).

When the threshold and the smoothing parameter in the transition function are known, the TV-VAR model is linear in the rest of autoregressive parameters. Thus, conditioning on the values of c and γ, the model can be estimated by ordinary least squares (Lundbergh et al., 2000).

Once the reduced form of the model is estimated, one needs to identify it in order to compute the exchange rate pass-throughs into import, producer and consumer prices – as is specified in equation (5). McCarthy (1999) and Winkelried (2003) utilize the Cholesky decomposition to identify their respective models and exalt the benefits of this method in shedding light on the shocks' distributional chain. In particular, the import, producer, and consumer price inflations will depend on supply, demand, exchange rate, and import price shocks. In addition, the producer price inflation will also depend on its own innovations while the consumer price inflation will depend on the former's innovations as well as its own. In this paper, the Cholesky decomposition is also utilized to identify the TV-VAR model.

In order to calculate the pass-throughs, one needs to first calculate the impulse response functions of the exchange rate and import, producer, and consumer price inflations to exchange rate innovations. In nonlinear models, unlike linear models, these functions depend on the history of the series and the shocks to which they are exposed. For this reason, Koop et al. (1996) propose to use generalized impulse response functions, which can be interpreted as averages of what would happen to a series conditioned on its past and present.

The pass-throughs, which are calculated with generalized impulse response functions[9] as a reaction to a one standard deviation exchange rate shock, are reported in Figure 4. The sample utilized is from April 1994 until December 2007.

Figure 4 shows a statistically significant decrease of the exchange rate pass-throughs into import, producer, and consumer prices for up to three years after the shock.

[9] The generalized impulse response functions were calculated following the methodology proposed in chapter 5 of Koop et al. (1996), utilizing 1000 Monte Carlo replications.

Next, the robustness of the model to the specification of the smoothing parameter is analyzed; see Figure 5. For this purpose, the exchange rate pass-throughs into import, producer, and consumer prices (to a one standard deviation exchange rate shock), utilizing different values for the smoothing parameter, are presented. The juxtaposition of the exchange rate pass-throughs into the three price indexes considered in the model, as shown in Figure 5, indicate that the model is robust to the specification of the smoothing parameter. Nevertheless, Figure 4 shows that the difference between the pass-throughs for the pre and post IT periods are statistically different at a 0.05 significance level.

Since generalized impulse response functions are sensitive to the sign and magnitude of the shock to which they are exposed, a sensitivity analysis of the pass-throughs to different types of shocks (large ones, negative ones, and a combination of both) is presented below. Table 3 shows that the exchange rate pass-throughs into import, producer, and consumer prices are seldom sensitive to the characteristics of the shock.

Table 4 presents different estimates of the pass-through. The pass-through one year after an exchange rate shock found in Winkelried (2003) – for the inflation acceleration period, is very close to the one estimated for the pre-IT period in this paper. These two pass-throughs are twice the size of that estimated by Miller (2003). Additionally, the post-IT pass-through one year after the initial shock is not significantly different from zero. Nonetheless, the post-IT long run pass-through is significantly different from zero, and is 62.5% smaller than the one found in Winkelried (2003) for inflation deceleration periods.

On another note, the PCB intervened frequently in the foreign exchange market during the period of observation, so it is worth asking if this could have biased the results obtained in this paper. In section 2 it was shown that a negative relationship exists between exchange rate volatility and the pass-through and that the adoption of IT increased the former. Nonetheless, the effect of foreign exchange market interventions is the inverse of that associated with adopting IT in that exchange rate volatility falls. So if there were a bias in the estimation, it would be in the direction of underestimating the decrease of the pass-through.

4. Conclusions

IT, which was first adopted by New Zealand and is currently being implemented by 25 other countries, focuses primarily on keeping inflation within an established range in the medium term. When monetary authorities remain committed to meeting their respective targets, it is possible to exercise more control over inflation expectations, which subsequently contributes to price stability. Nonetheless, another mechanism through which IT can ensure price stability is by reducing the effects that exchange rate shocks have on inflation.

In this paper, the last of the aforementioned mechanisms was explored and it was shown that PCB's decision to adopt IT in January 2002 led to a decrease in the exchange rate pass-throughs into import, producer, and consumer prices. From a theoretical standpoint, this result is explained by an exchange rate variance increase following the adoption of IT which, in turn, reduced the share of firms that set their prices in foreign currency. Consequently, by having a greater proportion of firms setting their invoices in domestic currency, the exposure of price stability to exchange rate shocks was weakened.

This paper has obviated a formal analysis of the residuals due to the fact that the no residual autocorrelation, parameter constancy, and no remaining nonlinearity tests – usually applied in STAR models – have not been generalized for the multivariate case (VSTAR or TV-VAR). Notwithstanding, the flexibility of VSTAR models to account for nonlinear dependencies and the usefulness of impulse response analysis in making predictions make this kind of model a suitable tool for evaluating the behavior of the pass-through. Accordingly, models similar to the one proposed in this paper could be generalized to include exogenous dynamics such as foreign exchange interventions to determine if they contribute to the understanding of the pass-through. Additionally, extending the model to other countries that adopted IT could be key in determining if the pass-through reduction experienced in Peru constitutes a regularity or should be classified an empirical outlier.

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Appendix A

The dynamic stochastic general equilibrium model utilized corresponds to that of Gali and Monacelli (2005) and has been augmented with a Taylor rule using lagged information. The calibration of the model corresponds to that of Bask (2006). The specification of the model is as follows:

Dynamic IS

$$x_t = x_{t+1}^e - \alpha\left(r_t - \pi_{H,t+1}^e - rr_t\right) \quad (1)$$

Neokeynesian Phillip's curve

$$\pi_{H,t} = \beta\pi_{H,t+1}^e + \gamma x_t \quad (2)$$

Inflation's decomposition

$$\pi_t = \pi_{H,t} + \delta\Delta s_t \quad (3)$$

Terms of trade

$$s_t = e_t + p_t^* - p_{H,t} \quad (4)$$

Uncovered interest parity

$$r_t - r_t^* = \Delta e_{t+1}^e \quad (5)$$

Taylor rule

$$r_t = \zeta_r r_{t-1} + \zeta_x x_{t-1} + \zeta_\pi \pi_{t-1} + \zeta_e \Delta e_{t-1} \quad (6)$$

where x_t is the output gap, r_t is the nominal interest rate, $\pi_{H,t}$ is the domestic inflation, rr_t is the natural interest rate, π_t is the consumer price inflation, s_t is the terms of trade, e_t is the nominal exchange rate, p_t^* is the foreign goods price index, $p_{H,t}$ is the domestic goods price index, and the super index e indicates rational expectations.

Appendix B

With a demand function of the form $D(p) = p^{-\mu}$ and a cost function of the form $C(q^*) = w^* q^*$, we can write the expected profit functions when a firm follows LCP or PCP respectively, as follows:

$$\Pi^I = \left(\frac{p^I}{S} - w^*\right)(p^I)^{-\mu}$$

$$\Pi^E = (p^E - w^*)(p^E S)^{-\mu}$$

By performing a second order Taylor expansion for each function, we obtain (the equilibrium values around which the expansions are made are in bold):

$$\Pi^I \approx \left(\frac{p^I}{\boldsymbol{S}} - \boldsymbol{w}^*\right)(p^I)^{-\mu} - \frac{(p^I)^{1-\mu}}{\boldsymbol{S}^2}(S - \boldsymbol{S}) - (p^I)^{-\mu}(w^* - \boldsymbol{w}^*) + \frac{1}{2!}\left\{\frac{2(p^I)^{1-\mu}}{\boldsymbol{S}^3}(S - \boldsymbol{S})^2\right\}$$

$$\Pi^E \approx (p^E - \boldsymbol{w}^*)(p^E \boldsymbol{S})^{-\mu} - \frac{\mu(p^E - \boldsymbol{w}^*)(p^E)^{-\mu}}{\boldsymbol{S}^{\mu+1}}(S - \boldsymbol{S}) - (p^E \boldsymbol{S})^{-\mu}(w^* - \boldsymbol{w}^*)$$
$$+ \frac{1}{2!}\left\{\frac{\mu(\mu+1)(p^E - \boldsymbol{w}^*)(p^E)^{-\mu}}{\boldsymbol{S}^{2+\mu}}(S - \boldsymbol{S})^2 + 2\frac{\mu(p^E)^{-\mu}}{\boldsymbol{S}^{\mu+1}}(S - \boldsymbol{S})(w^* - \boldsymbol{w}^*)\right\}$$

The foreign exporting firm will choose to set its prices in its own currency if by doing so it obtains higher expected profits than what it would achieve by setting its prices in the local currency: $E\Pi^E - E\Pi^I > 0$. Taking expectations:

$$E[\Pi^I] \approx E\left[\left(\frac{p^I}{\boldsymbol{S}} - \boldsymbol{w}^*\right)(p^I)^{-\mu}\right] + \frac{(p^I)^{1-\mu}}{\boldsymbol{S}^3} var(S)$$

$$E[\Pi^E] \approx E[(p^E - \boldsymbol{w}^*)(p^E \boldsymbol{S})^{-\mu}] + \frac{\mu(\mu+1)(p^E - \boldsymbol{w}^*)(p^E)^{-\mu}}{2\boldsymbol{S}^{2+\mu}} var(S)$$
$$+ \frac{\mu(p^E)^{-\mu}}{\boldsymbol{S}^{\mu+1}} cov(S, w^*)$$

Assuming that: $E\left[\left(\frac{p^I}{\boldsymbol{S}} - \boldsymbol{w}^*\right)(p^I)^{-\mu}\right] = E[(p^E - \boldsymbol{w}^*)(p^E \boldsymbol{S})^{-\mu}]$, we get the following condition:

$$\left[\frac{(\mu+1)(p^E - \boldsymbol{w}^*)}{2\boldsymbol{S}^{2+\mu}} - \frac{(p^I)^{1-\mu}(p^E)^{\mu}}{\mu \boldsymbol{S}^3}\right] var(S) + \frac{1}{\boldsymbol{S}^{\mu+1}} cov(S, w^*) > 0$$

Normalizing the exchange rate to one ($\boldsymbol{S}$ =1), the previous condition can be rewritten as:

$$\left[\frac{(\mu + 1)(p^E - \boldsymbol{w}^*)}{2} - \frac{(p^I)^{1-\mu}(p^E)^{\mu}}{\mu}\right] var(S) + cov(S, w^*) > 0$$

Appendix C

Let the consumer price index (p_t^{CPI}) be defined as follows:

$$p_t^{CPI} = I[\lambda(S_t + p_t^E) + (1-\lambda)p_t^I] + (1-I)p_t^{NT}$$

where all the variables are expressed in logarithms, p^{NT} is the non-tradable goods price index, p^E is the import good (or bundle of goods) price denominated in foreign currency, p^I is the import good (or bundle of goods) price denominated in domestic currency, S is the exchange rate, I is the proportion of import goods in the consumption basket, and λ is the share of foreign exporting firms that set their prices in foreign currency. Totally differentiating the equation results in:

$$\pi_t^{CPI} = I[\lambda(\Delta S_t + \pi_t^E) + (1-\lambda)\pi_t^I] + (1-I)\pi_t^{NT}$$

Then, by partially differentiating with respect to an exchange rate shock (u_t^e) we obtain:

$$\frac{\partial \pi_t^{IPC}}{\partial u_t^e} = I\lambda$$

Finally, by replacing the latter expression in the pass-through definition, the result is the following functional form:

$$PT_\tau = \frac{I\lambda + \sum_{j=1}^{\tau} \frac{\partial \pi_{t+j}^{IPC}}{\partial u_t^e}}{\sum_{j=0}^{\tau} \frac{\partial \Delta S_{t+j}}{\partial u_t^e}}$$

Table 1. Unit root test

	s	y	Δe	πm	πw	πc
DF-GLS*	-3.1791	-3.9314	-8.9799	-7.9085	-6.6860	-1.9361
Critical value (5%)	-1.9425	-1.9425	-1.9425	-1.9425	-1.9425	-2.9440
Number of lags	4	4	0	0	0	4
Zivot & Andrews*						-4.6077
Critical value (5%)						-5.3640
Dummy**						T
Break date						APR 2001

* Test statistics are provided, ** Indicates M if a change in mean is contrasted, T if a change in trend is contrasted and TM if both a change in mean and trend are contrasted.

Table 2. Nonlinearity test – likelihood ratio

VAR(p)	log-likelihood		LR statistic	Critical value (5%)
	H1: Unrestricted	H0: Restricted model		
1 *	4672.0	4618.0	108.0	58.1
2 **	4733.2	4648.2	170.1	99.6
3	4780.1	4666.6	227.0	139.9
4	4818.5	4674.1	288.7	179.6
5	4885.7	4709.1	353.2	218.8

* Order of the linear VAR that minimizes the Schwarz criterion. ** Order of the linear VAR that minimizes the final prediction error criterion.

Table 3. Sensitivity analysis of the pass-through to the shock's characteristics

		Into import prices				Into producer prices				Into consumer prices			
		e=1	e=-1	e=2	e=-2	e=1	e=-1	e=2	e=-2	e=1	e=-1	e=2	e=-2
t+3	Pre-IT	0.361	0.361	0.361	0.361	0.169	0.169	0.169	0.169	0.068	0.068	0.068	0.068
	Post-IT	0.175	0.174	0.174	0.174	0.016	0.016	0.016	0.016	-0.010	-0.010	-0.010	-0.010
t+12	Pre-IT	0.389	0.389	0.389	0.389	0.368	0.368	0.369	0.369	0.304	0.304	0.305	0.305
	Post-IT	0.193	0.193	0.193	0.193	0.080	0.080	0.080	0.080	0.000	0.000	0.000	0.000
t+30	Pre-IT	0.407	0.407	0.407	0.407	0.467	0.467	0.468	0.468	0.421	0.420	0.421	0.421
	Post-IT	0.205	0.204	0.204	0.204	0.227	0.227	0.227	0.226	0.049	0.049	0.049	0.049

Note: The values tabulated correspond to the pass-throughs t+k periods after an exchange rate shock of 'e' standard deviations. When e=-1, e=2 and e=-2 the impulse response functions were multiplied by -1, divided by 2 and divided by -2, respectively, in order to make them comparable with the base scenario of e=1.

Table 4. Comparison with other papers that analyze the pass-through in Peru

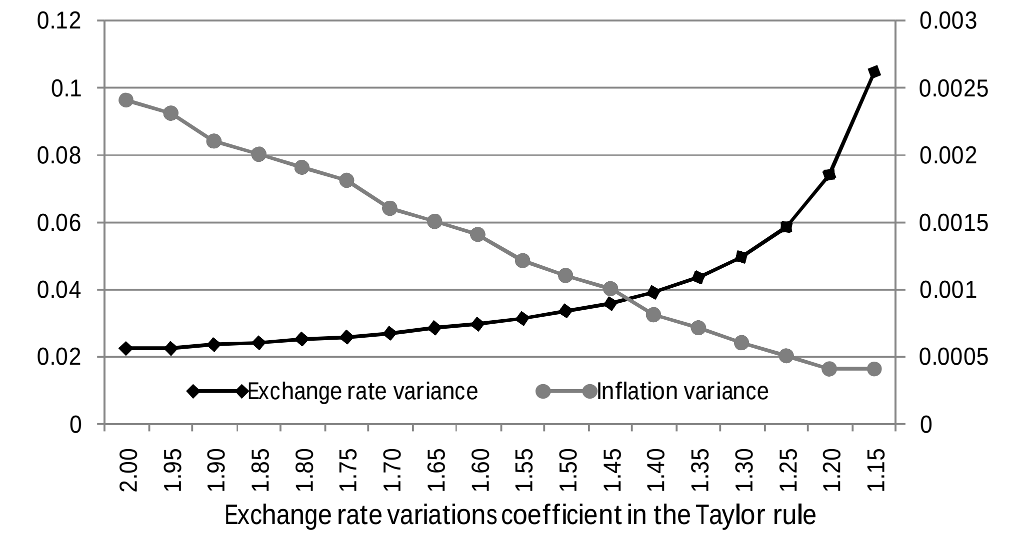
Author(s)	Pass-through		Mean life (monthly)	Sample	Type of model
	After 1 year	Long-run			
Miller (2003)	15	15	6	1994-2002	L
Winkelried (2003)	30* 12**	33* 16**	4 5	1994-2002	NL
Authors' estimations	30*** 0****	43*** 6****	8 19	1994-2007	NL

*For periods of inflation acceleration, ** for periods of inflation deceleration, *** for pre-IT periods, **** for post-IT periods.

Note: The mean life refers to the number of months that take for one to observe 50% of the long-run pass-through . The type of model column indicates L if linear and NL if nonlinear.

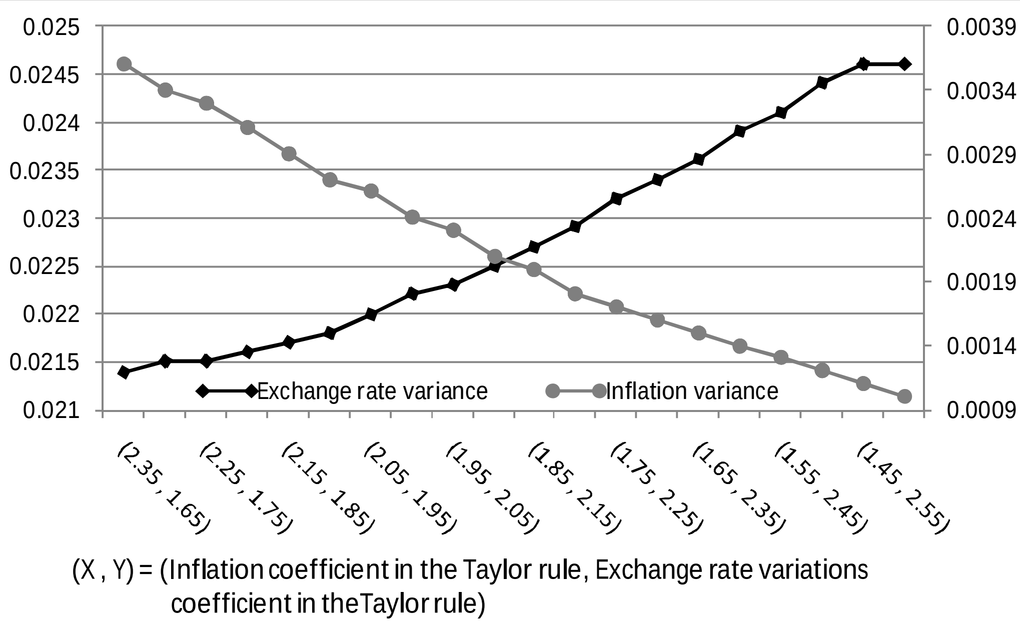
Sources: Miller (2003), Winkelried (2003) and authors' estimations.

Figure 1. Exercise (a) – Exchange rate and inflation theoretical variances



Note: The left axis corresponds to the exchange rate variance and the right axis to the inflation variance.

Figure 2. Exercise (b) - Exchange rate and inflation theoretical variances



Note: The left axis corresponds to the exchange rate variance and the right axis to the inflation variance.

Figure 3. Series of the VSTAR model

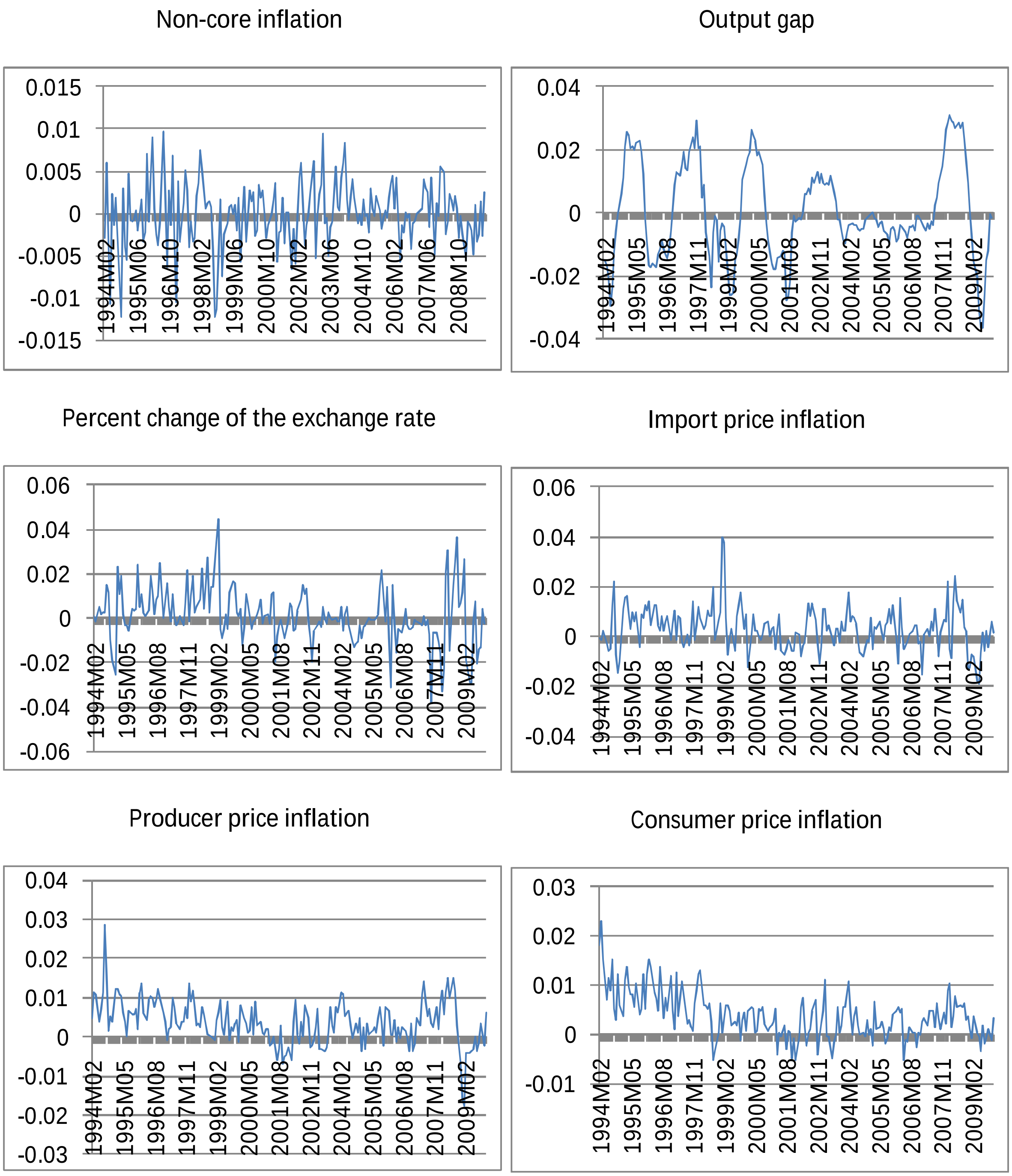
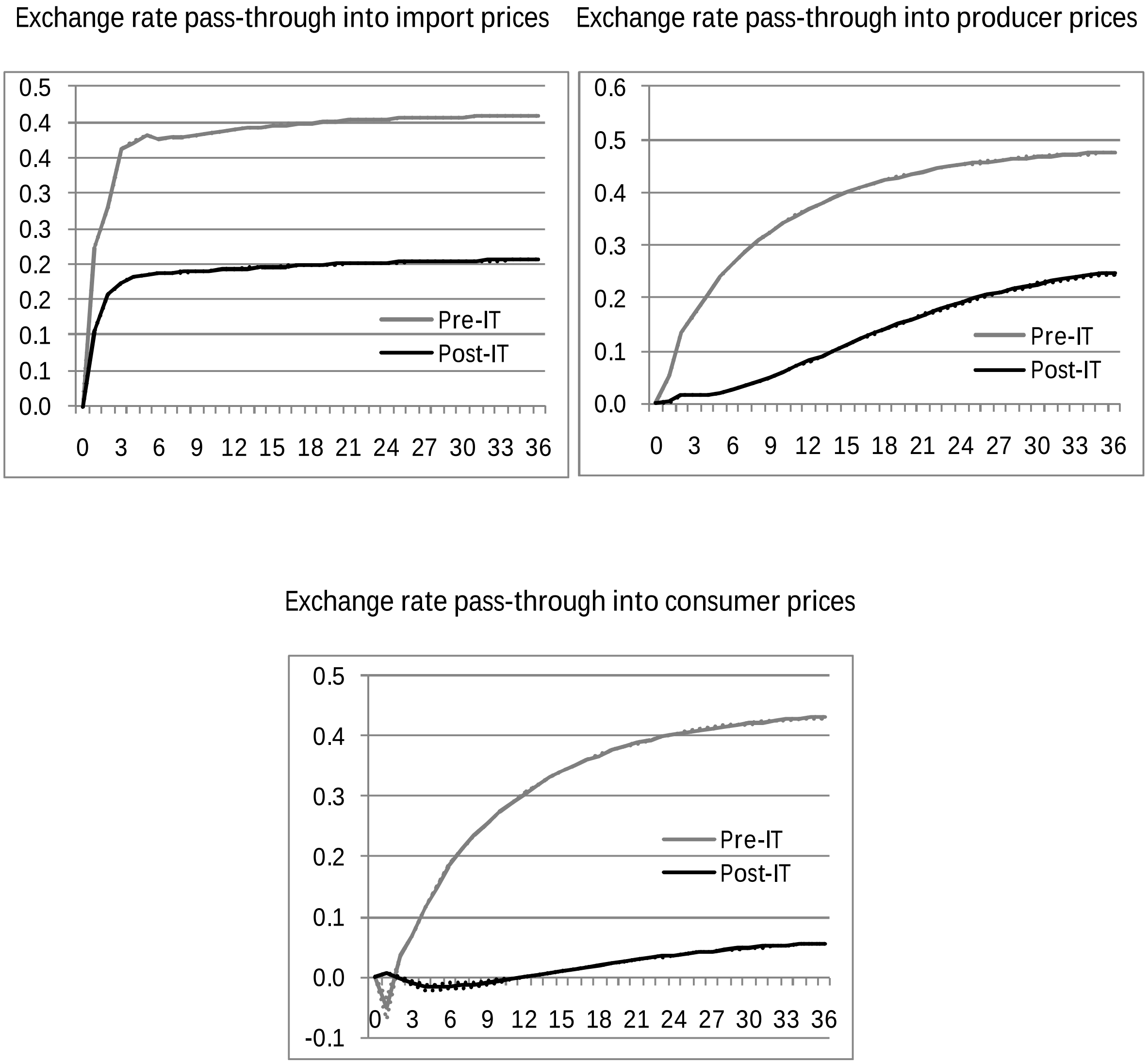


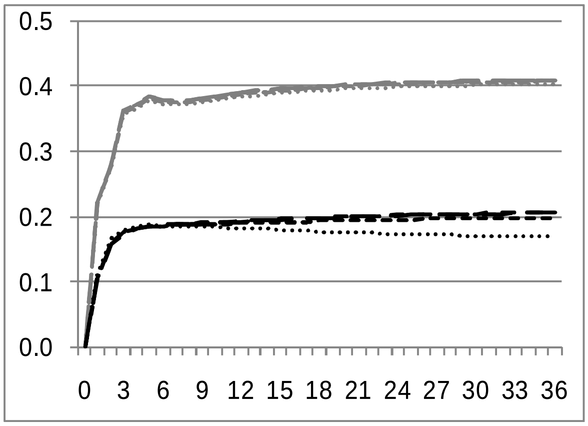
Figure 4. Pass-throughs using γ=2.5



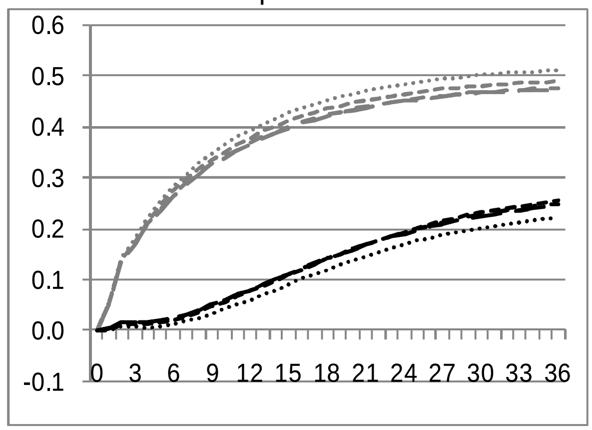
Note: The dotted lines represent confidence bands at a 5% significance level.

Figure 5. Robustness analysis to the smoothing parameter

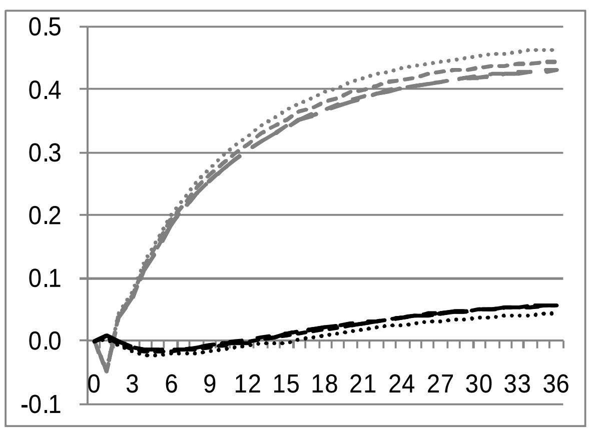
Exchange rate pass-throughs into import prices



Exchange rate pass-throughs into producer prices



Exchange rate pass-throughs into consumer prices



Note:

Pre-IT smoothing parameter γ=0.5 γ=1 γ=2.5 γ=10 γ=25

Post-IT smoothing parameter γ=0.5 γ=1 γ=2.5 γ=10 γ=25

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