A THEORETICAL APPROACH TO STERILIZED FOREIGN EXCHANGE INTERVENTION

Mauricio Villamizar-Villegas*
Central Bank of Colombia

David Perez-Reyna
Universidad de los Andes

Abstract. In this paper, we survey prominent theories that have shaped the literature on sterilized foreign exchange interventions. We identify three main strands of literature: (1) that which deems interventions futile; (2) that which requires some market friction (i.e. limited arbitrage) in order for interventions to be effective; and (3) that which advocates the use of interventions as long as they convey signals on the stance of future monetary policy. We contribute to the literature in three important ways. First, by reviewing new theoretical models that have surfaced within the last decade. Second, by further penetrating into the theory of interventions in order to analyze the key features that make each model distinct. And third, by only focusing on sterilized operations, which allows us to sidestep the effects induced by changes in the stock of money supply. In addition, the models that we present comprise both a macro and microstructure approach so as to provide a comprehensive view of the theory behind exchange rate intervention.

Keywords. Impossible trinity; Portfolio balance channel; Signaling channel; Sterilized foreign exchange intervention; Uncovered interest rate parity

1. Introduction

The breakdown of the Bretton Woods system in the early 1970s marked the beginning of the greatest exchange rate liberalization in history. Major currencies were allowed to float, while others fluctuated within narrow bands. Decades later, during the aftermath of the European exchange rate crisis of the 1990s, countries steered away from intermediate schemes toward either hard pegs or fully flexible rates. It was during this time that the “corner hypothesis” (Eichengreen, 1994) or the “fix or float” proposition (Obstfeld and Rogoff, 1995) became conventional wisdom. This idea quickly spread to emerging markets, intensely reinforced by the East Asia crises of 1997–1998, and the failure of Argentina’s currency board in 2001. Since then, central banks have allegedly opted for monetary policy autonomy where inflation targeting plays a leading role.

Notwithstanding, the empirical evidence has shown that most countries have been reluctant to relinquish control over the value of their currencies. In fact, industrialized countries have led concerted initiatives to affect the value of major exchange rates, some of which include the Smithsonian Agreement (December

*Corresponding author contact email: mvillavi@banrep.gov.co, mv276@georgetown.edu.co; Tel: +57-1-3431111.
In this paper, we survey prominent theories that have shaped the literature on sterilized foreign exchange interventions (i.e. purchases or sales of foreign currency, intended to affect the exchange rate, but without altering the monetary base). In the context of Blanchard et al. (2015), “Most economists agree that unsterilized intervention is effective at influencing the exchange rate... but the case for effectiveness of sterilized intervention is less obvious on both theoretical and empirical grounds.” 1 Hence, while there has been a wide array of empirical surveys on the effectiveness of central bank interventions, few have elucidated the mechanisms through which they affect the economy. To the best of our knowledge, less than a handful of nonempirical surveys exist that center on the various propagation mechanisms of interventions; for instance, Sarno and Taylor (2001), Evans (2008), and Lyons (2006). However, these surveys either provide a descriptive reading of how interventions affect the exchange rate, or predominantly focus on a microstructure approach.

Our paper contributes to the literature in three important ways: (i) by reviewing new theoretical models that have surfaced within the last decade; (ii) by further penetrating into the theory of interventions in order to analyze the key features that make each model distinct; and (iii) by only focusing on sterilized operations, which allows us to sidestep the effects induced by changes in the stock of money supply. In addition, the models that we present comprise both a macro and microstructure approach so as to provide a comprehensive view of the theory behind exchange rate intervention.

We identify three main strands of literature based on the different channels through which interventions affect the exchange rate. In Section 2, we portray the theoretical underpinnings of each view, in light of the assets and goods market approach. This section intends to familiarize readers with the general framework by which sterilized interventions can affect the equilibrium exchange rate, as well as to present the basic notation that is used throughout the various models that follow.

In Section 3, we present the views that deem interventions futile (where the impossible trinity is ever binding). Generally, this strand of literature employs no-arbitrage conditions, such as the uncovered interest rate parity (UIP), but with no risk premium. Hence, agents are indifferent between holding foreign and domestic assets as long as they guarantee the same level of consumption in each state of the economy. As a consequence, sterilized interventions do not affect equilibrium prices nor do they represent an additional monetary instrument for central banks.

In Section 4, we present models in which the UIP does not hold. In other words, models that require the inclusion of market frictions in order for interventions to be effective. A key underlying result of this strand of literature is that agents are not indifferent to holding different currency-denominated assets. Thus, in the event of a sterilized intervention, agents require a change in either the relative rates of return or the value of domestic currency in order to offset changes in their portfolio composition. Most of the works reviewed in this section consider capital controls, currency risks, differences in return distributions (when agents are risk averse), and default risks as the main constituents of market constraints. In essence, these frictions limit arbitrage opportunities that would have been otherwise exploited.

Finally, in Section 5 we present the works that advocate the use of sterilized interventions (rendering the impossible trinity possible) as long as they convey signals on the stance of future monetary policy. Given that this channel operates through changes in agents’ expectations, we emphasize the role of private information and the inability to distinguish between informed and uninformed agents, using a microstructured approach.
We acknowledge the ample empirical literature that exists on the effectiveness of central bank intervention. However, in this paper we intend to cover only the theoretical inner workings of interventions, both new and mainstream. For a thorough compilation of empirical findings, we refer readers to Dornbusch (1980), Meese and Rogoff (1988), Dominguez and Frankel (1993), Edison (1993), Dominguez (2003), Fatum and Hutchison (2003), Neely (2005), and Menkhoff (2010), among others. We do, however, present a compilation of empirical findings in Appendix B. In sum, the general consensus indicates that interventions have a small and short-lived effect on exchange rates. This result has remained valid ever since the Economic Summit at Versailles in June 1982, when the Jurgensen Group declared that “the role of intervention can only be limited.” Nonetheless, authors who do not find any significant effects have increased in number over the past decade. Examples include Fischer (2001a,b), Blanchard (2013), and Villamizar-Villegas (2015).

2. Assets and Goods Market

The literature that supports a managed exchange rate regime identifies two main channels through which interventions affect the exchange rate, even when opting for monetary policy autonomy and allowing for free capital flows. The first channel is known as the signaling channel and conveys information regarding the future value of money supply and interest rates. Thus, forward-looking markets affect the exchange rate today. The second channel is known as the portfolio balance channel and comprises the supply of assets denominated in different currencies. If assets are imperfect substitutes, changes in expected returns induce agents to rebalance their portfolios. And, since the money supply and interest rates remain unchanged (as is the nature of sterilized interventions), the exchange rate then absorbs any alteration in expected returns.

In this section, we portray the general underpinnings of these channels, in light of the assets and goods market approach. We also present the basic notation that is used throughout the various models that follow. As such, we consider a world with two countries, home (h) and foreign (f). We denote the exchange rate, $e_{i,j,t}$, as the units of country i’s currency per unit of country j’s currency at time t. Hence, $e_{i,j,t} = 1$ for all periods. Furthermore, let $e_{i,j,h,f,t} = e_t$. Additional notation is presented in each model.

2.1 Asset Market Approach

The asset market approach is based on the UIP condition, as exemplified in equation (1):\(^3\)

$$E_t[e_{t+1} - e_t | \Omega_t] = i^h_t - i^f_t - rp_t$$

(1)

In this equation, $e$ is the log exchange rate, $\Omega_t$ is the relevant information set at time t, $rp$ is the risk premium,\(^4\) and $i^h$ and $i^f$ correspond to domestic and foreign returns, respectively. Contemporaneous and past exchange rate interventions, $INT_t$, are included in $\Omega_t$, so that $\{INT_t\}_{t=-\infty}^{\infty} \subseteq \Omega_t$.

A useful representation of UIP that lends itself to the interpretation of policy effects is shown in equation (2). It is constructed by iterating equation (1) forward:

$$e_t = \sum_{j=0}^{T-t-1} E_t \left[ i^f_{t+j} - i^h_{t+j} + rp_{t+j} | \Omega_t \right] + E_t[e_T | \Omega_t]$$

(2)

Under the portfolio channel, the rebalancing of domestic and foreign bonds operates through the term $E_t[rp_{t+j} | \Omega_t]$. Under the signaling channel, the term $E_t[i^h_{t+j} | \Omega_t]$ conveys changes in the expected future policy rate. This channel also contains exchange rate expectations captured by the term $E_t[e_{t+j}^{h,f} | \Omega_t]$ which are often pinned down by the Purchasing Power Parity condition (PPP). In sum, all terms can be expressed as a function of exchange rate interventions so that $e_t = e_t(INT_t)$.

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In this setup, a sterilized intervention implies that both \( i^h_t \) and \( i^f_t \) remain unchanged. Therefore, the exchange rate can be affected by: (i) signals on future monetary policy, (ii) changes in the expected future exchange rate, and (iii) movements in the contemporaneous and future values of the risk premium.\(^5\) In related literature, authors such as Kearns and Rigobon (2002) find a substantial effect of interventions, especially during the day in which they are conducted. Most authors however, find scant evidence of any significant effects.

### 2.2 Goods Market Approach

The goods (and services) market approach is generally linked to the exchange rate behavior in the long run. As such, many central banks follow this methodology, albeit with different techniques, to decide over equilibrium levels of exchange rates. We follow Mussa (1976) and Frenkel (1976) to further analyze this approach.

In the long run, currencies should have equal purchasing power so the “generalized law of one price” (or PPP) is expressed as

\[
e_t = p^h_t - p^f_t \tag{3}
\]

where \( e_t \) again corresponds to the log exchange rate and \( p^i_t \) denotes the price (in logs) of a representative basket of goods and services in country \( i \). The model now turns to the real money market where money supply equals demand. In the literature, this equilibrium is typically expressed as

\[
m_t - p_t = \alpha y_t - \beta i_t \tag{4}
\]

where \( m_t \) is the money supply, \( y_t \) corresponds to real output, and \( i_t \) is the short-term interest rate (all variables in logs). By substituting equation (4) and the UIP condition of equation (1) into (3), we obtain equation (5),

\[
e_t = (m^h_t - m^f_t) - \alpha (y^h_t - y^f_t) + \beta (E_t[e_{t+1} - e_t | \Omega_t] + r p_t) \tag{5}
\]

which, by iterating forward and defining \( \lambda \equiv \frac{\beta}{1+\beta} \), yields

\[
e_t = \sum_{j=0}^{\infty} \left( \frac{\lambda^j}{1+\beta} \right) E_t[(m^h_{t+j} - m^f_{t+j}) - \alpha (y^h_{t+j} - y^f_{t+j}) + \beta (r p_{t+j} + \vartheta_{t+j} | \Omega_t)] \tag{6}
\]

As it turns out, equation (6) is simply a different representation of the same flexible-price model of equation (2). In other words, equation (6) highlights the effect of the money supply (as opposed to asset returns) and includes the potential impact of real output. Thus, a sterilized intervention in this case implies that \( m^h_t \) and \( m^f_t \) remain unchanged. In sum, a sterilized intervention can affect the exchange through: (i) signals on the future money supply, (ii) movements in the contemporaneous and future values of the risk premium, and (iii) changes in the expected value of output growth.\(^6\)

We extend this framework to characterize the sticky-price model of Dornbusch (1976) with one small alteration: prices are assumed to be sticky in the short run, exhibiting a gradual adjustment toward their long-run (flexible) value. Namely, equation (6) is reexpressed as (7),

\[
e_t = \sum_{j=0}^{\infty} \left( \frac{\lambda^j}{1+\beta} \right) E_t[(m^h_{t+j} - m^f_{t+j}) - \alpha (y^h_{t+j} - y^f_{t+j}) + \beta (r p_{t+j} + \vartheta_{t+j} | \Omega_t)] \tag{7}
\]

where \( \vartheta_t \) represents a short-run departure from PPP. Hence, an unexpected permanent increase in the money supply deprecates domestic currency by creating a positive wedge (\( \vartheta_t \)). The expected value of the future exchange rate then increases, given that \( \vartheta_t \) dissipates only in the long run when prices finally adjust.
In terms of the UIP condition (equation 2), this corresponds to an increase in $E_t[e_T | \Omega_t]$. It follows that, when prices finally adjust, the exchange rate remains depreciated.

Sections 4 and 5 provide an in-depth analysis of the portfolio balance and signaling channels, respectively. However, in Section 3 we begin by surveying the literature that deems intervention futile, when faced with the monetary “trilemma.”

3. Impossible Trinity Remains Impossible

In the models that follow the UIP condition holds (i.e. no significant risk premium). In terms of equations (2) and (6), this implies that $r_p t = 0$, for all $t$. In other words, agents are indifferent between holding foreign and domestic assets as long as they guarantee the same level of consumption in each state of the economy. As a consequence, sterilized interventions do not affect equilibrium prices nor do they represent an additional monetary instrument for central banks.

This section proceeds as follows. Section 3.1 analyzes Backus and Kehoe (1989) and uses their model as benchmark. We believe that most works that encompass the “trilemma” share similar features, or in some cases, are directly derived from their model. In Section 3.2, we present the central argument of Cunha (2013), for which fiscal policies conflate with exchange rate effects.

3.1 Backus and Kehoe (1989)

Backus and Kehoe (1989) show that, as long as there is perfect capital mobility, sterilized interventions have no effect on equilibrium prices and quantities. This result is similar to one of the applications found in Sargent and Smith (1987), for which these authors generalize as a Modigliani–Miller theorem for government finance. For exposition purposes, we only present the setup in Backus and Kehoe since the result is more general. The basic setup of their model is as follows.

There are two countries, home ($h$) and foreign ($f$), each represented by a consumer and a government. Consumers face a cash-in-advance constraint and maximize their utility by choosing consumption of the final good of both countries, $c$, currency, $M$, and bond holdings, $b$. In addition, they purchase bonds issued in each country and receive an endowment of the final good of the country where they reside. Finally, each government issues bonds and determines the domestic money supply.

The consumer of country $i$ solves the problem

$$\max_{e^{i,j}, M_{i,j}^{H}, b_{i,j}} \sum_{t=0}^{\infty} \beta^t u^i(c^i_t)$$

subject to the following two constraints:

$$p^j c^i_t \leq M_{i,j}^{H}$$

$$A^i_t = \sum_{j \in \{h, f\}} e^{i,j}_t M_{i,j}^{H} + \sum_{j \in \{h, f\}} e^{i,j}_t b_{i+1,j}^{i,H} \frac{1 + r_{i+1}}{1 + r_{i+1}}$$

where $\beta \in (0, 1)$, $c^i$ is the total consumption from goods produced in both countries, $p^j$ is the price of the good produced in country $j$, $M_{i,j}^{H}$ are money holdings of currency of country $j$, and $b_{i,j}^{i,H}$ denotes bond holdings in currency $j$ and with return $r^j$. Consumer claims are defined as

$$A^i_t \equiv \sum_{j \in \{h, f\}} e^{i,j}_t b_{i+1,j}^{i,H} + p^i_t y^i_t + \sum_{j \in \{h, f\}} e^{i,j}_t \left[M_{i,j}^{H} - p_{i-1}^j c_{i-1}^{i,j}\right],$$

where $y^i_t$ is the endowment of the final good of country $i$.
Equation (9) corresponds to the cash-in-advance constraint for buying goods in both countries. Equation (10) is the budget constraint: the household uses the endowment of the final good, the currency left over from the previous period (i.e. not used in purchasing goods), and the return on securities from the previous period to acquire currency and securities issued by both countries.

The government of country $i$ issues bonds, $b^{i,j(G)}$, and determines monetary policy, $M^{i(G)}$. It funds itself by issuing currency and bonds, and uses these resources to pay for bonds issued in previous periods as well as to support the currency of the previous period. The government’s budget constraint of country $i$ is specified as follows:

$$
\sum_{j \in \{h,f\}} e^{i,j} \frac{b^{i,j(G)}_{t+1}}{1 + r^{j}_{t+1}} + M^{i(G)}_t = \sum_{j \in \{h,f\}} e^{i,j} b^{i,j(G)}_t + M^{i(G)}_{t-1}
$$ (12)

An equilibrium in this economy is defined as a set of allocations $Q_i \equiv \{n_i, (c_{i,j}, M_{i,j}, b_{i,j})_{j \in \{f,h\}}\}$, prices $P = \{p_i, e_i, (r_{i,j})_{j \in \{f,h\}}\}_{i \in \{f,h\}}$ and government policies $\Pi_i \equiv \{M^{i}_j, (b^{i,j}_j)_{j \in \{f,h\}}\}$, such that given $P, Q_i$ is a solution to (8) and $\Pi_i$ satisfies (12) for $i \in \{f, h\}$. Also, the markets for goods, assets and money must clear in each period $t$. That is,

$$\sum_{i \in \{h,f\}} e^{i,j} = y^{j}_i$$

$$\sum_{i \in \{h,f\}} b^{i,j(H)}_t = \sum_{i \in \{h,f\}} b^{i,j(G)}$$

$$\sum_{i \in \{h,f\}} M^{i,j(H)}_t = M^{i(G)}_t$$

The main result of Backus and Kehoe (1989) is that any change in bond policies of country $i$, such that the total value of bond holdings remains unchanged, does not affect equilibrium prices or quantities. In particular, consider a sterilized foreign exchange intervention where the home government is selling foreign currency. In the context of the model, this is equivalent to selling foreign assets. Since the intervention is sterilized, there must be a purchase of assets issued by the home country in the same quantity as of the home currency. Now, if the change in the home government portfolio is channeled through the domestic household (i.e. the home government sells foreign assets and buys domestic assets to and from the household), then the agents’ budget constraints are not affected. Hence, the new allocations and the set of prices that existed before the intervention took place are still an equilibrium. In other words, a sterilized foreign exchange operation does not affect the exchange rate.

In sum, a sterilized intervention will not affect the equilibrium exchange rate. This result is derived from the UIP condition as shown in equation (13).

$$1 + r^{h}_{t+1} = \frac{e_{t+1}}{e_t}$$ (13)

The fact that there is no risk premium follows from bonds being perfect substitutes.

Backus and Kehoe (1989) argue that the result is valid even when they include distortionary taxes on consumption. Since it does not matter how government consumption is being financed, as long as all other policies of the government (except bond holdings) are constant, the main result does not depend on the Ricardian equivalence. The authors refer to this as a strong-form intervention. If there is a change in another government policy at the same time (weak-form intervention), there could be an effect on the equilibrium exchange rate. However, this change is not attributed to the foreign exchange intervention. This is similar to a result found in Sargent and Smith (1987), who prove that fiscal policy is required in order for sterilized interventions to affect the equilibrium exchange rate.
3.2 Cunha (2013)

Cunha (2013) proposes a model of indeterminacy in the currency denomination and maturity structure of public debt. In the model, a floating exchange rate policy is able to support any competitive equilibrium induced by a fixed exchange rate regime. Also, an exchange rate policy (where the government intervenes every period) can decentralize any allocation and prices induced by a floating exchange rate. Thus, a competitive equilibrium only pins down the total government debt but not its composition. This result holds whenever the term structure of the discount rates satisfies certain spanning conditions. In particular, a sterilized foreign exchange intervention is ineffective, since the same allocations and prices can be achieved under a floating exchange rate regime.

4. From Trinity to Binity: The Effect of Market Constraints

The middle ground that exists within the literature regarding the effectiveness of sterilized interventions consists of models that require some market friction (i.e. limited arbitrage) in order for interventions to be effective. In other words, the impossible trinity ceases to be binding given that the UIP does not hold. A key underlying result of this strand of literature is that agents are not indifferent to holding different currency-denominated assets. Thus, market constraints generate a wedge for exchange rate maneuverability.\(^{10}\)

This section is further subcategorized as follows. Section 4.1 introduces the early views of the portfolio balance channel, both under a macro and microstructured approach. Specifically, Section 4.1.1 presents the portfolio balance model as presented in Weber (1986) and expands on some key results that are not explicitly derived in his paper. In turn, Section 4.1.2 reviews one of the earliest microstructure views of the portfolio balance channel, by Evans and Lyons (2001).

The remaining models in this section consider various forms of market constraints which account for a nonzero risk premium. Some of these include: differences in return distributions (when agents are risk averse), fiscal policies, capital controls, and financial frictions. In particular, Section 4.2.1 presents a model by Blanchard et al. (2015) in which the level of “risk appetite” coupled with departures from the UIP affect the exchange rate. Section 4.3.1 lays out the central argument of Kumhof and van Nieuwerburgh (2007) and Kumhof (2010) for which exogenous fiscal shocks cannot be financed thorough lump-sum taxes.

Finally, Section 4.4 centers on the effects of capital controls and financial frictions. In Section 4.4.1, we review the model proposed by Kuersteiner et al. (2015). In Sections 4.4.2–4.4.6, we comment on some recent works by Jeanne (2012), Céspedes et al. (2012), Canzoneri and Cumby (2013), Gabaix and Maggiori (2015), and Cardozo et al. (2015).

4.1 Portfolio Balance Channel: Early Views

4.1.1 Weber (1986)

Weber considers the case in which the impossible trinity is not impossible, provided that bonds denominated in different currencies are not perfectly interchangeable. In the related literature, this is attributed to a variety of reasons including the risk of enacting currency controls, default risks, liquidity premiums, and various forms of capital market imperfections. Essentially, anything that sustains a nonzero risk premium \((r_p)\), as presented in the UIP condition of equation (1), is sufficient for assets to be imperfect substitutes. Weber’s portfolio balance model, which contains many of the characteristics found in Branson and Henderson (1985), assumes perfect capital mobility across countries and monetary independence in each country. The general framework is as follows.
There are no financial intermediaries in the economy so the assets of the central bank of country $i$ are the claims that it holds from country $j$, denoted by $b_{i,j}^{CB}$. Also, each central bank’s only liability is the money supply ($M'$), which is assumed to be exogenously determined as follows:

$$M_i' = \sum_{j \in \{h, f\}} e_{i,j}^{CB} b_{i,j}^{CB}$$  \hspace{1cm} (14)

The model also assumes that the total stock of home and foreign bonds are exogenously determined and equal to $\bar{b}_i^h$ and $\bar{b}_i^f$, respectively. This implies that

$$\bar{b}_i^j = \sum_{i \in \{h, f\}} \left[ b_{i,j}^{CB} + b_{i,j}^{H} \right]$$  \hspace{1cm} (15)

where $b_{i,j}^{H}$ denotes the claims that the representative household ($H$) of country $i$ has on country $j$. The model assumes that the household can only hold currency of the country in which it resides and uses its exogenous wealth, $W_i'$, to hold currency and bonds as shown in equation (16):

$$W_i' = M_i' + \sum_{j \in \{h, f\}} e_{i,j} b_{i,j}^{H}$$  \hspace{1cm} (16)

Weber (1986) assumes that the household’s demand for assets depends on the level of aggregate wealth and on the expected rates of return of each type of asset. Differences in the latter indicate the degree of substitutability between bonds. Consequently, reduced-form demands for bonds are expressed as

$$e_{i,j} b_{i,j}^{H} = \tilde{g}_{i,j} \left( \tilde{\pi}_{i,h} - \tilde{\pi}_{i,f}, W_i' \right)$$  \hspace{1cm} (17)

In equation (17), $\tilde{g}_{i,j}$ is the return of bonds issued by country $j$ in terms of country $i$’s currency. Formally, $\tilde{\pi}_{i,j} \equiv r_{i,j} + \pi_{i,j}$ where $\pi_{i,j}$ is the expected change in the exchange rate: $\pi_{i,j} = E_t [e_{t+1,j}^i] / e_{t,j}^i$. Demand for bonds is assumed increasing in both the household’s wealth and the return of the home bond and decreasing in the return of the foreign bond. Since demands for bonds are modeled as reduced forms, to solve the model Weber (1986) performs a first-order linear approximation. The idea is to express the expected depreciation, $\pi_{i,j}$, in terms of bond holdings of the home country’s central bank.\(^{[11]}\)

There are four markets in the economy: money supply ($M'$) and bonds ($\tilde{b}'$) which are issued by each country. By Walras’ we need only to consider the market clearing condition for both types of bonds and the home country’s money supply. The mechanics are as follows. We first perform a linear approximation of $g_{i,j}$ around $(0,0,0)$. We then solve for $b_{i,j}^{H(CB)}$ in equation (14) and substitute into equation (15). Finally, we use equation (16) for $i = h$ to obtain

$$\pi_{i,f} = \alpha_0 + \alpha_1 b_{i}^h + \alpha_2 e_{i} b_{i}^f + \alpha_3 M_i^h - \alpha_1 e_{i} M_i^f + \alpha_4 W_i^h + \alpha_5 e_{i} W_i^f +$$ \hspace{1cm} (18)

$$\left( \alpha_1 - \alpha_2 \right) e_{i} \left[ b_{i,f}^{H(CB)} + b_{i,f}^{H(CB)} \right]$$

All coefficients in (18) depend on the derivatives of $g_{i,j}$ with respect to its arguments. However, since these functions are not made explicit, the signs are undetermined. Nonetheless, equation (18) is useful to analyze the effects of a sterilized intervention. We consider the case in which the central bank of the home country sells $b_{i,f}^{H(CB)}$ and purchases $b_{i,h}^{H(CB)}$ without offsetting the money supply. That is,

$$\Delta b_{i,h}^{H(CB)} = - \Delta e_{i}^{h,f} b_{i}^{H(CB)}$$  \hspace{1cm} (19)

Consequently, the sign of $\alpha_1 - \alpha_2$ determines the effect of the sterilized intervention on the exchange rate, as seen in equation (18). In particular, sterilized interventions will have no effect if $\alpha_1 = \alpha_2$. A key contribution of Weber (1986) is to show that a sufficient condition for $\alpha_1 = \alpha_2$ is for assets to be perfect substitutes. We explain this result as follows.

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Let $g_{k}^{i,j}$ be the derivative of $g^{i,j}$ with respect to its $k$th argument evaluated at $(0, 0, 0)$. Then

$$
\alpha_1 = \frac{1}{\pi} \left( \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + g_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{2}^{i,j} \right) - \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + e_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right) \right)
$$

$$
\alpha_2 = \frac{1}{\pi} \left( \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + g_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{2}^{i,j} \right) - \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + e_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right) \right)
$$

where

$$
H = \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + e_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right) - \left( \frac{h_{1}^{i,j}}{s_{1}^{i,j}} + e_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right) \left( \frac{h_{2}^{i,j}}{s_{2}^{i,j}} + g_{1}^{i,j} \right)
$$

We next assume that households are indifferent to holding home and foreign bonds, as long as they have the same return. Formally, $g_{k}^{i,j} = g_{k'}^{i,j'}$, for $i, j, j' \in \{h, f\}$, $k \in \{1, 2\}$, $j \neq j'$, and $k \neq k'$. Notice that in this case $\alpha_1 = \alpha_2$.

In the empirical literature, some studies estimate the demand functions for bonds to establish whether or not different currency-denominated bonds are perfect substitutes. Other studies estimate equation (18) directly. Finally, some works determine whether a no-arbitrage condition holds (i.e. $r_{f}(t) = r_{f}(t) + \pi(t)$). As mentioned in Section 1, most of the recent evidence seems to be consistent with $\alpha_1 = \alpha_2$.

### 4.1.2 Evans and Lyons (2001)

The model by Evans and Lyons (2001) constitutes one of the earliest works on the portfolio-balance channel under a microstructure approach. Similar to Vitale (1999), the authors estimate a partial equilibrium model in which the trading process reveals information contained in order flows. This information, in turn, is subcategorized into two types according to their lasting effects on portfolio balances: temporary and persistent. While the former refers to the price compensation that risk-averse dealers demand for holding positions that they would otherwise not hold, the latter refers to the compensation that the market as a whole demands for holding positions that it would otherwise not hold. Temporary effects dissipate once the dealer positions are known by market participants. Alternatively, persistent effects remain active because all risks are shared at the market level.

Sterilized foreign exchange interventions do not reveal any additional information. Nonetheless, they can potentially affect the exchange rate by altering the total order flow (i.e. total number of trades that dealers execute within a given period). The effect on prices is a direct consequence of imperfect substitutability, and not of asymmetric information, as in Kyle (1985). The general framework of the model is as follows.

There are three types of agents: $N$ dealers, a continuum of customers and one central bank. There are also two assets, one of which is risky (the foreign exchange) with an observed return of $e$. Four rounds of trading occur within each period. In the first round, dealers trade with the central bank and with the customers. The model assumes that the central bank trades are sterilized, secret, and convey no information about future monetary policy. Dealers trade among themselves in the second trading round. At this stage, the temporary portfolio-balance effects appear to compensate the dealers, which are risk averse. The size of this effect depends on the size of the exercised orders. In the third round, $e_{i}$ is realized and the dealers trade among themselves once again. Finally, in the fourth round dealers pass positions onto the customers. The risk associated with these positions cannot be fully insured, generating persistent effects.

Formally, at the beginning of period $t$, each dealer $i$ quotes a price $P_{1}^{i}$ for the foreign exchange that is bought (sold) from (to) the public and the central bank. In round 2, dealer $i$ quotes a price $P_{2}^{i}$ to
other dealers. At this point, agents observe a noisy signal denoted by \( X_2 \) of interdealer order flow that depends on trades \( (T^2_1) \) such that \( X_2 = \mathbb{E} \left[ \sum_{i=1}^{N} T^2_i \right] \). A foreign exchange intervention affects \( \sum_{i=1}^{N} T^2_i \), and, therefore, \( X_2 \) and \( P^i_1 \). At the beginning of round three, \( e_t \) is realized. Similar to the dynamics of round 2, dealer \( i \) quotes a price \( P^i_t \) to other dealers. At the end of this round, all agents observe the interdealer flow \( (X_3) \) such that \( X_3 = \sum_{i=1}^{N} T^3_i \). Finally, in round four each dealer \( i \) quotes foreign exchange to the public at price \( P^i_t \).

An equilibrium in this model consists of market quotes \( P^j_t \) and trades \( T^k_t \), for \( j \in \{1, 2, 3, 4\} \), \( k \in \{2, 3\} \), and \( i \in \{1, \ldots, N\} \) such that each dealer maximizes its expected utility at the end of round four, subject to: (i) the fact that outstanding positions at the end of each period must remain unchanged, and (ii) new information is revealed at each round (order flow). In equilibrium, all dealers post equal quotes in each round so that

\[
P^2_{2,t} = P^1_{1,t} = P^4_{4,t-1} \\
P^3_{3,t} = P^2_{2,t} + \lambda_3 t X^2_{t} \\
P^4_{4,t} = P^3_{3,t} + \lambda_2 t X^2_{t} + \delta_t (e_t - e_{t-1}) - \phi_t \left( P^3_{3,t} - P^2_{2,t} \right)
\]

where \( \lambda_2, \lambda_3, \delta_t, \phi_t > 0 \). Intuitively, the price change between each round depends on the new information available. No information is revealed after the first round since trades are not made public. Only between the second and third rounds is the interdealer order flow \( (X^2_t) \) publicly observed. It is at this stage that a foreign exchange intervention can affect the exchange rate. Similarly, between the third and fourth rounds, dealers observe the interdealer order flow \( (X^3_t) \) and the corresponding change in the exchange rate \( (e_t - e_{t-1}) \). The second-order flow between dealers has more information than \( X^2_t \) since it is observed without noise. Moreover, the change in the exchange rate is persistent, and therefore priced. Finally, \( P^4_{4,t} - P^3_{3,t} \) takes into account part of the price change between the second and third rounds. It dissipates because dealers transfer some of the risk onto customers.

### 4.2 Differences in Return Distributions: The Case of Risk Averse Agents

#### 4.2.1 Blanchard et al. (2015)

Blanchard et al. (2015) study the effects of sterilized foreign exchange intervention for a group of 35 countries that, in principle, attempt to mitigate the appreciation of the exchange rate in periods of large capital inflows. The authors argue that interventions operate mostly through the portfolio-balance channel, in which different currency-denominated assets are imperfect substitutes (as seen in Section 4.1.1). They propose a model to rationalize their empirical results, which relies on the following balance of payment identity:\(^{13}\)

\[ CA_t = Outflows_t - Inflows_t + INT_t \]  

(20)

where \( CA_t \) is the current account, \( INT_t \) are net purchases of foreign assets by the central bank, and \( Outflows_t \) and \( Inflows_t \) correspond to the net movement in private international assets and liabilities. Capital flows are then assumed to be affected by departures from UIP (see equation 1) as well as by an exogenous measure of risk appetite “\( z_t \)” as shown in equations (21) and (22),

\[ Inflows_t = \alpha (rp_t) + z_t \]  

(21)

\[ Outflows_t = -\beta (rp_t) - \rho z_t \]  

(22)

Inflows depend positively on the risk premium (i.e. higher expected domestic return) and on the amount of domestic risk that investors are willing to take. Alternatively, outflows depend negatively on
the risk premium and on the amount of foreign risk. We note that some studies like Broner et al. (2013) and Bianchi et al. (2013) model capital flows in a manner in which they collapse during a crisis. The framework presented in Blanchard et al. (2015) allows for a reduction on inflows and outflows (i.e. greater home bias) when there is higher risk aversion, as long as $\rho < 0$.14

If we then model the current account to be linear on the exchange rate, so that $CA_t = \gamma e_t$ (where $\gamma \geq 0$ is the current account – exchange rate elasticity), then equation (20) can be reformulated as

$$\gamma e_t = -rp_t(\alpha + \beta) - z_t(1 + \rho) + INT_t$$

(23)

Under this specification, foreign exchange purchases depreciate the exchange rate, even if the risk premium is zero (i.e. when $rp_t = 0$). In other words, the portfolio balance channel enhances central bank intervention, but is not necessary for a depreciation of the exchange rate, given the additional effect of the term $INT_t$ on the exchange rate.

We focus our attention to the equilibrium exchange rate when assuming: (i) a simplified version of the Taylor rule, $i^h_t = i^f_t + \delta(e_t)$, where the central banks sets its interest rate based on the foreign interest rate and the exchange rate, and (ii) a policy function for foreign exchange intervention, $INT_t = (1 + \rho)\phi z_t$, where net purchases of foreign assets are set as a proportion $\phi$ of net capital flows. Finally, the authors assume that $z_t$ follows an AR(1) process with coefficient $\psi$. Combining both policy functions (Taylor rule and policy function for exchange rate intervention) into equation (23) yields equation (24):

$$e_t = \frac{(1 + \rho)(\phi - 1)}{\gamma - (\alpha + \beta)(\psi - 1 - \delta)}z_t$$

(24)

The central bank can then dampen the appreciation of the exchange rate by decreasing its policy rate (through $\delta$) or by increasing its net purchases (through $\phi$). However, in the absence of a risk premium we have that $(\alpha + \beta)(\psi - 1 - \delta) = 0$, so the central bank loses its former monetary instrument.

### 4.3 Fiscal Constraints

#### 4.3.1 Kumhof and van Nieuwerburgh (2007) and Kumhof (2010)

Kumhof and van Nieuwerburgh (2007) and Kumhof (2010) argue that the composition of different currency-denominated assets matters, at least for fiscal policies. Both models assume exogenous fiscal shocks that cannot be financed through lump-sum taxes.16 As a result, taxes do not change when these shocks are realized. The exchange rate then adjusts in order to rebalance the government’s nominal liabilities (and pins down a portfolio composition). Within this setup, a sterilized foreign exchange intervention results in a depreciated nominal exchange rate. Moreover, the relationship between the return on different currency-denominated assets depends on the outstanding stock of government bonds.

### 4.4 Capital Controls and Financial Frictions

#### 4.4.1 Kuersteiner et al. (2015)

Most of the recent literature on central bank intervention introduces either capital controls or financial frictions to escape the monetary “trilemma.”17 We analyze the model presented in Kuersteiner et al. (2015) given its simplicity and general applicability. The general framework is as follows.

Consider a world with two countries, home and foreign, where UIP holds. Thus, the central bank can affect either the interest rate or the exchange rate, but not both. Given some demand for funds to invest, equilibrium in financial markets is fully determined once the central bank of each country sets its policy.
rate. Similarly, the market for foreign exchange requires net capital outflows to be balanced with net exports in the current account.

If one country enacts capital controls, UIP no longer holds. Kuersteiner et al. (2015) consider an unexpected proportional tax on capital inflows for one period at rate $\tau$. This type of control generates two types of capital: (i) incumbent capital, which has remained in the home country beyond the enactment of capital controls, and (ii) new capital, which is traded after controls have been enforced. Consequently, two different no-arbitrage conditions emerge and thus a discontinuity in the supply of capital. Equations (25) and (26) describe the UIP conditions for incumbent and new capital, respectively.

\[(1 + i^h_t) = \frac{E_t[e_{t+1}]}{e_t} (1 + i^f_t) \]  
\[(1 + i^h_t)(1 - \tau) = \frac{E_t[e_{t+1}]}{e_t} (1 + i^f_t) \]  

where $e_t$ corresponds to the exchange rate (in levels), and $i^h$ and $i^f$ correspond to the interest rates of the home and foreign country, respectively. Incumbent capital will remain as long as the gross return (not including taxes) to investing in the home country does not fall below the return of investing in the foreign country. But new capital will not flow in immediately if the return to capital increases. This will only occur if the return to investing in the home country (net of taxes) exceeds the return to investing in the foreign country.

As noted, there is a middle range in which the return to investing in the home country is sufficiently high so that incumbent capital will not flow out, but not high enough for new inflows to compensate the newly imposed tax. The resulting wedge plays out as a supply curve with a jump (i.e. a vertical portion in which monetary authorities can manage the exchange rate while still maintaining the equilibrium interest rate). Formally, finite but positive capital inflows occur when

\[\left(1 + \frac{i^f_t}{1 + i^h_t}\right) E_t[e_{t+1}] \leq e_t \leq \frac{(1 + i^f_t)E_t[e_{t+1}]}{(1 + i^h_t)(1 - \tau)} \]  

However, starting from an equilibrium without capital controls, the discretion of the central bank is not symmetrical. That is, the exchange rate can either remain constant or increase without affecting the policy rate. In the nature of sterilized foreign exchange interventions, this means that central banks can affect the exchange rate as long as equation (27) holds. It follows that higher controls on capital (a higher $\tau$) generate a larger wedge of maneuverability for the central bank to affect the exchange rate.

Kuersteiner et al. (2015) also consider an alternative version of equation (26) in which inflows incur a unit cost, proportional to the aggregate amount of inflows $V_t$. Formally:

\[(1 + i^h_t) - \tau(V_t) = \frac{E_t[e_{t+1}]}{e_t} (1 + i^f_t) \]  

The main difference with equation (26) is that the exchange rate now depends on the amount of capital flows but the mechanics and results of the model remain the same.

4.4.2 Jeanne (2012)

Jeanne (2012) presents a model where a small open economy can appreciate its real exchange rate through restrictions on capital mobility. In the model, only the government is able to access foreign assets. This allows the government to control the level of net foreign assets, and, therefore, control the current account balance. Consequently, the government also obtains control over the trade balance, and is able to determine
the real exchange rate. In particular, when the government accumulates foreign assets, while concurrently issuing domestic bonds (i.e. sterilized intervention), the real exchange rate depreciates.\textsuperscript{19}

4.4.3 Céspedes\textit{ et al.} (2012)

Céspedes\textit{ et al.} (2012) develop a small open economy model where banks intermediate resources from abroad to firms. In this model, banks can borrow up to a collateral constraint, which depends on the real exchange rate. When the constraint is binding, sterilized foreign exchange interventions have an effect on the equilibrium exchange rate.

In this model, there is no currency, so the exchange rate is given by the price ratio between tradable and nontradable goods. In this sense, a sterilized foreign exchange intervention is an (exogenous) injection of tradable goods into the economy in exchange for nontradables, which is offset by credit to firms or banks. When the constraint on banks is binding, the sterilization part of the intervention comprises resources that banks can use to relax their constraint, and thus are able to provide more credit to the economy. As a result, the real exchange rate appreciates and production and welfare increase. It is important to highlight that the intervention only has an effect when the collateral constraint binds. That is, the financial friction plays a crucial role in the success of the intervention. If the constraint does not bind, then there is no effect on the real exchange rate.

4.4.4 Canzoneri and Cumby (2013)

There have been several extensions to the underlying asset risk-structure of the portfolio balance model. However, few studies rely on a liquidity premium to explain why assets are imperfect substitutes. Such is the case of Canzoneri and Cumby (2013) for which we sketch their central argument as follows.

The authors present a model with standard features of New Open Economy Models (NOEM). They assume that the home country uses both home bonds and a key currency bond to facilitate trade. In addition, money is introduced but assumed to be an imperfect substitute for bonds. The model then prices one bond with no liquidity services (denoted as the Consumption Capital Asset Pricing Model (CCAPM) bond) with a higher return. Portfolios in each country need not be symmetric. Namely, foreign residents hold claims on home firms while home residents hold foreign bonds. Also, foreign residents earn the CCAPM rate on foreign equity, while home residents earn a liquid bond rate on foreign holdings. It turns out that, since liquid assets carry a liquidity premium, foreign investors earn a higher return on foreign assets than what they pay for their foreign liabilities.

The model uses a Taylor rule to control for inflation while concurrently allowing for foreign exchange interventions.\textsuperscript{20} Results show that sterilized interventions (i.e. bond swaps) have a lesser effect on output and inflation than when allowing for the monetary base to change (i.e. open market operations). Nonetheless, the authors show that interventions (even when sterilized) have a significant impact on the exchange rate.

4.4.5 Gabaix and Maggiori (2015)

In Gabaix and Maggiori (2015), international financiers intermediate currency between two countries. However, this intermediation is imperfect because financiers can divert a portion of the traded funds. This results in a limited commitment constraint, which in practice, is a friction that limits the ability of financiers to hold foreign exchange positions. For this reason, assets denominated in either currency are not perfect substitutes. In other words, in equilibrium, the UIP does not hold. Gabaix and Maggiori justify this friction by positing that there is an excess supply of one currency (e.g. domestic) relative to another currency (e.g. foreign). In order for this imbalance to be absorbed by the financiers, they demand
a premium for holding domestic currency. Hence, a foreign exchange intervention alters the balance sheet of financiers, and affects the exchange rate through the risk premium (the effect is increasing in the magnitude of the friction).

4.4.6 Cardozo et al. (2015)

Cardozo et al. (2015) construct a general equilibrium model to analyze whether sterilized interventions have an effect on the exchange rate. The authors explore the effects of banking limits on the exposure of foreign currency (i.e. limits to the total amount of foreign currency that banks can hold) in a small open economy. As a result, the UIP condition does not hold. Instead, interest rate differentials between domestic and foreign bonds depend on the expected exchange rate and a nonzero risk premium, which in turn is a function of relative bond holdings. This model is related to Gabaix and Maggiori (2015) in the sense that the UIP condition is violated because agents are constrained in their ability to intermediate foreign currency. Nonetheless, in Cardozo et al. (2015) this constraint is imposed by the regulatory framework. The model’s predictions are then empirically tested, using proprietary data from the Central Bank of Colombia that include daily bond holdings by market participants.

5. Impossible Trinity Might Not Be Impossible

In this section, we present the works that advocate the use of sterilized interventions (rendering the impossible trinity possible) as long as they convey signals on the stance of future monetary policy. Given that Section 2 provides an explanation of the signaling channel as viewed from a macroeconomic perspective, we now turn to a model by Vitale (1999), one of the pioneering works to study the effects of foreign exchange market intervention using a microstructured approach. For a review of the empirical literature regarding the effects of the signaling channel, see Obstfeld (1988), Klein and Rosengren (1991), Ghosh (1992), Fischer and Zurlinden (1999), Beine and Lecourt (2004), Fratzscher (2008), and Bauer and Rudebusch (2014).

5.1 Signaling Channel

5.1.1 Vitale (1999)

Through the signaling channel, Vitale examines how the private information of central banks regarding the fundamental value of domestic currency affects exchange rate expectations, via order flows. Recall from Section 2.1 that under a sterilized intervention, the signaling channel consists of: (i) signals on future monetary policy and (ii) changes in the expected future exchange rate.

As opposed to Mussa (1981), who favors announced interventions in order to publicly reveal what the fundamental value of the exchange rate is, Vitale (1999) favors unannounced or “secret” methods of intervention. The main reason is that secrecy allows for strategic behavior, especially when the objective of the central bank differs from the fundamental value. As such, monetary authorities advantageously transmit wrong signals to traders and dealers. We refer readers to Lyons (2006) for an in-depth discussion on announced versus secret interventions.

Most authors who follow a microstructure approach, including Vitale (1999) and Evans and Lyons (2001), present alterations to the work-horse model proposed by Kyle (1985). Given its impact on the recent literature, we present a sketch of Kyle’s batch framework in Appendix A. In essence, a dealer (often referred to as the market maker) receives quotes from liquidity traders and the central bank before prices are determined. The dealer then determines the market-clearing price based on these orders.
the central argument of the model centers on the dealer’s inability to distinguish between informed and uninformed traders.

Formally, the fundamental value of the exchange rate, $e_0$, is assumed to be normally distributed with mean $\mu_0$ and variance $\Sigma_0$. Only the central bank observes the realization of $e_0$, which occurs in period 0. In period 1, the central bank and traders place their quotes, $x$ and $\epsilon$. The dealer then fixes the exchange rate and executes all orders. Perfect market competition coupled with risk neutrality on the dealer’s behalf enforces a semistrong efficiency condition that results in zero-expected profits. Therefore, the exchange rate in period 1 is expressed as

$$e_1 = E[e_0 | \Omega_1]$$

where $\Omega_1$ is the relevant information set in period 1. Concurrently, the central bank chooses its market order $x$ to minimize its loss function:

$$L = (e_1 - e_0)^2 - q(e_1 - \bar{e})^2$$

where $\bar{e}$ is the central bank’s target rate, which is common knowledge, and $q > 0$ is the commitment to $\bar{e}$. Intuitively, the first term captures the cost of intervention while the second term captures the cost of missing its target.

In light of restricting our analysis to the effects on the exchange rate (and sidestepping the effects on market efficiency and liquidity), we next highlight two of the relevant propositions in Vitale (1999).

**Proposition 1.** If the target rate of the central bank, $\bar{e}$, is common knowledge, then there is a unique Nash equilibrium in which the central bank is incapable of targeting the value of domestic currency. That is, the dealer is able to filter out the wrong signal emitted by the central bank.

**Proposition 2.** If the target rate of the central bank, $\bar{e}$, is secret, then there is a unique Nash equilibrium in which the central bank is capable of targeting the value of domestic currency. Namely, the dealer is able to only partially filter out the wrong signal emitted by the central bank.

Consequently, in both these cases the exchange rate is affected by sterilized foreign exchange interventions.

6. Concluding Remarks

Since the East Asian crises of 1997–1998 and the failure of Argentina’s currency board in 2001, central banks have allegedly opted for monetary policy autonomy. However, the empirical evidence has shown that most countries have been reluctant to relinquish control over the value of their currencies. In fact, industrialized countries have led concerted initiatives to affect the value of major exchange rates, some of which include the Smithsonian Agreement (December 1971), the Plaza Accord (September 1985), the Louvre Accord (February 1987), the Chiang Mai Initiative (May 2000), and the Pittsburg Agreement (December 2009). Similarly, emerging markets have conducted frequent and large-scale interventions (although in less coordinated fashion), to the extent of becoming an empirical regularity. But allowing for free capital flows while having autonomous monetary policy and a managed exchange rate is an impossible trinity due to arbitrage by foreign investors. In principle, this “trilemma” limits the effects of policy.

In this paper, we bring together prominent theories that have shaped the literature on sterilized foreign exchange interventions (i.e. purchases or sales of foreign currency, intended to affect the exchange rate, but without altering the monetary base). Generally, central banks adopt this method of intervention when targeting the exchange rate while avoiding inflationary pressures induced by movements in the money supply. However, the effects of sterilized interventions often conflict with other monetary instruments, such as the policy rate, and in some cases, their effects can offset each other.
Paradoxically, in spite of the ample empirical literature that exists on the effectiveness of central bank intervention, little is known about the mechanisms through which they affect the economy. Hence, we contribute to the literature in three important ways. First, by reviewing new theoretical models that have surfaced within the last decade. Second, by further penetrating into the theory of interventions in order to analyze the key features that make each model distinct. Third, by only focusing on sterilized operations which allow us to sidestep the effects induced by changes in the stock of money supply. In addition, the models that we present comprise both a macro and microstructure approach so as to provide a comprehensive view of the theory behind exchange rate intervention.

We identify three main strands of literature based on the different channels through which interventions affect the exchange rate: (1) that which deems interventions futile (where the impossible trinity is ever binding); (2) that which requires some market friction (i.e. limited arbitrage) in order for interventions to be effective; and (3) that which advocates the use of interventions (rendering the impossible trinity possible) as long as they convey signals on the stance of future monetary policy. We believe that a better understanding of the different theoretical frameworks will help design more effective monetary policy regimes. It will also help us to understand the reasons and conditions under which central banks intervene in the foreign exchange market today. Hence, most of the key topics in international economics are extensively discussed. Some include the degree of asset substitutability, the effects of market constraints, and the various channels through which interventions affect the exchange rate.

We note that in recent years, especially after the financial world crisis of 2008, much attention has been given to the role of sterilized versus unsterilized foreign exchange intervention in the context of a zero lower bound on nominal interest rates. In particular, when the interest rate is at zero, domestic assets and currency become perfect substitutes, so the sterilization step of an intervention becomes irrelevant (see Christiano, 2000). Notwithstanding, the debate on whether unsterilized interventions are effective around the zero bound constraint is still wide open, and the mechanics lie at the heart of this paper. We explore various mechanisms in which the UIP does not hold (or is modified), or when the commitment to loosen monetary policy is ineffective (i.e. when the signaling channel does not work). We refer readers to Fuhrer and Madigan (1997), Krugman (1998), Christiano (2000), McCallum (2000), Svensson (2000), and Gunter et al. (2004) for a useful discussion on this issue, which generally applies more to advanced economies that have exhibited sharp declines in interest rates.

However, regardless of considering an advanced economy constrained by the zero lower bound, or an emerging market with room for policy rate maneuverability, we believe that this offers key insights into the inner workings of interventions that ultimately determine whether interventions are effective. We thus provide a comprehensive and up-to-date survey that can be used for ongoing and future work.

Notes

1. Blanchard et al. (2015, p. 2).
2. See last paragraph of Jurgensen (1983).
3. See Kearns and Rigobon (2002) and Almekinders and Eijffinger (1996).
4. Intuitively, the risk premium can be thought of as the difference between a risk-free investment (foreign asset) and a risky investment (domestic asset) subject to unexpected exchange rate changes. If agents are risk averse, the risk premium takes on positive values in order to compensate for the increased uncertainty of the risky asset. Nonetheless, there can be other reasons why the risk premium can take on positive values, even when agents are risk neutral. We further explore this in Section 4.4.
5. A change in the risk premium ($\Delta rp$) is possible provided that assets are imperfect substitutes.
6. Changes in the expected value of output would, most likely, only enhance the effects of the other channels, assuming that real output responds to an effective depreciation.
7. We simplify the setup that is explained in Backus and Kehoe (1989) since the main result that we want to highlight does not change. Backus and Kehoe consider an economy where households in
each country supply labor that is used as input to produce the final good and obtain utility from leisure. In addition, they also assume that the government in each country levies distortionary taxes on production. Moreover, we describe a setup where there is only one possible state per period whereas Backus and Kehoe consider a finite number of possible states. However, we note that their result does not depend on the assumption of complete markets.

8. Backus and Kehoe (1989) claim that the result does not change if the government of country \( i \) is restricted to issuing bonds denominated in the currency of country \( i \).

9. \( u' \) is assumed concave and increasing.

10. Recall from Section 2 that shifts in the portfolio composition operate through the term \( E_t[r p_{t+1} \mid \Omega_t] \) as seen in equations (2) and (6).

11. Weber (1986) assumes that \( e_t \) does not depend on exogenous variables. One alternative is to assume that exchange rate expectations \( E_t[e_{t+1}] \) are formed rationally.

12. Evans and Lyons (2001) state that this last condition is equivalent to assuming that the exchange rate floats.

13. We adjust Blanchard et al. (2015) model to our setting and express foreign exchange intervention as purchases rather than sales of foreign assets.

14. The opposite case is when \( \rho > 0 \), in which domestic and foreign investors move in the same direction.

15. This is equivalent to assuming that \( \psi = E_t[e_{t+1} \mid \Omega_t] \).

16. According to Kumhof and van Nieuwerburgh (2007) and Kumhof (2010), this assumption is supported by empirical evidence.

17. See, for example, Bacchetta et al. (2014) and Gabaix and Maggiori (2015).

18. Equivalently, the central bank can only conduct monetary tightening while maintaining the same exchange rate value.

19. Jeanne (2012) does not incorporate monetary policy, but adding it will not affect the model’s mechanisms.

20. Empirical studies that center on simultaneous monetary policies include Ostry et al. (2012) and Villamizar-Villegas (2015).

21. The model also assumes that traders’ orders, \( \epsilon \), are normally distributed and independent of \( e_0 \), with zero mean and variance \( \sigma^2 \).

22. Other propositions and proofs are found in Vitale (1999).

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Villamizar-Villegas, M. (2015) Identifying the effects of simultaneous monetary policy shocks. Contemporary Economic Policy. doi: 10.1111/coep.12111.
Appendix A: Kyle (1985)

Kyle (1985) models the trading strategy of an insider in a dynamic model of efficient price formation. Specifically, the model shows how the characteristics of a liquid market can be obtained in this setup. In addition, the model examines how much information prices carry and the value of private information to an insider.

There are three types of agents in the model: a single risk neutral insider, random noise traders, and competitive risk neutral market makers. Agents trade a risky asset for a riskless asset. While the insider knows about the liquidation value of the risky asset, noise traders trade randomly. Also, market makers set prices efficiently, conditional on the total quantity traded by other agents (i.e. order flow). Therefore, price fluctuations are a direct consequence of innovations on order flows.

Formally, the insider is the only trader that observes the liquidation value of the risky asset, denoted by $\tilde{v}$. He chooses how much to trade, $\tilde{x}$, in order to maximize expected profits. In doing so, he internalizes how his decision affects the price set by market makers, $\tilde{p}$, after the insider and the noise traders have chosen quantities to trade. Noise traders trade a quantity $\tilde{u}$, which is random and independent from $\tilde{x}$. Market makers determine $\tilde{p}$ by observing the order flow, $\tilde{x} + \tilde{u}$. Thus, profits of the informed trader are given by $(\tilde{v} - \tilde{p})\tilde{x}$. An equilibrium in this economy is defined as a pair $(X, P)$, defined implicitly as $\tilde{x} = X(\tilde{v})$ and $\tilde{p} = P(\tilde{x} + \tilde{u})$, such that the informed trader maximizes profits and the market is efficient, in the sense that $\tilde{p}(X, P) = X[\tilde{v}|\tilde{x} + \tilde{u}]$.

Now consider a model where there are a sequential number of rounds of trading, or auctions. The informed trader now chooses how much to trade taking into account the prices from the previous auctions, as well as $\tilde{v}$. The prices set by market makers will now depend on the order flows of all auctions up to that point. Nonetheless, a result of the model is that the price of a given auction will be that of the previous auction plus a term that depends on the order flow innovation.

The model is extended to an environment where auctions occur continuously. In this setup, Kyle shows that the insider trades in such a way that his private information is incorporated into prices at a constant rate. In addition, the entire insider’s information is incorporated onto prices by the end of trading. Furthermore, the continuous auction equilibrium results in a market that has similar characteristics to those found in a liquid market.

Appendix B: Compilation of Empirical Works

Table B1 shows a compilation of empirical works that analyze the effectiveness of foreign exchange intervention in different currencies. It is by no means intended to be comprehensive, but rather an illustration of this vast literature. For a thorough recent survey on empirical studies in emerging markets, see Menkhoff (2013).
Table B1. Selected Works on the Effects of Sterilized Interventions.

| Author                  | Exchange rate | Period       | Methodology | Intervention effective? |
|-------------------------|---------------|--------------|-------------|-------------------------|
| Adler and Tovar (2014)  | EM/USD        | 2004–2010    | 2SIV        | YES (depends on country’s openness) |
|                         | (15 countries)| (Intraday)   |             |                         |
| Aguilar and Nydahl (2000) | SEK/DEM      | 1993–1996    | GARCH       | NO                      |
|                         | SEK/USD       |              |             |                         |
| Baillie and Osterberg (1997) | DEM/USD   | 1985–1990    | GARCH       | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |
| Neil and Fillion (1999) | CAD/USD       | 1995–1998    | GARCH       | YES                     |
|                         | (Intraday)    |             |             |                         |
| Beine et al. (2002)    | DEM/USD       | 1985–1995    | FIGARCH     | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |
| Bonser-Neal and Tanner (1996) | DEM/USD  | 1985–1991    | GARCH       | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |
| Chang and Taylor (1998) | JPY/USD       | 1992–1993    | ARCH        | YES                     |
|                         | (Intraday)    |             |             |                         |
| Danker et al. (1987)   | DEM/USD       | 1982–1987    | 2SLS        | NO                      |
|                         | JPY/USD       | (monthly)    |             |                         |
|                         | CAD/USD       |              |             |                         |
| Disyatat and Galati (2007) | CZK/EUR  | 2001–2002    | 2SIV        | NO                      |
|                         |              | (daily)      |             |                         |
| Domaç and Mendoza (2004) | MXN/USD  | 1996–2002    | E-GARCH     | YES                     |
|                         | TKL/USD       | (Daily)      |             |                         |
| Dominguez (1993)       | DEM/USD       | 1985–1991    | GARCH       | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |
| Dominguez and Frankel (1993) | DEM/USD | 1982–1988    | 2SIV        | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |
| Echavarría et al. (2013) | COP/USD   | 1999–2012    | PGARCH      | YES                     |
|                         |              | (Daily)      |             |                         |
| Eijffinger and Gruijters (1989) | DEM/USD | 1985–1988    | AR          | YES                     |
|                         |              | (Intraday)   |             |                         |
| Fatum and Hutchison (1999) | USD/JPY  | 1989–1993    | GARCH       | YES                     |
|                         | USD/DEM       | (Daily)      |             |                         |
| Fatum and Hutchison (2003) | DEM/USD | 1985–1995    | EVENT STUDY | YES                     |
|                         |              | (Daily)      |             |                         |
| Gersl and Holub (2006) | CZK/USD       | 2001–2003    | GARCH       | NO                      |
|                         |              | (Daily)      |             |                         |
| Ghosh (1992)           | DEM/USD       | 1980–1988    | VAR         | YES                     |
|                         |              | (Monthly)    |             |                         |
| Guimaraes and Karacadag (2005) | MXN/USD  | 1997–2003    | GARCH       | Mixed                   |
|                         | TKL/USD       | (Daily)      |             | (small)                 |
| Huang (2007)           | DEM/USD       | 1978–1995    | GARCH       | YES                     |
|                         | JPY/USD       | (Daily)      |             |                         |

(Continued)
Table B1. Continued

| Author                     | Exchange rate | Period       | Methodology    | Intervention effective? |
|---------------------------|---------------|--------------|----------------|-------------------------|
| Humala and Rodríguez (2010) | PEN/USD       | 1994–2007 (Daily) | GARCH         | YES (on volatility)     |
| Humpage (1999)            | DEM/USD       | 1987–1990 (Daily) | LOGIT         | YES                     |
| JPY/USD                   |               |              |                |                         |
| Kamil (2008)              | COP/USD       | 2004–2007 (Daily) | TOBIT         | YES                     |
| Kaminsky and Lewis (1996) | DEM/USD       | 1985–1990 (Daily) | MS            | YES                     |
|                          | JPY/USD       |              | GARCH          | (in some periods)       |
| Kim et al. (2000)         | USD/AUD       | 1983–1997 (Daily) | PROBIT        | YES (sustained and large) |
| Obstfeld (1988)           | DEM/USD       | 1976–1986 (Daily) | AR            | YES                     |
|                          | JPY/USD       |              |                | (small)                 |
| Payne and Vitale (2003)   | USD/CHF       | 1985–1995 (Intraday) | EVENT      | YES                     |
| Rincón and Toro (2010)    | COP/USD       | 1993–2010 (Intraday) | GARCH       | YES (only with capital controls) |
| Rogoff (1984)             | CAD/USD       | 1973–1980 (Weekly) | 2SLS         | NO                      |
| Stone et al. (2009)       | BRL/USD       | 2008–2009 (Daily) | EGARCH       | YES                     |
| Tapia et al. (2004)       | CLP/USD       | 1998–2001 (Intraday) | 2SLS        | YES (in some periods)   |
| Taylor (2004)             | DEM/USD       | 1985–1998 (Daily) | MS           | YES                     |
| Toro and Julio (2005)     | COP/USD       | 2004–2005 (Intraday) | ARCH        | YES                     |
| Villamizar-Villegas (2015)| COP/USD       | 1999–2012 (Daily) | BI-TOBIT     | NO                      |

Source: Authors’ compilations.

2SIV corresponds to two-stage instrumental variables, 2SLS corresponds to two-stage least squares, AR corresponds to Auto-Regressive processes, ML corresponds to maximum-likelihood, and MS corresponds to Markov-switching models. AUD: Australian dollars; BRL: Brazilian Real; CAD: Canadian dollars; CLP: Chilean Pesos; COP: Colombian Pesos; CHF: Swiss francs; CZK: Czech koruna; DEM: German marks; EM: emerging markets; EUR: euro; MXN: Mexican peso; JPY: Japanese yens; PEN: Peruvian soles; SEK: Swedish kronas; TKL: Turkish lira; USD: US dollars.