A Model of Exchange Rates in Iceland

Andy Pham

Advisor: Professor Maurice Obstfeld

ABSTRACT

This paper develops a partial equilibrium model of the dual official and offshore markets for foreign exchange stylized towards Iceland following the imposition of capital controls in November 2008. The model's dynamics are examined with particular emphasis on the effect of various central bank announcements. The results are then tested empirically through weighted least squares regressions and the effects of announcements on the offshore and official rates are compared.

I would like to thank Professor Maurice Obstfeld for his invaluable advising and mentorship in the development of this paper. His insights and suggestions contributed extensively as he refined my ideas and cultivated their development over time and I am incredibly grateful to have had the opportunity to work with him. I would also like to thank Professor David Romer for early advice on topics and empirical methodology. The Central Bank of Iceland provided excellent assistance in finding data and clarifying discrepancies on their website. Finally I would like to thank my family and friends for their continual support.

Following the 2008 Financial Crisis, Iceland's financial system was on the brink of destruction. Years of overexpansion and borrowing by residents and financial institutions left Iceland vulnerable to a liquidity drought, an event that was realized during the crisis. To stabilize the exchange rate and prevent massive capital outflows, the Central Bank of Iceland instated capital controls in November 2008, freezing foreign deposits and temporarily suspending the foreign exchange market. When the worst of the crisis was over, Iceland was left with a large stock of offshore liabilities that would seriously undermine the financial system and depreciate the exchange rate in absence of capital controls. As a result, an offshore market developed with an independent exchange rate in which these frozen assets are traded.

This paper seeks to develop a model of the foreign exchange market in Iceland following the imposition of capital controls. The model follows a portfolio balance approach in which individuals decide their asset allocations based on relative returns. Nonresidents and the central bank exchange official, unrestricted assets on the official market at the official floating exchange rate. The existence of an offshore market creates an independent market in which offshore krona assets are traded at a separate exchange rate. As nonresidents can choose to hold official or offshore assets, their demand shifts between the two assets contingent on expected returns, causing leakages between the official and offshore markets that equilibrates the official rate at a higher value than in the absence of an offshore market.

stock demands for and supplies of assets determine short-run equilibrium in both markets, while the long-run dynamics are determined by the current account as in Kouri (1983). Note that as the offshore assets are inconvertible, their stock remains constant and exchange rate dynamics are governed entirely by nonresidents' portfolio demands. The interaction between the two markets stems from two sources: the shift of demand between official and offshore assets and leakages from the reported current account to the unofficial current account.

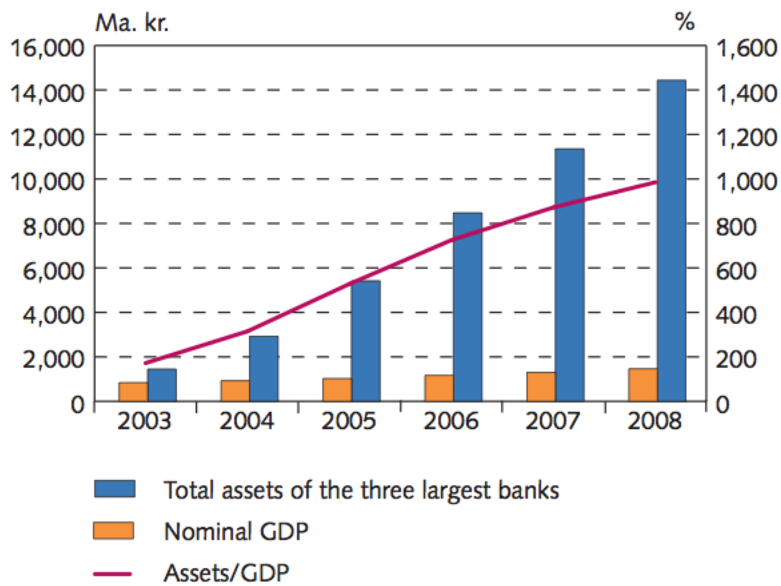
Given that the offshore market is extremely shallow and does not function as fluidly as an official market due to a lack of participants at all times and trading volume, changes in the rate should be primarily driven by major news announcements. I examine this notion by collecting data on interest rate changes in Iceland and the Eurozone, foreign currency auctions held by the Central Bank of Iceland, Icelandic credit rating changes, and long-term and main refinancing operations (LTRO and MRO respectively) by the European Central Bank. Through weighted least squares, I show that changes in the offshore rate are primarily driven by changes in the Icelandic interest rate, while the official rate is affected significantly by the currency auctions, namely reserve movements.

The paper is organized as follows: Section I gives an overview of the Icelandic financial crisis, market for foreign exchange since then, and most importantly, a description of the capital controls regime and the offshore market. Section II provides a brief review of relevant literature of portfolio balance in exchange rate determination, black markets, and dual exchange rate regimes. Section III describes the model and its dynamics. Section IV provides empirical analysis to test the effect of news announcements on the two exchange rates. Section V concludes.

I. Background

A. *Overview of the Crisis*

Beginning in 2003, the privatization of Icelandic banks and low interest rates lead to period of rapid financial expansion. Banks expanded their balance sheets and operations overseas, swelling the combined assets of the three largest banks, Glitnir, Kaupthing, and Landsbanki, from 170% to 880% of GDP between the ends of 2003 and 2007 (Financial Stability Report 2009). Banking operations reflected an appetite for higher risk, with activities more closely resembling investment banks and the bulk of these operations heavily reliant on short-term financing. Given that these three banks alone accounted for 85-88% of the entire banking sector, the collapse of these institutions would have catastrophic effects on the Icelandic financial system (Financial Stability Report 2009).



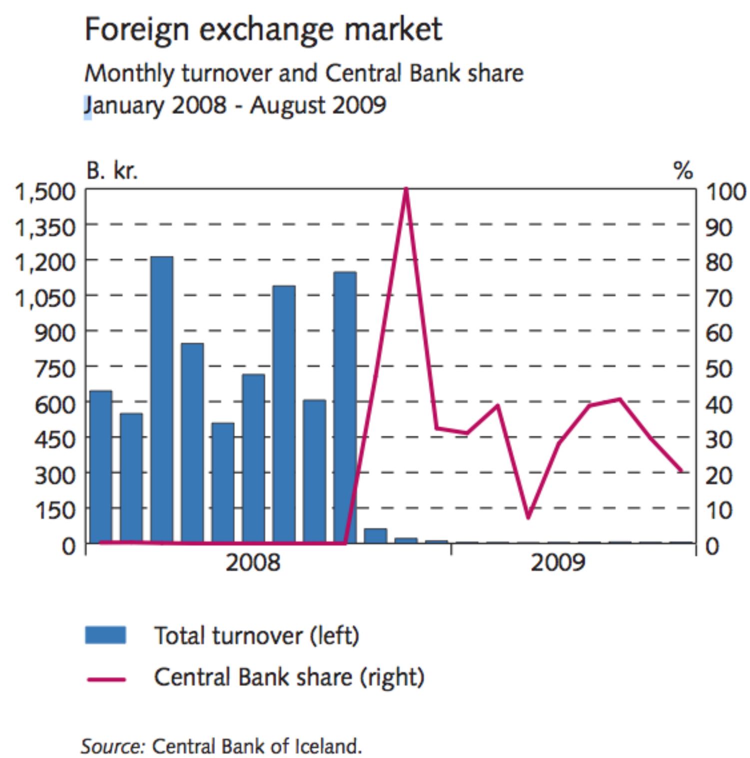
Source: Central Bank of Iceland.

This scenario was realized following the U.S. subprime mortgage crisis starting in late 2007. Global financial conditions were already deteriorating, but with the collapse of U.S. investment bank Lehman Brothers in September 2008, liquidity completely dried up, leaving Icelandic banks unable to fulfill debt obligations due to the lack of supply of short-term finance. Glitnir was the first to fall, unable to sell off assets in time to meet bond payments for liabilities maturing in October. The Treasury entered an agreement to acquire a 75% stake in Glitnir in exchange for a capital contribution of 600 million euros, but the damage was already done (Financial Stability Report 2009). Ratings agencies downgraded the banks and the sovereign, a hit to the financial system that was amplified by deteriorating economic and financial conditions abroad directly affecting the Icelandic financial system due to overexposure to foreign financing risk from overseas operations.

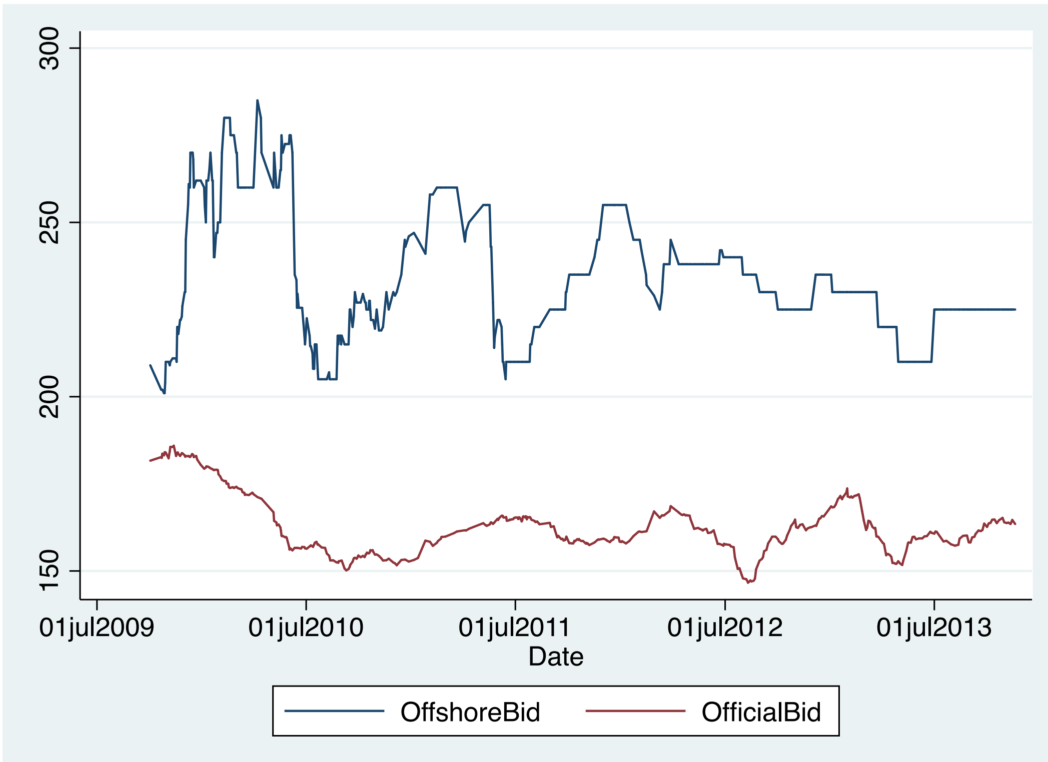
With financial conditions rapidly deteriorating, withdrawals and capital outflows became commonplace. The sheer size of the banking sector made government bailouts impossible and unwise given that government guarantees would cause further downgrades of sovereign credit ratings as well, reinforcing the decline of the financial system. The Icelandic government made the key choice to prioritize the smooth functioning of domestic payment intermediation, creating three new state-owned banks to replace the domestic activities of Landsbanki, Glitnir, and Kaupthing. However, cross-border payment intermediation was largely ignored, leaving dire repercussions for the foreign exchange market.

B. The Foreign Exchange Market During the Crisis

With the imminent failure of the Icelandic financial system in September 2008, the foreign exchange market ceased to function. Total foreign exchange turnovers plummeted to a fraction of their previous values, dropping from an average of 813 billion kronur between January and September 2008 to 31 billion kronur per month between October and December 2008 (Financial Stability Report 2009). Most of the turnover came from central bank activities, a key signal that the market was no longer properly functioning on its own.



During the crisis and immediately after, the central bank ensured that foreign exchange transactions still took place in spite of the stagnant market by holding daily auctions. The Central Bank initially fixed the exchange rate in these auctions, proportioning it to accepted auction bids, and refloated the krona in December 2008 following the removal of temporary crisis controls on current account transactions and the imposition of capital controls to prevent outflows of capital. The temporary current account restrictions were aimed to prioritize crucial goods and services trade in the queue for foreign exchange transactions, while the latter were imposed to prevent further excess depreciation of the krona. During the transitionary crisis period between October and December 2008, the krona depreciated from approximately 150 kronur per euro to 187 kronur per euro, appreciating slightly following the re-float due to the conversion of domestic foreign currency deposits to kronur (Financial Stability Report 2009).



As foreign exchange markets had ceased to work and were now facilitated entirely by the Central Bank at a fixed exchange rate, excess demand for foreign currency caused an offshore market to develop. The offshore exchange rate was and still is substantially higher than the official rate, suggesting that it serves as a source of funding for those desperate to evade the controls and liquidate from their frozen positions.

C. Description of the Capital Controls

As stated above, the Central Bank initially limited foreign exchange transactions to those involving the trade of essential goods and services. These restrictions were replaced by official capital account restrictions following the passage of the Rules on Foreign Exchange passed on November 28, 2008, outlining rules and regulations on foreign exchange transactions commensurate with temporary provisions to the Foreign Exchange Act no. 87/1992. Revisions and amendments have been made to close loopholes, most notably in late October 2009 when the importation of offshore kronur was strictly prohibited. In this same amendment controls on capital inflows were lifted, allowing nonresidents to make domestic investments once again.

The first feature of the controls is that transactions involving the trade of goods and services are generally unrestricted. Residents may purchase foreign exchange from a domestic undertaking only for the use of trade of goods and services abroad, but may not use foreign exchange for transactions among each other. Nonresidents are required to pay for Icelandic exports with convertible foreign currency, which is expected to be repatriated by residents within three weeks of reception. The repatriated foreign exchange then must either be sold or deposited in a foreign exchange account with a domestic financial undertaking. Imports must be paid for in foreign currency as cross-border movements involving kronur are prohibited.

Profits from foreign investments made by residents before November 28, 2008 can be redeposited or reinvested offshore. In addition, residents may purchase foreign exchange for the payment of interest, dividends, or contractual payments.

Given that capital movements in kronur are prohibited and residents cannot purchase foreign exchange for reasons other than current account transactions, they are prohibited from acquiring foreign financial assets and depositing kronur to offshore accounts. Withdrawal of funds from offshore accounts is subject to Central Bank approval, which I assume in the model implies a restriction for simplicity. Residents may potentially acquire foreign exchange or offshore krona through the offshore market and not report these capital movements to the central bank, depositing these funds in an offshore account. Technically speaking, these movements are restricted by the central bank as opening an offshore foreign exchange account requires central bank approval, but the IMF notes that this rule has not been strictly enforced (IMF AREAER 2013). However for simplicity of the model, I assume that this restriction is indeed binding.

Nonresidents may freely purchase Icelandic financial assets and make investments if they first deposit and convert their foreign exchange to kronur with a domestic undertaking. Investments made after October 31st, 2009 are free from controls, namely they are freely transferrable abroad and convertible back to foreign currency from kronur. Existing balances in krona accounts in domestic undertakings are generally frozen as they cannot be converted back to foreign currency and movement of krona capital is prohibited. These funds may only be used for domestic investment.

D. Offshore Market

Given the restrictions on the capital account and excess demand for foreign exchange, a parallel offshore market for foreign exchange exists in Iceland. Market participants are primarily nonresident holders of offshore krona assets who cannot convert these assets back to foreign currency due to capital controls. As a result, they trade these assets among each other at an offshore rate much higher than the official rate due to the inconvertibility of these assets. Note that residents also hold offshore assets, but for simplicity of the model, I assume their fraction of total offshore kronur holdings is negligible.

The Central Bank notes that price formation in the offshore market is quite shallow and erratic, driven primarily by market related news and the settlement of financial instruments. For the model I thus assume that the component affected by market related news is primarily reflected in the risk premium and/or expected depreciation rate of the offshore krona, while the settlement of financial instruments reflects the equilibrium exchange rate equating supply and demand of offshore kronur assets. Furthermore it is noted that the existence of the offshore market negatively affects the official market through leakages from current account transactions and the role of expectations of depreciation.

The current account leakage refers to a common practice of capital controls evasion, namely the under invoicing of exports and over invoicing exports. This implies that there must exist an unreported current account reflecting leakages from the official current account due to the wedge in exchange rates. The divergence of the official and offshore rates creates an incentive for individuals to under invoice exports as they could take part of their payment and convert it on the offshore market for more domestic currency. Thus foreign currency that should have flown into the official market is absorbed instead by the offshore market, causing the official exchange rate to be higher than it should.

E. Investment Programme

The Central Bank of Iceland released its original capital account liberalization strategy on August 5th, 2009. The document outlines preconditions and the stages for lifting the capital controls, most notably macroeconomic stabilization, a sound financial system, and an adequate level of reserves (Capital Controls Liberalisation Strategy). The strategy was revised on March 25th, 2011 with a more detailed description of programs the Central Bank would employ to meet the preconditions for lifting the controls. The revised strategy focuses first on transferring Icelandic assets from those that would immediately sell them upon the removal of the capital controls, which could potentially initiating large scale capital flight and creating substantial vulnerabilities to Iceland's financial system (Report on Capital Controls Liberalisation Strategy).

To mitigate this risk, the Central Bank of Iceland proposed a series of foreign exchange auctions remove offshore krona assets from distressed investors and downsize the total stock of offshore kronur. The newly acquired offshore krona assets could then be sold to long-term investors interested in investing in Iceland, allowing for both a reduction in the stock of unstable offshore kronur and the productive channeling of these funds into domestic investment projects. These auctions also included the purchase of euros in exchange for Icelandic bonds by the Central Bank to increase foreign reserves. The auction dates and sales are displayed in the following table:

Auction Date	Offshore Kronur Purchased (b.kr)	Euros Purchased (m.eur)
6/28/11	0	61.7
7/12/11	14.9	0
8/16/11	0	3.4
3/28/12	4.9	22.5
5/9/12	9.1	38.6
6/20/12	7.5	23.7
8/29/12	3.8	18.6
11/7/12	4.7	19.7
12/18/12	6.8	30.9
3/19/13	8.2	37.3
4/30/13	6.0	28.9
6/11/13	9.9	44.1
9/3/13	4.4	19.4
10/15/13	4.9	21.4

II. Literature Review

This paper develops a partial equilibrium model of a dual market for foreign exchange, using the portfolio balance approach popular in foreign exchange models in the 1970's and 1980's. The portfolio balance approach focuses on the notion that individuals' desired holdings of various assets are proportions of their total wealth. The proportion of wealth allocated to an asset is determined by its relative return to other available assets. Relative returns thus affect desired holdings, or demand, for each asset, suggesting that changes in expected yields of assets lead to excess demand for some assets, affecting the exchange rate as the prices of these assets increase with the excess demand. Decaluwe and Steinherr (1976), Flood (1978), Macedo (1982), Kouri (1983), Dooley and Isard (1983), Dornbusch et al. (1983), and Frenkel (1990) utilize this approach to examine models of floating, dual exchange rate regimes, and black markets for foreign exchange.

The theoretical basis of the model largely stems from Kouri (1983) who developed his partial equilibrium model of foreign exchange on the notion that foreign exchange markets clear continuously, suggesting that stock demands for and supplies for assets on the capital market solely determine the short-run equilibrium value of the exchange rate. In addition unlike monetarist models, which assume that the exchange rate is determined by the relative price of two currencies, Kouri's approach focuses on the fact that capital flows are determined by the rate of change of the exchange rate and as capital flows are related to the current account, the long-run equilibrium value of the exchange rate must be constant and determined by the current account. His acceleration hypothesis states that a current account deficit (surplus) must depreciate (appreciate) the exchange rate to keep the foreign exchange market in equilibrium, a phenomenon observed in exchange rate behavior.

Given that Iceland has capital controls, the structure of its foreign exchange market is most similar to a dual exchange rate regime or the existence of a black market for foreign exchange arising from currency inconvertibility. Work in dual exchange rate regimes include Argy and Porter (1972), Fleming (1974), Decaluwe and Steinherr (1976), Flood (1978), Cumby (1984), Adams and Greenwood (1985), and Dornbusch (1986). These papers focus on the notion that a dual exchange rate regime isolates current and capital account transactions into two different markets, each with their own exchange rate. I take a similar approach, but instead of isolating current and capital account transactions completely, I develop an official market for current account transactions and capital account transactions free from capital controls and a parallel offshore market in which nonresidents trade inconvertible offshore assets, leading to distinct official and offshore exchange rates.

Capital controls induce currency inconvertibility and restrictions preventing the acquisition or sale of foreign assets, which can lead to the creation of a black market for foreign exchange. Papers examining black markets and inconvertibility include Dornbusch et al. (1983), Macedo (1979, 1980, 1982), and Frankel (1990). The closest counterpart to the model developed in this paper is Macedo (1979), who applies Kouri's approach to a case involving domestic currency inconvertibility and a black market for foreign exchange. His work suggests that the official and black rates are determined in the short run by portfolio balance as introduced above and the interaction between the two markets arises from leakages between the official and unreported current accounts. As one rate changes relative to the other, exports and importers have incentive to smuggle and under or over invoice, channeling funds that would otherwise go through the official current account to the unreported current account. Under the assumption of the Marshall-Lerner condition, this implies that the official current account is increasing in the official rate and decreasing in the black rate. My model differs from Macedo as I allow nonresidents to hold domestic assets, consistent with Icelandic capital controls since October 2009, and the dual market comprises of nonresidents trading inconvertible domestic assets instead of residents and nonresidents trading illicit foreign exchange. Furthermore in addition to current account leakages, I emphasize the effect of the existence of the offshore asset on nonresidents' portfolio allocation decisions as a higher relative return in this asset will induce them to demand less of the official assets and more of the offshore asset, providing an additional linkage between the two markets.

III. The Model

Consider a small open economy with controls on capital outflows. I assume no growth or inflation, with prices of exports and imports taken as given. Cross-border movement of domestic assets is restricted, so I assume here that domestic residents have no demand for foreign assets given that they are prohibited from financing these purchases. Nonresidents on the other hand have freedom over their capital movements if financed through an initial inflow of foreign exchange. Foreign exchange is converted to domestic currency, which is then used to acquire domestic assets that may be sold in the future for domestic currency that is freely convertible and transferrable abroad. The Central Bank and government, which I assume are one entity, also participate in trade of financial assets, occasionally acquiring or selling foreign assets.

An important caveat is that nonresident domestic asset purchases may not be financed by pre-existing domestic assets held offshore as in Iceland currently. As a result, an offshore market for financial assets exists in which nonresidents trade domestic financial assets among each other given that they cannot free themselves from these positions in the official market. In the real world domestic residents also participate in this market to a minor extent, but I assume for simplicity that their supply and demand here is equivalently zero. The only time when this restriction is relaxed is during official auctions for foreign exchange held by the central bank. At these instances, the stock of offshore krona decreases as the central bank purchases these assets from nonresidents in exchange for foreign assets.

The model comprises of two markets, an official regulated market and the offshore market. Nonresidents and the Central Bank are the sole participants in the official market, trading official, onshore assets between each other at the official exchange rate, e. In the offshore market, nonresidents trade an unofficial offshore krona asset at the offshore rate, s. The two markets are linked in two ways: through leakages of foreign exchange from the official to the unreported current account and shifts of demand between offshore and official assets. The existence of the offshore krona provides an additional asset which nonresidents factor into their portfolio allocation decisions. For example, if the expected return of an offshore krona asset increases ceteris paribus, there will be a decline in demand for official krona assets and a corresponding increase in demand for the offshore krona asset as nonresidents will be inclined to allocate more of their wealth to the now more attractive offshore asset. This notion will be formalized when I define the asset demand functions shortly.

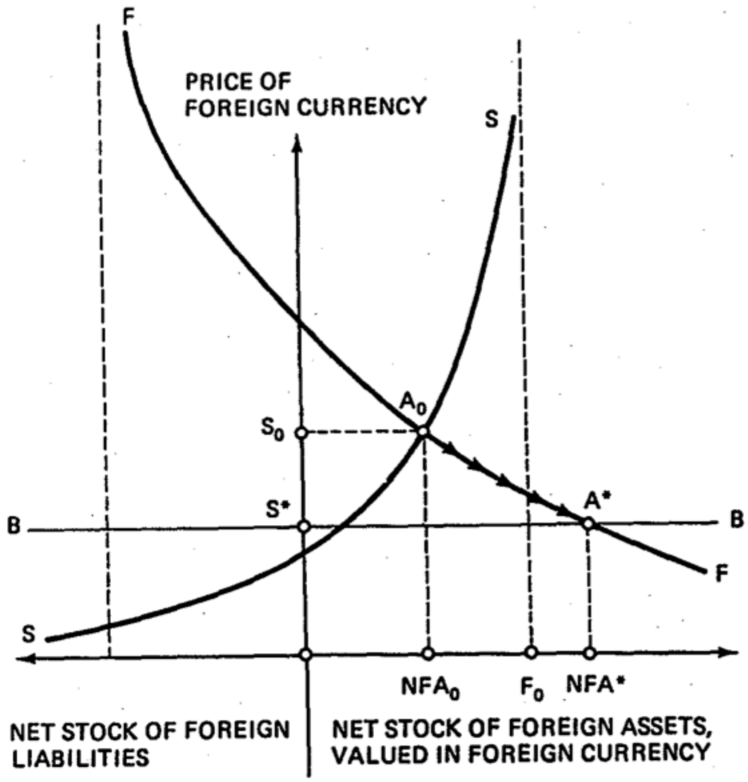
To start we recall Kouri's requirement for short-run equilibrium:

$$F^d - F^0 + R^d - R^0 = \frac{G^d}{e} + \frac{G^0}{e}$$

F^d = Domestic demand for foreign assets
F^0 = Initial domestic stock of foreign assets
R^d = Central bank demand for foreign asset reserves
R^0 = Initial central bank holdings of foreign asset reserves
G^d = Foreign demand for domestic assets
G^0 = Initial foreign stock of domestic assets
e, s = Domestic price of foreign currency $\frac{ISK}{EUR}$

We may rearrange this condition to represent the interaction between supply and demand for net foreign assets, denoted NFA^s and NFA^d respectively:

$$NFA^d = F^d + R^d - \frac{G^d}{e} = F^0 + R^0 - \frac{G^0}{e} = NFA^s$$



A partial short-run equilibrium is obtained at the intersection of the net foreign asset demand and supply schedules, F and S respectively, at exchange rate S_0. This is displayed in the above diagram from Kouri's original paper. Both markets will follow this approach closely, varying slightly to depict the stylistic differences between the two.

A. The Official Market

As stated before, capital controls restrict cross-border movement of domestic assets. As a result, residents cannot purchase foreign assets and their existing foreign holdings I assume are frozen and thus nonexistent in the official market. Thus their demand and supply for official foreign assets is equivalently zero. This simplifies our equilibrium condition to:

$$NFA_o^d = R^d - \frac{G_o^d}{e} = R^0 - \frac{G_o^0}{e} = NFA_o^s$$

The above equation specifies that in the official market, net demand for foreign assets is the difference between the central bank's demand for foreign assets (reserves) and nonresidents' demand for official krona assets, which we assume are government bonds or investments given that residents cannot sell any assets when the transaction includes kronur and foreign currency. Likewise as residents cannot liquidate their existing foreign holdings, the existing supply is simply the holdings of the central bank less those of nonresidents, valued in foreign currency.

Before defining the nonresidents' asset demand function for official krona assets, it will be useful to specify the various asset returns as they will be key parameters:

Holder/Asset	Official Krona Asset	Official Euro Asset	Offshore Krona Asset
Nonresident	$r_{isk} - \frac{e^e - e}{e}$	r_{eur}	$r_{isk} - \frac{s^e - s}{s} + \phi$

Nonresidents choose to hold proportions of their wealth in the three assets. Official krona and euro assets are traded in the official market at the official exchange rate; the availability of official krona assets depends on the central bank's demand for foreign assets. Offshore krona assets are purchased in the unofficial market from other nonresidents at the offshore rate. These assets have a risk premium, ϕ, to equate the returns of official and offshore assets. Note that the krona assets involve a depreciation term as a future change in the exchange rate can affect returns, namely an increased future depreciation of the exchange rate will provide a lower return in euros.

I now define nonresidents' demand function for domestic assets. I assume portfolio balance, namely that individuals allocate portions of their overall wealth, W^f, to the various available assets. For nonresidents in the official market, their demand for official domestic assets satisfies:

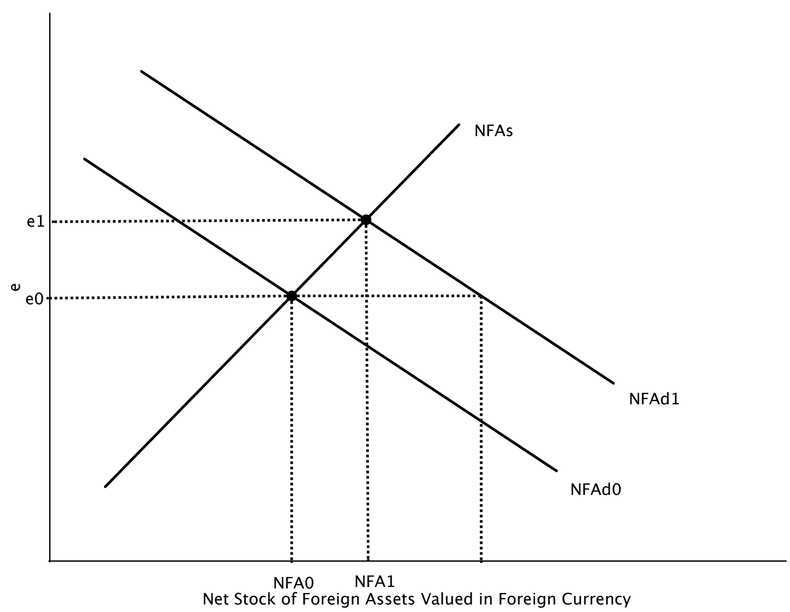
$$\frac{G_o^d}{e} = g_{official}(r_{eur}, r_{isk} - \frac{e^e - e}{e}, r_{isk} - \frac{s^e - s}{s} + \phi)W^f$$

This demand function is increasing in return of the official asset, namely $r_{isk} - \frac{e^e - e}{e}$, and decreasing in return of all other available assets. I rewrite the previous function isolating its various parameters for ease of analysis later on:

$$\frac{G_o^d}{e} = g_{official}(r_{eur}, r_{isk}, \frac{e^e - e}{e}, \frac{s^e - s}{s}, \phi)W^f$$
$$\frac{dg_{official}}{dr_{eur}} < 0, \frac{dg_{official}}{dr_{isk}} > 0, \frac{dg_{official}}{d\dot{e}} < 0, \frac{dg_{official}}{d\dot{s}} > 0, \frac{dg_{official}}{d\phi} < 0$$

Substituting this function for foreign demand in our equilibrium equation yields:

$$NFA_o^d = R^d - g_{official}(r_{eur}, r_{isk}, \frac{e^e - e}{e}, \frac{s^e - s}{s}, \phi)W^f = R^0 - \frac{G_o^0}{e} = NFA_o^s$$



The schedules of NFA_o^d and NFA_o^s are shown in the above diagram. Note that as the domestic currency depreciates, the value of existing foreign holdings of assets increases, suggesting an upward sloping supply curve. Short-run equilibrium is obtained at the intersection of these schedules at exchange rate e_0 and net foreign assets NFA_0. The adjustment process is as follows: Suppose the central bank decides it wants to increase its foreign asset (reserve) holdings, namely an increase in R_o^d. The NFA_o^d curve shifts to the right to represent the new desired stock of foreign assets. At the current exchange rate e_0 there is an excess supply of domestic assets and equivalently an excess demand for foreign assets. As a result, the exchange rate depreciates to e_1 so that the central bank increases its holdings of foreign assets by exactly how much nonresidents increase their holdings of domestic assets given their cheaper price.

Taking for now the offshore rate and risk premium as given, the derivation of long-run equilibrium in the official market closely follows Kouri. As in his paper, the rate of change of the exchange rate must equate net outflow of capital and the official current account. Formally:

$$NCF = \dot{R}^d - \frac{\dot{G}_o^d}{e} = \dot{R}^d - g_{official} W^f \frac{\dot{e}}{e} = CA_{official}(e, s)$$

The above equation states that net capital outflows is equal to the outflow of capital via central bank purchases of foreign assets less the inflow of capital from nonresidents, which must equal the official current account for flow equilibrium. Solving for the rate of appreciation of the domestic currency:

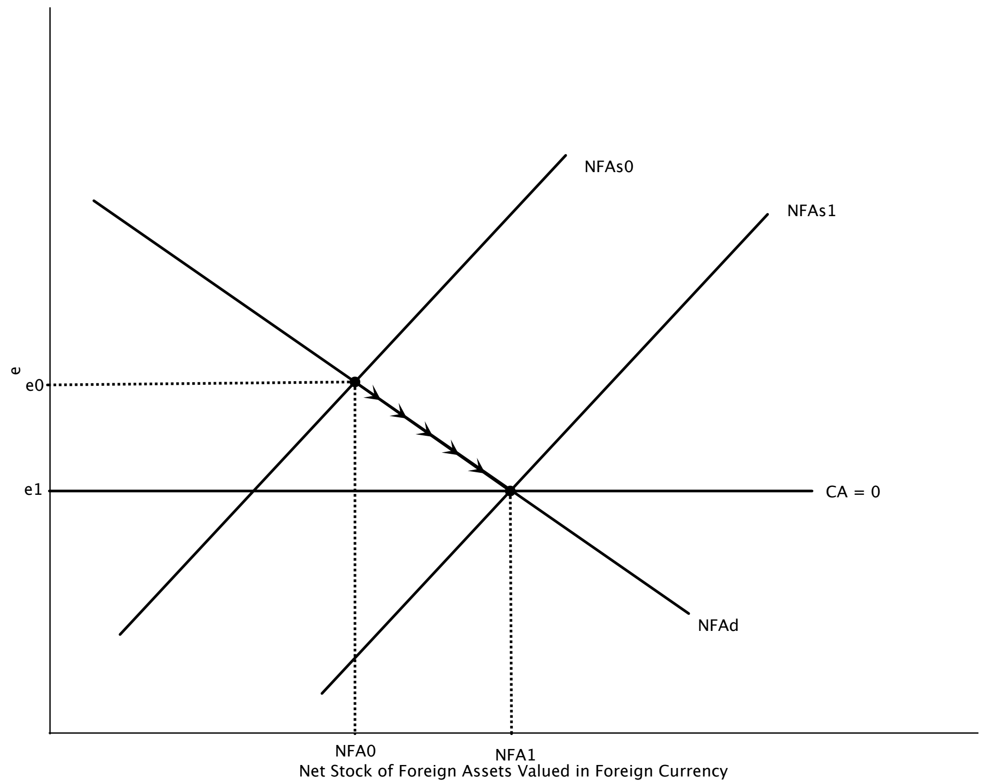
$$\frac{\dot{e}}{e} = \frac{\dot{R}^d - CA_{official}(e,s)}{g_{official} W^f}$$

This equation is Kouri's acceleration equation. Note that this equation supports the notion that if the central bank were fixing the exchange rate then change in central bank reserves would be equal to the current account exactly, namely $\dot{R}^d = CA_{official}(e, s)$.

To complete our description of the official market we must find the equation of motion for $NFA_{official}^d$ to determine our path to long-run equilibrium. Taking time derivatives of our flow equilibrium equation and substituting our previous result:

$$N\dot{F}A_o^d = \dot{R}^d = g_{official} W^f \frac{\dot{e}}{e} + CA_{official}(e, s)$$

Assume we are initially at short-run equilibrium with the official exchange rate at e_0, the central bank is not changing its reserves, and the current account is an increasing function of the exchange rate. The latter assumption holds if our economy obeys the Marshall-Lerner Condition as a depreciation of the exchange rate will improve the trade balance given that the quantity effect outweighs the price effect. The CA line is at drawn the exchange rate that will balance the current account. The economy is at a current account surplus at e_0, so there will be an accumulation of foreign assets due to payment from foreigners. We move along the NFA_d schedule down to e_1, where the CA is balanced in both diagrams. Consistent with the acceleration hypothesis, a current account surplus leads to an appreciation of the domestic currency and vice-versa for a deficit. Note that the NFA_d doesn't shift as residents are not demanding more foreign assets; the supply of foreign assets is increasing due to payments from foreigners, shifting the NFA_s curve to the right until there is short-run equilibrium at the intersection of the CA and NFA_d curves. Domestic net foreign assets increases from NFA_0 to NFA_1.



B. *The Offshore Market*

The offshore market differs from the official market in that offshore krona assets are traded among nonresidents and there is no central bank intervention, influence, or regulation for that matter. As a result, the returns on these offshore assets include a risk premium that I interpret as the necessary excess return to equate returns across official and offshore assets. Intuitively, an offshore asset runs the risk of being seized or never maturing, so holders of these assets must be compensated for taking on this risk. I assume that the influence of residents is negligible so as to equate their supply and demands to zero.

Macedo's work on exchange rate behavior under currency inconvertibility suggests that the main interaction between the two markets stems from leakages in the current accounts. First there exists an official "reported" current account that I described above and the presence of currency inconvertibility creates an "unreported" current account. Macedo's paper suggests that leakages between the two markets occur via shifts between the current accounts from changes in the official or offshore rate. I use his result later in the description of the total interaction and equilibrium between the two markets, but this section focuses on the leakage of foreign demand for domestic assets between the two markets due to portfolio reallocations, as differing returns induce nonresidents to change their desired holdings of official and offshore domestic assets.

Given that the central bank does not utilize the offshore market and I have assumed only nonresidents trade assets in this market, short-run equilibrium is satisfied when nonresident demand for offshore domestic assets equals its supply:

$$\frac{G_b^d}{s} = \frac{G_b^0}{s}$$

where b subscripts denote offshore assets

Supply is fixed as nonresidents are trading inconvertible assets amongst each other, providing no change in the stock of assets. Thus dynamics are governed entirely by the demand function. Note also that foreign demand for domestic assets are now valued at the offshore rate, s. We define our offshore krona asset demand function of the portfolio variety similar to before:

$$\frac{G_b^d}{s} = g_b(r_{eur}, r_{isk} - \frac{e^e - e}{e}, r_{isk} - \frac{s^e - s}{s} + \phi)W^f = g_b(r_{eur}, r_{isk}, \frac{e^e - e}{e}, \frac{s^e - s}{s}, \phi)W^f$$
$$\frac{dg_{official}}{dr_{eur}} < 0, \frac{dg_{official}}{dr_{isk}} > 0, \frac{dg_{official}}{d\dot{e}} > 0, \frac{dg_{official}}{d\dot{s}} < 0, \frac{dg_{official}}{d\phi} > 0$$

Again, the asset demand function is increasing in parameters that increase its corresponding asset's return and decreasing in all others. Nonresidents are deciding how much to invest in the offshore krona asset given the alternative of an official krona or euro asset. As such I note at this point that the foreign asset demand functions must satisfy the following equality:

$$g_o + g_b + g_f = 1$$

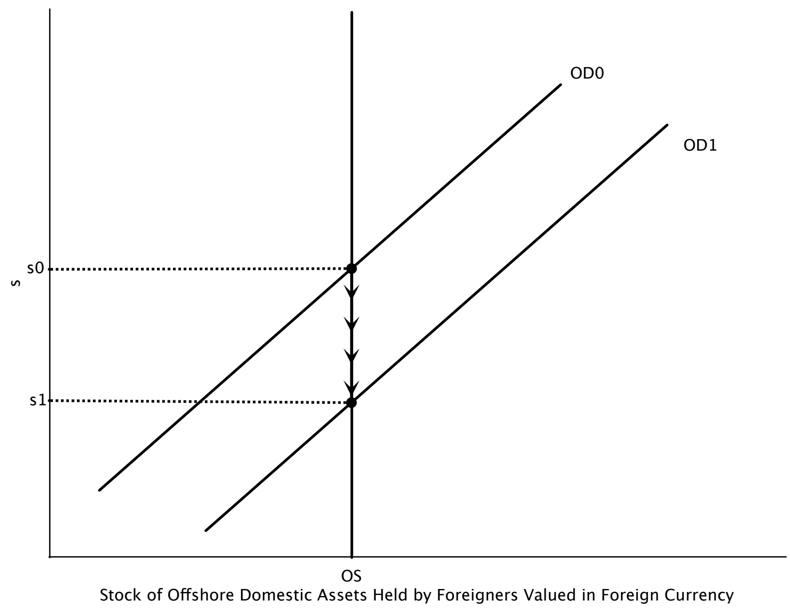
where g_f denotes foreign demand for euro assets

The above equation states that nonresidents allocate their entire wealth among available assets, namely they do not hold non-interest bearing assets (cash). Foreign exchange holdings are temporary in the sense that individuals will obtain foreign exchange and immediately use it for current account transactions, investing any proceeds back into available assets. This will simplify our analysis as we will not have to incorporate inflation or the money supply process into our equilibrium.

Now as stated above, the short-run dynamics in the offshore market are dependent solely on the demand function so the short-run equilibrium condition is:

$$G_b^d = s g_b(r_{eur}, r_{isk}, \frac{e^e - e}{e}, \frac{s^e - s}{s}, \phi)W^f = G_b^0, \text{ where } G_b^0 \text{ is fixed}$$

The offshore market is displayed in the following diagram. Equilibrium is obtained at the intersection of the foreign demand curve for offshore assets and the vertical supply curve at exchange rate, s_0. Note that nonresidents' demand for offshore assets is increasing in the offshore rate as indicated by the above equation, leading to an upward sloping demand curve. If foreign demand for offshore assets increases, due to an exogenous increase of the domestic interest rate, r_{isk}, for example, the demand curve shifts rightward. There is now excess demand for offshore krona assets at the original offshore rate, s_0, so given that there is a limited fixed supply, the offshore rate must appreciate to s_1 to re-establish equilibrium. The intuition here is that increased demand for an asset with limited supply increases the price of the asset due to competing bidders until some of them finally drop out at the higher price and the excess demand no longer exists.



For long-run equilibrium, let me first describe the unreported current account. Residents and nonresidents have the option of either fully reporting transactions and using the official current account or under invoicing (over invoicing) exports (imports) and channeling the unreported payment through the unreported current account. Given that residents will be receiving foreign exchange through payments for unreported exports from nonresidents, I assume that they simply spend all of their holdings on unreported imports.

This assumption has two implications. First, by assuming that residents receive no net foreign exchange through the restricted offshore market and equivalently the unreported current account, the existence of this additional channel of funds has no effect on residents' portfolio allocations, allowing us to continue assuming that they do not participate in either of the two asset markets. Second, as I am assuming that they spend of all of their foreign exchange holdings on unreported imports, the unreported current account will always be balanced. As a result, both current accounts have no effect on the offshore rate and unreported net foreign assets remains constant, allowing us to model the offshore market solely by the demand for offshore assets and the constant supply.

To show this formally, I recall the familiar condition that the rate of change of net foreign assets with respect to time must equal current account. From nonresidents' perspective this condition for unreported (offshore) net foreign assets and current account is:

$$\dot{NFA}_u^f = CA_{unreported}^f(e, s), \text{ where } f \text{ indicates nonresidents' perspective}$$

Since the current account is symmetric between two nations we may rewrite this in terms of the domestic current account, as $-CA = CA^f$. To determine an expression for foreigners' net foreign assets, first observe that their holdings of offshore krona assets don't affect net foreign assets as excess supply or demand is always corrected by a corresponding appreciation of depreciation of the offshore rate to keep the stock of offshore krona assets constant. Assuming that all current account transactions take place in euros, nonresidents finance purchases by selling their own holdings of foreign assets for foreign exchange, which they use for current account transactions. So for example if nonresidents are running a current account deficit, which is equivalently a domestic current account surplus, their holdings for foreign assets decreases as these assets are transferred to residents. The end result is nonresidents' net foreign assets thus decreases as residents have increased their foreign holdings. Formally we have:

$$\dot{NFA}_u^f = \frac{\dot{G}_f^d}{s} = g_f W^f \frac{\dot{s}}{s} = -CA_{unreported}(e,s)$$

Now as I assumed that the unreported current account is always balanced given that residents will return any foreign exchange acquired from exports to pay for imports this expression simplifies to:

$$\dot{NFA}_u^f = g_f W^f \frac{\dot{s}}{s} = 0$$

The above expression states that unreported net foreign assets is constant. To find an expression for the long-run change of the offshore rate, I rearrange to find:

$$\frac{\dot{s}}{s} = -\frac{CA_{unreported}(e,s)}{g_f W^f} = 0$$

C. Equilibrium Across Both Markets

From the previous two sections, we have the follow conditions for partial equilibrium in each market:

Official Market:

$$NFA_o^d = R^d - g_{official} W^f = R^0 - \frac{G_o^0}{e} = NFA_o^s$$

$$\dot{NFA}_o^d = \dot{R}^d = g_{official} W^f \frac{\dot{e}}{e} + CA_{official}(e,s)$$

Offshore:

$$G_b^d = s g_b(r_{eur}, r_{isk}, \frac{e^e - e}{e}, \frac{s^e - s}{s}, \phi) W^f = G_b^0, \text{ where } G_b^0 \text{ is fixed}$$

$$\dot{NFA}_u^f = g_f W^f \frac{\dot{s}}{s} = 0$$

To complete description of the model I now use Macedo's results from his paper on exchange rate behavior under currency inconvertibility. Specifically I use his derivation that the official current account is decreasing in the offshore rate and increasing in the official rate, and vice versa:

$$\frac{dCA_o}{ds} < 0, \frac{dCA_o}{de} > 0, \frac{dCA_b}{s} > 0, \frac{dCA_b}{e} < 0$$

Rationale for the above relationships stems from two sources. The first source comes from the quantity effect of a devaluation of the domestic currency, namely a depreciation of the corresponding exchange rate. If the Marshall-Lerner condition holds, a devaluation will improve the current account as the increase in the volume of exports and decrease in the volume imports outweighs the effect of the increased price of imports. So for example if the official exchange rate depreciates, exports become more attractive to nonresidents, thus increasing export demand, while domestic import demand simultaneously decreases, both effects improving the trade balance.

The second source comes from the leakage of foreign exchange between the two markets. As I am assuming exports and imports are purchased/sold using euros, exporters may choose to under invoice their exports and channel some euros from abroad through the parallel market. These transactions enter in through the unreported current account, thus causing a leakage of foreign exchange from the official market. Intuition is as follows: if the offshore rate depreciates, exporters being paid in euros can sell these euros at a higher price in the offshore market, collecting more kronur than if they would have used the official market. The same argument holds in the opposite direction, as a depreciation of the official rate will cause the unreported current account to deteriorate as individuals previously under invoicing exports now can obtain a similar return using the official market without the hassle of worrying about smuggling in restricted currency/assets.

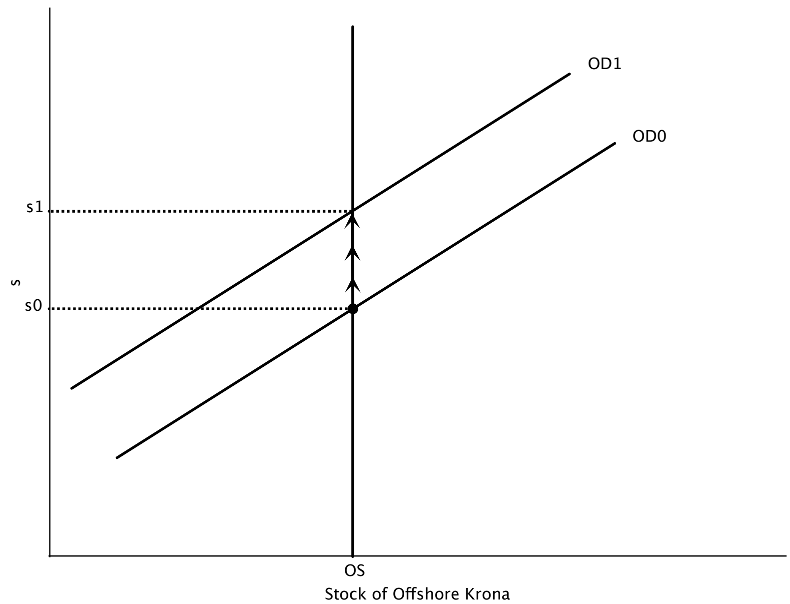
The above relationships between the two exchange rates and the two current accounts along with our equations for short-run and long-run equilibrium in both markets above complete the model. Short-run equilibrium is obtained simultaneously in both markets when there is no excess demand for official or offshore krona assets holding all parameters constant. Long-run equilibrium is established under these same conditions at the offshore and official rates, s and e, with the added requirement that the official and unreported current accounts are equal to 0. I have already assumed that the unreported current account is always balanced at 0, so we only have to examine the equation of motion for the official rate to see why this condition is stable:

$$\frac{\dot{e}}{e} = \frac{\dot{R^d} - CA_{official}(e,s)}{g_{official}W^f}$$

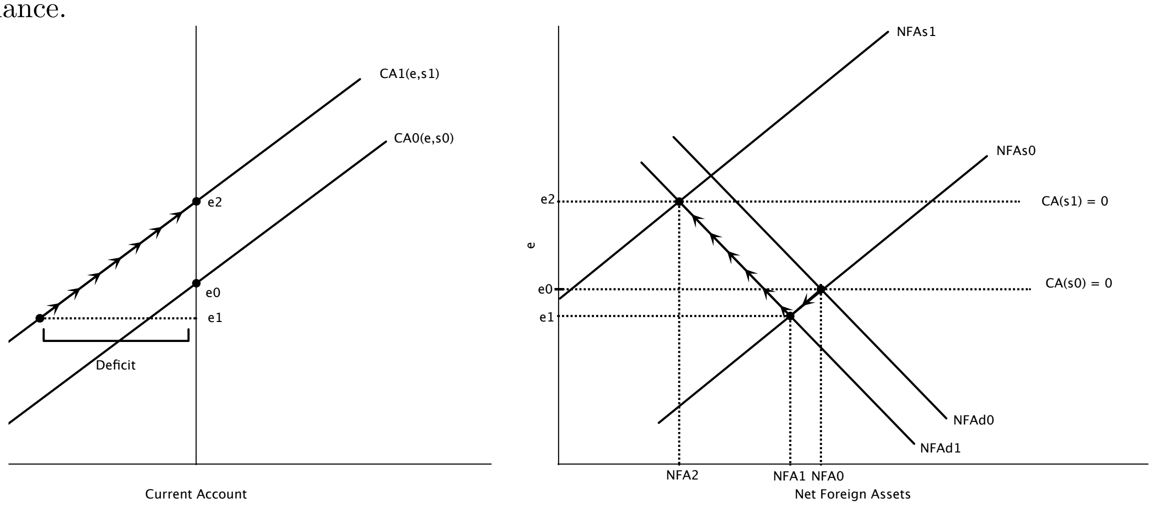
If the official current account is equal to 0 and we also assume the central bank if no longer accumulating reserves, namely $\dot{R^d} = 0$, then the official rate is constant. Given that we are at constant rates e and s equating demand and supply for assets in both markets, long-run equilibrium holds.

D. Model Dynamics

I now discuss the dynamics of the dual equilibrium. Suppose we are currently at long-run equilibrium across both markets at exchange rates e_0 and s_0. Consider a decrease in the demand for offshore kronur assets from an increase in the expected depreciation of the offshore rate. Demand for offshore kronur assets decreases, shifting the demand curve for offshore kronur to the left. For short-run equilibrium to be restored in the offshore market given excess supply at the original rate, the offshore rate must depreciate to s_1. The expected depreciation of the offshore rate also increases demand for official kronur assets as nonresidents expect a better return from this asset, implying that the decrease in demand for offshore kronur assets has shifted to official assets. The NFA_o^d schedule shifts left as the increase in demand for official assets implies an accumulation of domestic assets by nonresidents, appreciating the official rate to e_1. Our new short-run equilibrium is obtained at exchange rates e_1 and s_1 for the official and offshore markets, respectively.



The adjustment process back to long-run equilibrium now rests on the effects of these new rates on the official current account. Recall from the previous section that a depreciation of the offshore rate decreases the official current account shifting CA_o left. Since the offshore rate has permanently depreciated, the official rate must also depreciate in the long run to remove the incentive for agents to continue leaking current account transactions to the unreported current account, thus restoring balance.



At our new short-run equilibrium exchange rates, e_1 and s_1, the official current account is now in deficit. This occurs as the depreciation of the offshore rate first increases the volume of transactions funneled through the unreported current account as exporters can receive a higher relative payment in krona terms from the depreciated offshore rate compared to the official current account, shifting the $CA = 0$ schedule permanently to the left in (CA, e) space and up in (NFA, e) space. Second, as the official rate has appreciated, by the dominance of the quantity effect under the assumption of the Marshall-Lerner condition, the official current account falls further into deficit.

Given that the official current account is in deficit, the official exchange rate must depreciate to restore current account balance. This is Kouri's acceleration hypothesis at work and is justified by the equation of motion for the official exchange rate derived in the previous sections. Long-run equilibrium is restored once the official rate has depreciated to e_2 at which the current accounts are once again in balance and there is no excess demand for assets in either market.

Note that our new equilibrium exchange rates satisfy $e_2 > e_0 > e_1$ and $s_0 < s_1$. The intuition is as follows: an initial expected depreciation of the offshore rate induces nonresidents to reallocate their portfolio holdings away from offshore krona assets towards official krona assets, thus appreciating and depreciating the official and offshore rates in the short-run, respectively. As the offshore rate is only influenced by short-run changes and is invariant to current account influences due to the assumption of permanent balance in the unreported current account, it remains at s_1. Domestic net foreign assets has decreased to NFA_1 as nonresidents have increased their holdings of official assets.

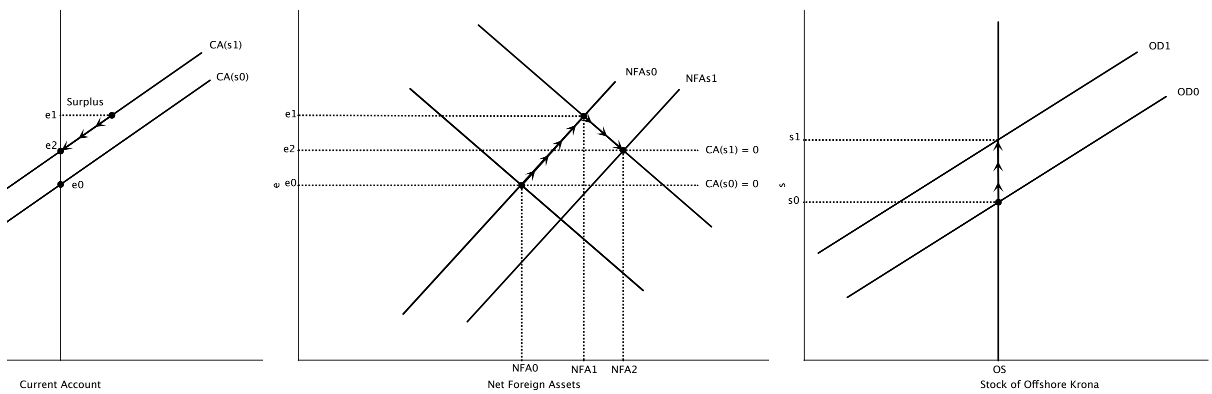
As we approach the long-run, the new exchange rates induce trade imbalances as the Marshall Lerner condition ensures that a depreciation (appreciation) improves (deteriorates) a respective current account, while a simultaneous leakage of exports from the official market to the offshore market reinforces this effect. With the official current account in deficit at the new exchange rates, domestic net foreign assets decreases further to NFA_2 to finance the imbalance as foreign assets are flowing out, causing a depreciation of the official rate to e_2. It is interesting to note that a decrease in demand for the offshore krona asset has actually depreciated the official exchange rate in the long-run in spite of an initial appreciation, supporting the notion that the existence of the offshore market equilibrates the official rate at a higher value than in its absence. Without the leakage of funds from the official current account to the unreported current account, the $CA = 0$ schedule would not shift, allowing the official rate to depreciate back to e_0 instead of the higher e_2.

E. Comparative Statics

Before going into the empirical tests, let us first work through a few comparative statics exercises to justify exchange rate movements in my model under various exogenous changes. I begin with an exogenous decrease in the Icelandic interest rate, r_{isk}.

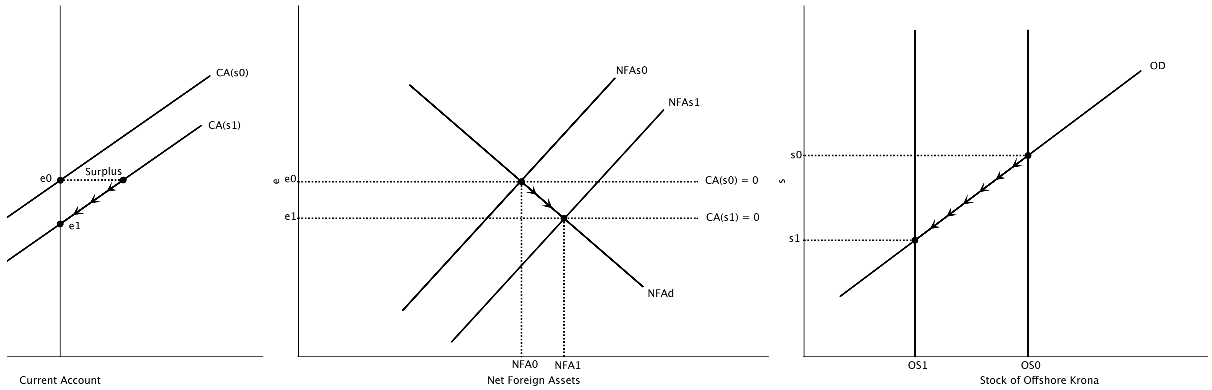
A decrease in r_{isk} reduces the expected returns of official and offshore krona assets, shifting demand from these assets towards the official euro asset. As a result the offshore demand curve shifts left, while the domestic demand schedule for net foreign assets shifts right as nonresidents have lower desired demand for all krona assets. The official and offshore rates both depreciate from e_0 and s_0 to e_1 and s_1 respectively, at which we obtain short-run equilibrium in both markets.

As in the case just discussed, the depreciation of the offshore rate increases incentives to use the unreported current account, shifting the CA schedule to the left in (CA, e) space and the $CA = 0$ schedule up in (NFA, e) space. The difference here is that the official rate has depreciated in the short-run, placing the official current account in surplus. In the long run, the official rate must appreciate to e_2 to rebalance the current account, consistent with the acceleration hypothesis. Net foreign assets increases throughout this process from NFA_0 to NFA_1 in the short run, finally ending up at NFA_2 in the long run. Note that an exogenous decrease in r_{eur} would produce precisely the opposite effects as just discussed. The dynamics occur the same way, but in the opposite direction.



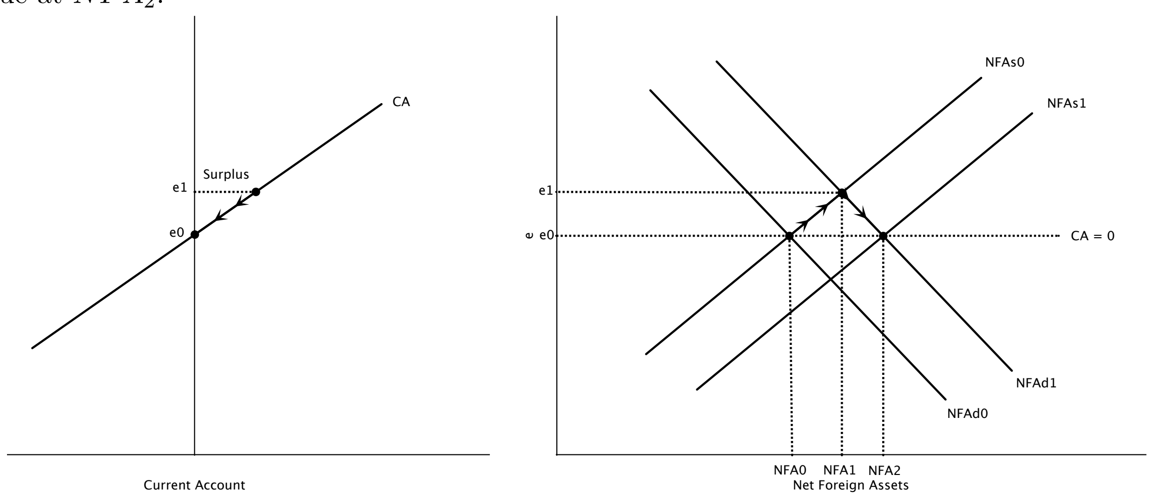
The next exercise examines dynamics following a decrease in the stock of offshore kronur, an exogenous change that occurs following an auction in which the central bank purchases offshore krona assets from nonresidents. The vertical supply curve shifts left as the stock of offshore kronur has permanently decreased. There is now excess demand for the offshore krona asset at the initial offshore rate, s_0, so the offshore rate appreciates to s_1 as the price of the offshore asset has increased due to competitive bidding by nonresidents. At s_1 a sufficient number of nonresidents have dropped out of bidding for the asset, decreasing desired demand to equate it to the new, lower stock of offshore krona.

No relative returns have changed, so in the short run, the official market and rate should be unchanged. However the appreciated offshore rate reduces incentives to use the unreported current account, thus improving the current account at every official exchange rate and shifting the CA schedule right in (CA, e) space and the $CA = 0$ schedule down in (NFA, e) space. As the official current account is now in surplus at the original official exchange rate e_0, it must appreciate to e_1 to rebalance the current account. Throughout the process, net foreign assets has increased from NFA_0 to NFA_1. One can infer from these dynamics that a decrease in the stock of offshore krona is beneficial to the official market as the exchange rate appreciates and the domestic country accumulates foreign assets, strengthening their international position.



The final case we examine is a foreign reserve purchase by the central bank, which occurs when the central bank purchases euros during an auction. The central bank's desired demand for foreign assets increases, so the NFA_d schedule shifts right, depreciating the official rate from e_0 to e_1 as there is excess demand for foreign assets at the original rate, bidding up the price of foreign assets and equivalently decreasing the price of domestic assets. As the central bank has acquired foreign assets, net foreign assets has increased from NFA_0 to NFA_1 in the short run.

As there is no change in expected return of any asset, the offshore market is unaffected, hence the current account schedule remains the same. However, the depreciation of the official rate has left the economy at a current account surplus by the Marshall-Lerner condition, so the currency must reappreciate back to e_0 in the long run. Net foreign assets increases further to its long-run value at NFA_2.



IV. Empirical Tests

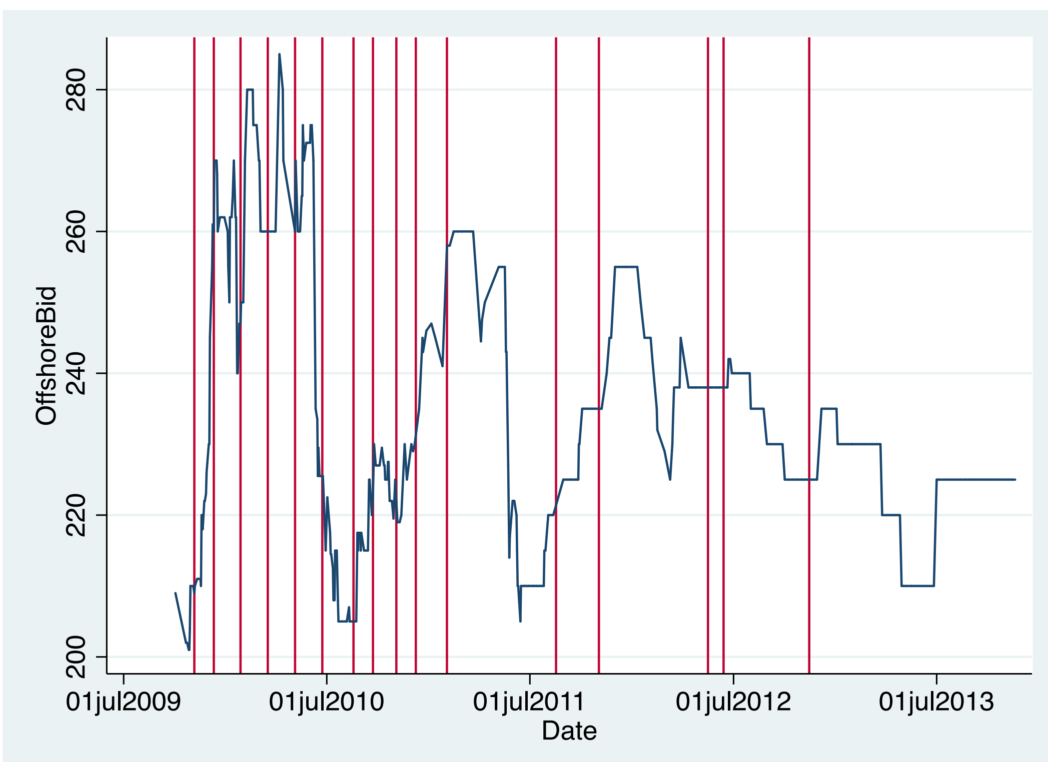
A. Data Description

The data is aggregated from the Central Bank of Iceland, European Central Bank, and Keldan. Official Icelandic exchange rates, interest rate changes, and foreign currency auction announcements are obtained from the News and Speeches and Statistics sections of the Central Bank of Iceland's website. Eurozone interest rate changes and long-term and main refinancing announcements come from the European Central Bank's Key Euro Rates and Key Dates of the Financial Crisis pages. The offshore rate is obtained from Keldan, an Icelandic financial statistics reporting service suggested to me by the Central Bank of Iceland.

The data is merged as a time series data set with one observation for each date containing offshore exchange rate data starting on October 2nd, 2009. The main limitation is the lack of uniformity in the timing the offshore data as observations range from being 1 day to a maximum of 25 days apart. Furthermore there are cases in which an interest rate change or announcement occurs on a date with no offshore data, namely it occurs between two observations. In these cases I assign the announcement/change to the closest previous date with data as I assume exchange rate changes occur the day after an announcement/change and weight the observation by the number of days to the next observation. I will clarify upon this weighting and my regression specification shortly.

B. Preliminary Analysis

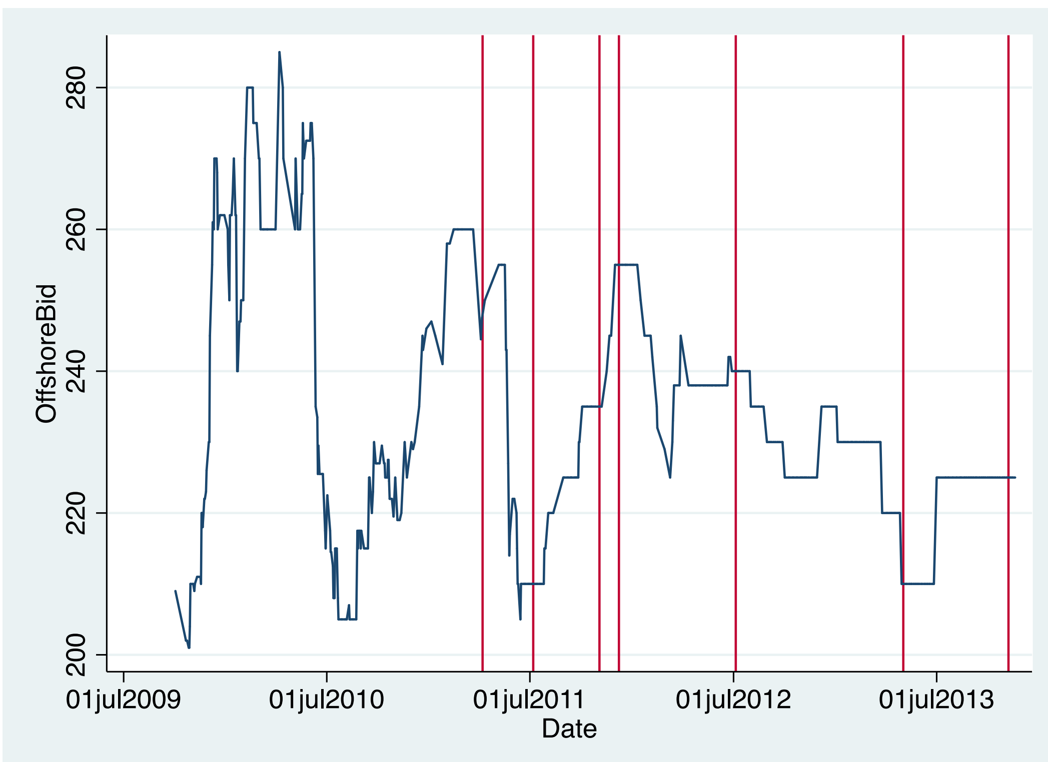
I begin my analysis by looking at time series plots of the offshore rate with lines indicating announcements of interest rate changes, foreign currency auctions, ratings changes, and long-term refinancing operations.



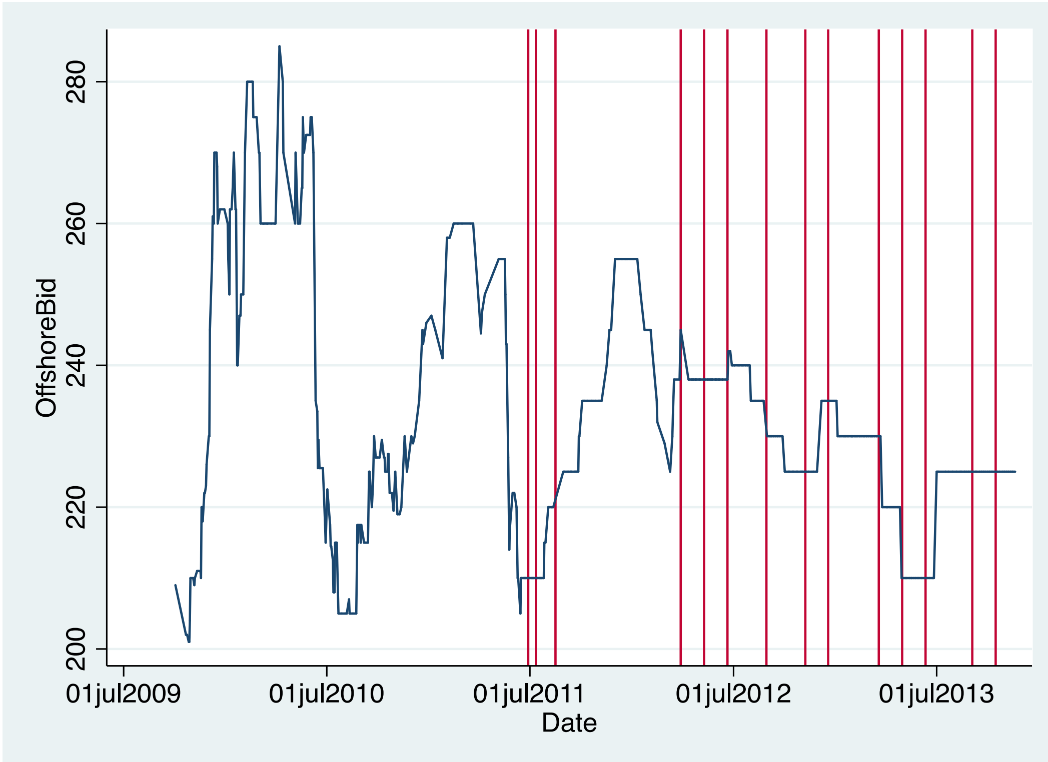
Red lines indicate changes Icelandic interest rate changes.

The first plot displays the offshore rate with red lines indicating Central Bank of Iceland announcements of interest rate changes. The plot suggests that Icelandic interest rate changes have a significant effect on the offshore rate as the offshore rate consistently changes following each event. This is consistent with the model delineated above as a decrease in the Icelandic interest rate decreases the returns from Icelandic assets, shifting demand towards foreign assets, and thus depreciating exchange rates. I will formally examine this in the regressions in the next section.

The following two plots perform the same exercise, plotting the offshore rate with lines indicating interest rate announcements by the European Central Bank and foreign currency auction results by the Central Bank of Iceland respectively. As we can see, in most cases the offshore rate is left unchanged following these announcements. This is surprising as I expect a portfolio reallocation to cause changes in the offshore rate following the change in the Eurozone interest rate. However it is convincing that the auctions do not affect the offshore rate as the decreases in the stock of offshore kronur following the auctions may be small relative to the total stock.



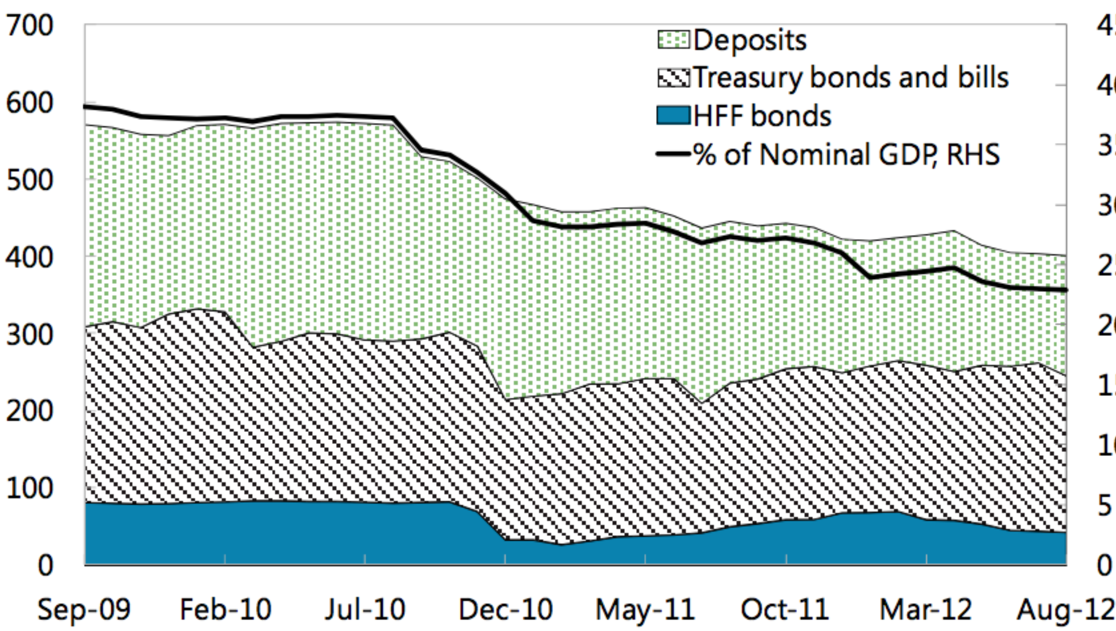
Red lines indicate ECB interest rate change announcements.



Red lines indicate CBI foreign currency auction result announcements.

Holdings of Offshore Krona

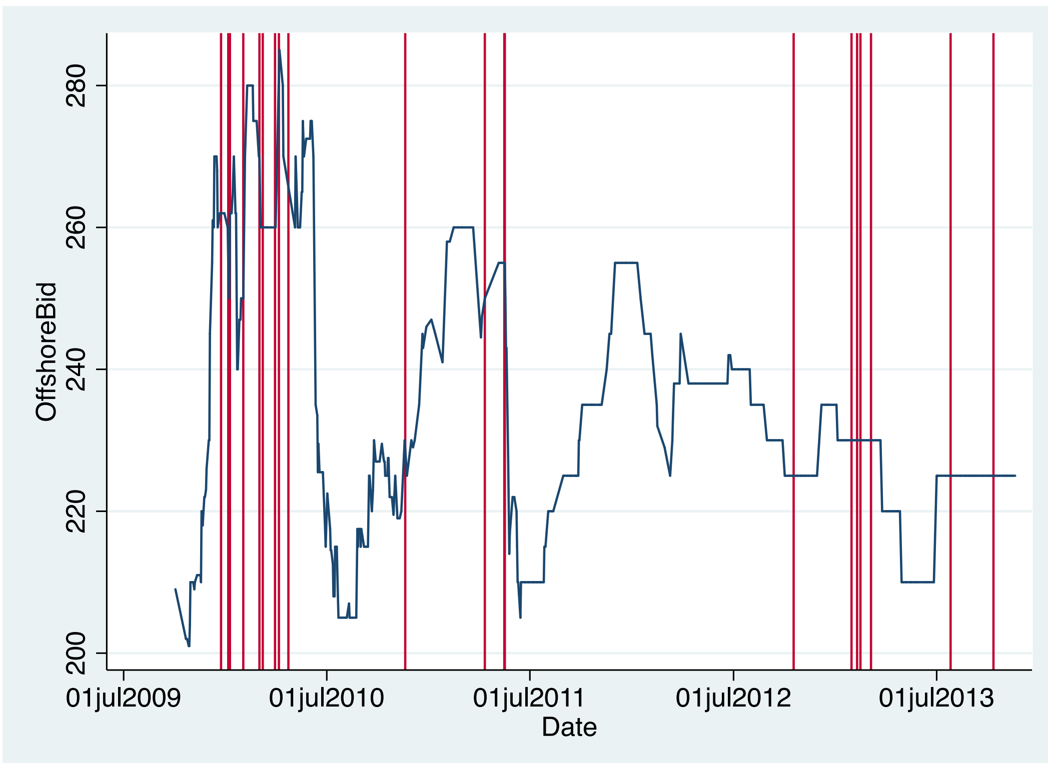
(Billions of krona)



Sources: Central Bank of Iceland; and IMF staff calculations.

The above graph displays the stock of offshore kronur over time, split into different asset classes. The total stock has declined about 100 billion kronur from September 2009 to August 2012, a little less than 16%. The volume of krona purchases in auctions since July 2011 has averaged about 7 billion kronur per auction, so each auction decreases the total stock by between 1-2% of the total stock, a very negligible amount. Thus it is not surprising to not see any significant movements of the offshore rate following these events.

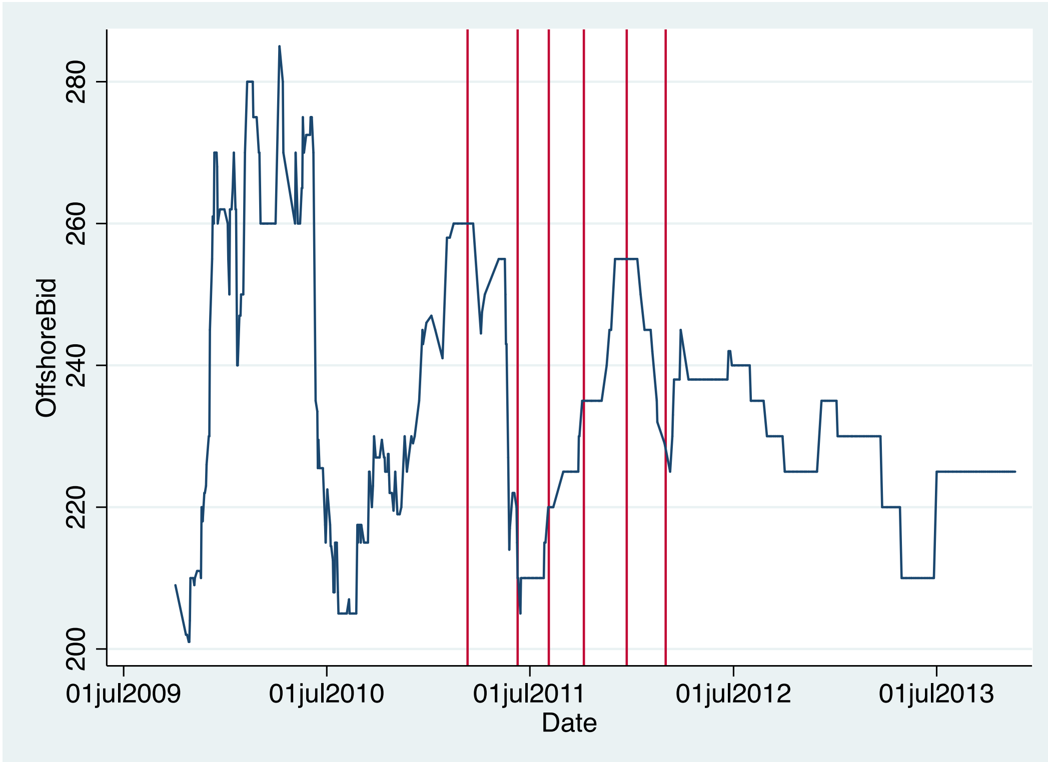
The following graph displays dates of news announcements regarding Icelandic credit ratings by agencies such as Moody's, Fitch, and Standard and Poor's:



Red lines indicate ratings news announcements.

As we can see in the high variability region between October 2009 and July 2010, there appears to be changes in the offshore rate following a ratings news announcement. I hypothesize that this change occurs as a change in ratings affects depreciation expectations, shifting our portfolio demand functions, thus causing the offshore rate to adjust to re-establish short-run equilibrium.

The final graph displays dates of long-term refinancing operations announcements by the European Central Bank. For the most part, there seems to be no systematic change in the offshore rate following these announcements. This may be because the offshore market is isolated from the official market and an increase in liquidity in the Eurozone may reallocate holdings in the official market between official krona and euro assets, but changes nothing in nonresidents' desired holdings of offshore assets.



Red lines ECB long-term refinancing announcements.

C. Regression Methodology

To examine the effect of announcements of changes in interest rates, the stock of offshore krona, and reserve assets, I propose the following baseline regression:

$$\Delta s_t = \alpha_0 + \alpha_1 r_{isk} Dummy_{t-1} + \alpha_2 r_{eur} Dummy_{t-1} + \alpha_3 KronaPurchaseDummy_{t-1} \\ + \alpha_4 \Delta EuroPurchaseDummy_{t-1} + \epsilon_t$$

This specification regresses changes of the offshore rate between $t-1$ and t on a set of indicator variables denoting an announcement of a change in the related variable on the previous day. The interest rate dummies are equal to 1 or -1 when the announcement at $t-1$ is a decrease or increase in the interest rate, respectively, and 0 otherwise. The purchase dummies are simply 1 if there is an announcement of foreign auction results at $t-1$ and 0 otherwise. This baseline regression examines whether there is indeed an effect from these announcements on the offshore rate, not yet accounting for the magnitude of the change. In addition to this initial specification, I will also add in dummies for ratings, long-term refinancing operations, and main refinancing operations announcements to see if they significantly change results. Given that these announcements may have a multitude of channels of influence on the asset market, it is difficult to isolate and predict their effects on the offshore rate.

The following specification accounts for the actual magnitude of the changes, namely the numerical value of the change in the interest rates and volume of purchases in the auctions:

$$\Delta s_t = \beta_0 + \beta_1 \Delta_{t-1} r_{isk} + \beta_2 \Delta_{t-1} r_{eur} + \beta_3 \Delta_{t-1} OffshoreKrona + \beta_4 \Delta_{t-1} EuroReserves + \nu_t$$

This regression provides a more precise measure of the effect of these announcements on the offshore rate. Each regressor measures the change in the relevant variable between $t-2$ and $t-1$. Given that the timing of these announcements is not uniform and the time of the offshore rate observation is uncertain, I assume that these changes are reflected in exchange rate the following day, t. So for example if the Central Bank of Iceland announces a decrease in the interest rate of 50 basis points on $t-1$, we have $\Delta_{t-1} r_{isk} = -.50$ which we use to determine the change in the offshore rate, $\Delta s_t = s_t - s_{t-1}$. As the change in the offshore rate should occur immediately after the announcement on day $t-1$, I expect this change to be reflected between $t-1$ and t. Similar to the above regression, I will also add in the indicator variables of ratings, long-term refinancing operations, and main refinancing operations announcements to observe whether they change the effects on the offshore rate and are significant determinants. I do not quantify these variables as the announcements are qualitative in nature.

Now as stated in the data description section, the main limitation of the data set is the lack of uniformity in the dates of the offshore rate observations. This leads to the possibility of heteroskedasticity as the change in the offshore rate could range from being the ideal one day difference to a maximum of twenty-five days. To account for this, I assume that the variance of each observation is proportional to the size of the window, so for example if there is only offshore data on $t-x$ and t, the conditional variance of the observation is x times as large as the conditional variance of an ideal observation. Data for all other variables aside from the offshore rate is complete, hence we do not have to worry about independent variables missing data on $t-x-1$. Finally if the announcement occurs between $t-x$ and t, I assign the announcement to date $t-x$ as the change in the offshore rate should be observed in the difference between $t-x$ and t, assuming no other changes during this period.

Formally, our original regression is of the form:

$$\Delta_x s_t = s_t - s_{t-x} = \beta_0 + \beta_1 \Delta_{t-x} r + \beta_2 \Delta_{t-x} OffshoreKrona + \eta_t, \text{ where } \eta_t = \sqrt{x}\nu_t$$

Our desired error term is ν_t, which is our homoskedastic error term if we had complete offshore data. To obtain the weighted least squares estimators, the best linear unbiased estimators (BLUE) which allow us to run ordinary least squares, we simply divide all terms of the above equation by $\sqrt{x}$ to obtain:

$$\frac{\Delta_x s_t}{\sqrt{x}} = \beta_0 \frac{1}{\sqrt{x}} + \beta_1 \frac{\Delta_{t-x} r}{\sqrt{x}} + \beta_2 \frac{\Delta_{t-x} OffshoreKrona}{\sqrt{x}} + \nu_t$$

The above specification ensures that the estimators obtained through ordinary least squares are BLUE, giving us estimates of the coefficients β_0, β_1, and β_2 with the least variance compared to other estimators. I will utilize this approach in any regressions involving observations with windows greater than 1 to ensure that my empirical results are statistically sound.

D. Results

I first regress the change in the offshore rate on the set of dummies indicating central bank announcements. I begin with the first specification delineated above as a baseline and subsequently add in ratings, long-term refinancing, and main-refinancing operations announcement dummies in search of any significant changes. For robustness, I run these same regressions on the subsample of observations with offshore data on $t-1$ to ensure that my results are not skewed by spurious correlation stemming from the larger windows or my weighted least squares method. The subsample results are displayed in columns (1), (3), and (5), while the full sample weighted least squares results are in columns (2), (4), and (6).

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δs_t	Δs_t	Δs_t	Δs_t	Δs_t	Δs_t
r_{isk} Announcement	5.077***	3.744**	5.067***	3.737**	5.066***	3.739**
	(1.872)	(1.452)	(1.877)	(1.453)	(1.883)	(1.456)
r_{eur} Announcement	-1.731	-1.289	-1.733	-1.291	-1.734	-1.291
	(1.396)	(0.838)	(1.390)	(0.835)	(1.394)	(0.838)
Krona Purchase Announcement	-0.115	-0.102	-0.133	-0.109	-0.135	-0.108
	(0.268)	(0.366)	(0.270)	(0.366)	(0.275)	(0.367)
Euro Purchase Announcement	-0.115	0.294	-0.133	0.288	-0.135	0.289
	(0.268)	(0.395)	(0.270)	(0.396)	(0.275)	(0.397)
Change in Ratings			1.317	1.158	1.318	1.157
			(1.130)	(0.904)	(1.135)	(0.906)
LTRO Announcement					-0.135	-3.255
					(0.275)	(2.610)
MRO Announcement						3.826
						(2.775)
Constant	0.115	0.0180	0.133	0.0298	0.135	0.0278
	(0.268)	(0.183)	(0.270)	(0.182)	(0.275)	(0.185)
Observations	146	483	146	483	146	483
R-squared	0.076	0.029	0.081	0.034	0.081	0.037

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As we can see a CBI announcement of monetary loosening, or a decrease in the Icelandic interest rate, is associated with a depreciation of the offshore rate. This effect is significant at the 5% level, suggesting a dominant effect of the domestic rate on the offshore market. On the other hand, an ECB announcement of a decrease in the Eurozone rate appreciates the offshore rate by about a third of the magnitude as the same announcement by the CBI. Unfortunately this effect is not significant at even the 10% level, but the sign is correct. Likewise the krona purchase announcement also appreciates the offshore rate, consistent with theory, although the effect is not significant. In addition, the magnitude is quite small, suggesting that the offshore market is not greatly affected by changes in the stock, consistent with the fact that these auctions only decrease the stock of offshore krona by a negligible amount. Note that adding additional indicators does not significantly change results or contribute any significant effects.

Results in the subsample and the full sample are relatively similar. The subsample results suggest a larger effect from announcements given the larger magnitude of coefficients compared to the full sample results. One possible explanation of this pattern is the existence of some other unaccounted announcement or event between $t-x$ and t that dampens the effect of the announcement of interest. Another possibility is a short-term overshooting of the offshore rate. The announcement may initially cause an immediate large change in the offshore rate stemming from increased activity in the offshore market the day after the announcement. However as time passes, activity declines, mildy reversing the effect and thus decreasing the overall change in the offshore rate.

Now although the coefficient of the ratings announcements is not significant, it is interesting to discuss the results. First let me explain the change in ratings variable. This variable is coded as an indicator variable taking values of -2, -1, 0, 1 and 2. A value of 2 or -2 indicates an explicit increase or decrease in ratings respectively say from BBB- to BBB. A value of 1 or -1 indicates good or bad news regarding ratings, but not an explicit change in the actual ratings. An example of this would be an announcement reaffirming Iceland's outlook as negative. I allow for different levels of ratings announcements because, realistically, an explicit downgrade of a sovereign's credit rating should have a much larger effect than an announcement reaffirming a poor rating given that investors perceive the former as relatively more significant new information. A large ratings announcement does not necessarily have twice the impact of a medium announcement, but this variable roughly captures the difference between the two. A precise treatment of this would require an objective quantification of qualitative ratings announcement, an exercise beyond the scope of this paper.

Returning to our results, notice the positive coefficient of the ratings variable, suggesting that an improvement in Icelandic credit ratings depreciates the offshore rate. This is quite surprising as a positive ratings announcement should improve (decrease) expected depreciation, thus increasing the expected return of all krona assets, compelling nonresidents to increase their desired holdings of onshore and offshore krona assets, which appreciates the official and offshore rates. Given that the results suggest a depreciation of the offshore rate, one possibility is that ratings announcements only affect the expected deprecation of the official rate. Following the model, this improves the return of official krona assets, causing nonresidents to reallocate their portfolio demand from offshore to official krona assets, decreasing demand for offshore krona assets, thus depreciating the offshore rate and appreciating the official rate. Note however that as the coefficient on the ratings indicator is insignificant, there could simply just be no effect from ratings regardless of this potential mechanism.

It is useful here to run the same regressions as above on the change of the official exchange rate to determine whether this mechanism is indeed at work and to compare general results. If the ratings announcements shift demand between offshore to official assets, we expect a negative coefficient on the ratings indicator.

VARIABLES	(1) Δe_t	(2) Δe_t	(3) Δe_t	(4) Δe_t	(5) Δe_t	(6) Δe_t
r_{isk} Announcement	-0.240	-0.0460	-0.242	-0.0465	-0.244	-0.0482
	(0.586)	(0.401)	(0.588)	(0.401)	(0.590)	(0.402)
r_{eur} Announcement	0.211	0.251	0.211	0.251	0.210	0.251
	(0.221)	(0.194)	(0.223)	(0.195)	(0.225)	(0.195)
Krona Purchase Announcement	0.324***	0.181	0.321***	0.180	0.316***	0.178
	(0.0394)	(0.142)	(0.0399)	(0.142)	(0.0404)	(0.141)
Euro Purchase Announcement	0.204***	0.0924	0.201***	0.0918	0.196***	0.0899
	(0.0394)	(0.135)	(0.0399)	(0.135)	(0.0404)	(0.134)
Change in Ratings			0.227	0.101	0.229	0.102
			(0.217)	(0.114)	(0.216)	(0.114)
LTRO Announcement					-0.339***	-0.308
					(0.0926)	(0.239)
MRO Announcement						0.0700
						(0.227)
Constant	-0.0241	-0.0379	-0.0209	-0.0368	-0.0161	-0.0337
	(0.0394)	(0.0322)	(0.0399)	(0.0323)	(0.0404)	(0.0327)
Observations	146	483	146	483	146	483
R-squared	0.013	0.006	0.018	0.007	0.025	0.009

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

As we can see, the coefficient for the change in ratings variable is again positive and insignificant, preventing us from making any substantial claims about the effect of ratings on exchange rates and my outlined mechanism. Most variables are insignificant, an unsurprising result as an official exchange rate should adjust much faster than an offshore rate due to the depth and larger volume of activity of the official market. This suggests a higher likelihood of exchange rate changes occurring in a shorter time frame than a day, so the effect of the announcement is already incorporated in e_{t-1}.

The significance of the krona and euro purchase announcements is interesting as it comes in highly at 1% only for the subsample, suggesting that changes in central bank reserve are the dominant determinant of the official exchange rate. Given that the capital controls prevent the free movement of assets and the volume of assets free from controls is likely very small compared to the total volume of assets, it is consistent that central bank reserve movements primarily account for significant changes in the exchange rate.

Lastly note the significance of the LTRO announcement for the subsample. The coefficient is negative at 1% significance, suggesting that increased Eurozone liquidity increases demand for official krona assets, thus appreciating the official rate to a minor extent in the shortest time frame. However, this result does not hold for the full sample, so we cannot extrapolate this conclusion for sure.

I now examine the effect of interest rate changes and central bank currency purchases on the offshore rate, accounting for the magnitude of the changes. Krona and euro purchases are scaled by billions and changes refer to the difference between the relevant variable from $t-2$ to $t-1$. Subsample results are in columns (1), (3), and (5) and full sample results are displayed in columns (2), (4), and (6). Note that there are only 3 observations with a Eurozone interest rate change and the MRO announcement indicator is perfectly collinear with the LTRO announcement indicator in the subsample, explaining the negligible and omitted effects respectively.

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Δs_t	Δs_t	Δs_t	Δs_t	Δs_t	Δs_t
$\Delta_{t-1} r_{isk}$	-6.744**	-5.502**	-6.724**	-5.489**	-6.723**	-5.492**
	(2.951)	(2.192)	(2.961)	(2.193)	(2.971)	(2.198)
$\Delta_{t-1} r_{eur}$	0	-1.299	0	-1.284	0	-1.287
	(0.229)	(0.925)	(0.283)	(0.923)	(0.288)	(0.926)
Krona Purchases (b.kr)	-0.00533	0.0231	-0.00656	0.0223	-0.00666	0.0225
	(0.0179)	(0.0371)	(0.0180)	(0.0371)	(0.0183)	(0.0373)
Euro Purchases (b.eur)	-1.288	1.010	-1.587	0.816	-1.610	0.854
	(4.329)	(5.384)	(4.348)	(5.376)	(4.427)	(5.408)
Change in Ratings			1.299	1.152	1.300	1.151
			(1.124)	(0.902)	(1.128)	(0.904)
LTRO Announcement					-0.0994	-3.235
					(0.273)	(2.618)
MRO Announcement						3.836
						(2.782)
Constant	0.0795	-0.0102	0.0980	0.00154	0.0994	-0.000774
	(0.267)	(0.184)	(0.268)	(0.183)	(0.273)	(0.185)
Observations	146	483	146	483	146	483
R-squared	0.073	0.032	0.077	0.036	0.077	0.040

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Consistent with the indicator announcement regressions, the dominant force behind offshore rate changes are Icelandic interest rate adjustments. The results suggest that an interest rate decrease of 50 basis points depreciates the offshore rate between 2.7 and 3.4 kronur per euro, an effect significant at the 5% level in the full and sub samples. As before, all other effects are insignificant and additional regressors do not significantly alter results. It is interesting to note that the coefficients for the subsample and full sample frequently do not agree for other regressors. However as we cannot reject the null hypothesis that these coefficients are equal to zero, this result is not a serious issue.

The following table presents the same regression specifications as above on the official exchange rate:

VARIABLES	(1) Δe_t	(2) Δe_t	(3) Δe_t	(4) Δe_t	(5) Δe_t	(6) Δe_t
Δr_{isk}	-0.0542	-0.166	-0.0508	-0.164	-0.0456	-0.161
	(0.685)	(0.482)	(0.688)	(0.482)	(0.691)	(0.483)
Δr_{eur}	-0.220	-0.115	-0.220	-0.114	-0.220	-0.110
	(0.270)	(0.306)	(0.261)	(0.306)	(0.248)	(0.306)
Krona Purchases (b.kr)	0.0220***	0.0187**	0.0218***	0.0186**	0.0215***	0.0184**
	(0.00265)	(0.00731)	(0.00269)	(0.00732)	(0.00272)	(0.00734)
Euro Purchases (b.eur)	3.380***	2.825	3.328***	2.808	3.251***	2.755
	(0.641)	(1.949)	(0.650)	(1.951)	(0.659)	(1.957)
Change in Ratings			0.225	0.101	0.227	0.101
			(0.219)	(0.115)	(0.218)	(0.114)
LTRO Announcement					-0.334***	-0.307
					(0.0927)	(0.239)
MRO Announcement						0.0706
						(0.227)
Constant	-0.0287	-0.0396	-0.0255	-0.0386	-0.0207	-0.0354
	(0.0396)	(0.0323)	(0.0401)	(0.0325)	(0.0407)	(0.0329)
Observations	146	483	146	483	146	483
R-squared	0.004	0.005	0.010	0.006	0.016	0.007

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The highly significant effect of central bank currency purchases on the official rate appears once again, supporting the notion that changes in the official rate stem largely from reserve movements. The subsample results suggest that a central bank purchase of one billion euros depreciates the exchange rate by approximately 3.2 krona per euro. The effect of krona purchases is intriguing as it is quite significant across all specifications, yet holds such a small magnitude. Furthermore my model predicts that a change in the stock of offshore kronur should not affect the official rate in the short run as it does not change expected returns. Regardless, given that central bank krona purchases have a mean of 4.5 billion kronur, the expected change on the official rate is less than .10 krona per euro, a negligible change relative to the actual rate.

Another interesting result we observe again is the significant effect from the LTRO announcement in the subsample. The negative coefficient suggests that a liquidity announcement from the European Central Bank appreciates the official rate with 1% significance, but note that the magnitude on the change is negligible similar to the krona purchase effect.

V. Conclusion

This paper has developed a variation of Kouri's partial equilibrium model of foreign exchange adapted for Iceland and its current capital controls regime. The model accounts for an offshore market for krona assets which affects nonresidents' portfolio allocations, establishing a partial dual market equilibrium across official and offshore markets. The two markets are linked by portfolio reallocations between assets sold separately in each market and current account leakages. Consistent with central bank predictions, the model shows that the official rate equilibrates at a value higher than in absence of the offshore market. Various comparative statics are analyzed and I find that decreasing the stock of offshore kronur is a promising strategy to strengthen Iceland's international position, appreciating its official exchange rate and increasing its stock of foreign assets.

The empirical section tests for effects of announcements from the Central Bank of Iceland and the European Central Bank, focusing specifically on interest rate changes and foreign currency auctions, on the offshore rate. Through weighted least squares, I find that changes in the Icelandic interest rate have the largest and most significant effect on the offshore exchange rate. This effect is consistent with the theoretical findings in the model. Note that although other announcements do not have significant effects on the offshore rate, they do possess the correct sign. I expected the foreign currency auctions to have a larger role in determining in the offshore rate, however given the fact that the volume of these auctions is only a small fraction of the total stock, my results are not surprising. The auctions do however have a significant effect on the official rate, although the magnitude is quite small.

My work can be improved and extended by obtaining more complete data on the offshore rate and lifting assumptions in the model by incorporating things such as inflation and the money growth process. The first logical extension would be to remove the assumption that nullifies the behavior of residents and model how their portfolio decisions affect the markets and exchange rates.

VI. References

Adams, Charles and Jeremy Greenwood, 1985. "Dual Exchange Rate Systems and Capital Controls: An Investigation," Journal of International Economics, Elsevier, vol. 18(1-2), pages 43-63, February.

Argy, Victor and Michael G. Porter, 1972. "The Forward Exchange Market and the Effects of Domestic and External Disturbances under Alternative Exchange Rate Systems," IMF Staff Papers, Palgrave Macmillan, vol. 19(3), pages 503-532, November.

Central Bank of Iceland, 2009. Capital Account Liberalisation Strategy, August.

Central Bank of Iceland, 2009, 2010, 2011, 2012, 2013. Financial Stability Report.

Central Bank of Iceland, 2011. Report on Capital Account Liberalisation Strategy, March.

Central Bank of Iceland, 2013. Rules no. 300/2013 on Foreign Exchange, March.

Central Bank of Iceland, 2013. Foreign Exchange Act no.87/1992, June.

Cumby, Robert E., 1984. "Monetary Policy under Dual Exchange Rates," Journal of International Money and Finance, Elsevier, vol. 3(2), pages 195-208, August.

Decaluwe, B. and Alfred Steinherr, 1976. "A Portfolio Balance for a Two-Tier Exchange Market," Economica, London School of Economics and Political Science, vol. 43(17), pages 111-25, May.

Dooley, Michael P. and Peter Isard, 1983. "The Portfolio-Balance Model of Exchange Rates and Some Structural Estimates of the Risk Premium," IMF Staff Papers, Palgrave Macmillan, vol. 30(4), pages 683-702, December.

Dornbusch, Rudiger, 1986. "Special Exchange Rates for Capital Account Transactions," NBER Working Papers 1659, National Bureau of Economic Research, Inc.

Dornbusch, Rudiger et al., 1983. "The Black Market for Dollars in Brazil," The Quarterly Journal of Economics, MIT Press, vol. 98(1), pages 25-40, February.

Fleming, J. Marcus, 1974. "Dual Exchange Markets and Other Remedies for Disruptive Capital Flows," IMF Staff Papers, Palgrave Macmillan, vol. 21(1), pages 1-27, March.

Flood, Robert P., 1978. "Exchange Rate Expectations in Dual Exchange Markets," Journal of International Economics, Elsevier, vol. 8(1), pages 65-77, February.

Frenkel, Michael, 1990. "Exchange Rate Dynamics in Black Markets," Journal of Economics, Springer, vol. 51(2), pages 159-176, June.

International Monetary Fund, 2009, 2010, 2011, 2012, 2013. Iceland: Annual Report on Exchange Agreements and Exchange Restrictions.

International Monetary Fund, 2008, 2010, 2012. Iceland: Article IV Consultation.

Kouri, Pentti, 1983. "Balance of Payments and the Foreign Exchange Market: A Dynamic Partial Equilibrium Model," in Economic Interdependence and Flexible Exchange Rates, edited by J. S. Bhandari and B. H. Putnam. Cambridge: MIT Press.

Macedo, Jorge Braga de, 1979 and 1980. "Exchange Rate Behavior under Currency Inconvertibility," respectively: EGC Discussion Paper No. 319, Yale University, September, and RPDS Discussion Paper No. 92, Princeton University, December.

Macedo, Jorge Braga de, 1982. "Exchange Rate Behavior with Currency Inconvertibility," Journal of International Economics, Elsevier, vol. 12, pages 65-81.

Stock, James H. and Mark W. Watson, 2007. "Weighted Least Squares." Introduction to Econometrics 3rd ed., Boston: Pearson/Addison Wesley.