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6513
2017

June 2017

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CESifo

Impressum:

CESifo Working Papers
ISSN 2364-1428 (electronic version)
Publisher and distributor: Munich Society for the Promotion of Economic Research - CESifo GmbH
The international platform of Ludwigs-Maximilians University's Center for Economic Studies and the ifo Institute
Poschingerstr. 5, 81679 Munich, Germany
Telephone +49 (0)89 2180-2740, Telefax +49 (0)89 2180-17845, email office@cesifo.de
Editors: Clemens Fuest, Oliver Falck, Jasmin Gröschl
www.cesifo-group.org/wp

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CESifo *Working Paper No. 6513*
Category 6: Fiscal Policy, Macroeconomics and Growth

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Abstract

For a long time, abundant natural resources brought Iceland a high and volatile real exchange rate with adverse effects on manufacturing and services. During 2003-2008, another national treasure, the sovereign's AAA rating, was used by privatized banks to attract foreign capital, elevating the real exchange rate even further. The financial collapse and the associated collapse of the currency in 2008 left the country with a large foreign debt which offset some of the effect of the natural resources on the real exchange rate. In effect, this was the Dutch disease in reverse as witnessed, in particular, by a massive increase in the number of tourists following the financial collapse. This paper discusses the behavior of the exchange rate of the Icelandic króna before and after 2008 as well as its relationship to natural resources, capital flows, output, exports and imports, including tourism.

JEL-Codes: F410, O230, O330.

Keywords: natural resource curse, Dutch disease, financial crisis.

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30 May 2017
We thank Benedikt Goderis, Gylfi Magnússon, Fredrick Van der Ploeg, Hamid Raza, Ron Smith and Ragnar Torvik for helpful comments on earlier versions of this paper and also Yu-Fu Chen for his comments as well as research assistance. The views expressed are our own and do not necessarily reflect the views of the Central Bank of Iceland. An earlier version of the paper appeared as OxCarre Research Paper 138, Oxford Centre for the Analysis of Resource Rich Economies, Oxford University, May 2014.

The Dutch Disease in Reverse: Iceland's Natural Experiment

Rarely does the opportunity arise for economists to revisit their theories using data from natural experiments. The recent economic history of Iceland offers such an opportunity. We refer to the literature, relaunched by Sachs and Warner (1995), on various aspects of the potentially adverse effects of natural resource discoveries on employment and investment as well as on economic growth. The inverse cross-country relationship between natural resources and growth has been broadly confirmed in several studies[1] while questioned by others.[2]

The literature on the macroeconomic consequences of natural resources highlights several channels through which economic growth can be retarded. These include rent seeking,[3] the Dutch disease,[4] poor governance,[5] political or ethnic conflict,[6] corruption,[7] autocracy,[8] excessive borrowing[9] and low levels of education.[10] Ross (2011), van der Ploeg (2011), Frankel (2014) and Venables (2016) survey the literature.

If learning-by-doing occurs mostly in the secondary (i.e., manufacturing and services) export sector and not in the primary (i.e., natural-resource-based) sector, a large and volatile primary sector will adversely affect the production of tradable goods by increasing real wages and the real exchange rate, lowering the relative price of tradable goods (i.e., exports and import-competing goods) and hampering employment, investment and growth.[11] Insofar as the trouble with abundant natural resources has to do with the real appreciation of the currency, the depreciation resulting from the sudden stop of a capital inflow and a financial crash can be viewed as a bout of the Dutch disease in reverse.

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[1] See, e.g., Sachs and Warner (2001), Gylfason and Zoega (2006), Collier and Goderis (2012) and Sala-i-Martin and Subramanian (2013).
[2] See Brunnschweiler and Bulte (2008), Lederman and Maloney (2008), Alexeev and Conrad (2009) and James (2015).
[3] See Paldam (1997), Tornell and Lane (1999), Auty (2001), Mehlum, Moene and Torvik (2006a, 2006b) and Robinson, Torvik and Verdier (2006).
[4] See Corden (1984), Corden and Neary (1982), Van Wijnbergen (1984) and Herbertsson, Skúladóttir and Zoega (2000).
[5] See Baland and Francois (2000), Tornell and Lane (1999), Torvik (2002), and Boschini, Pettersson and Roine (2007).
[6] See Easterly and Levine (1997) and Hodler (2006).
[7] See Arezki and Brückner (2011) and Arezki and Gylfason (2013).
[8] See Ross (2001), Collier and Hoeffler (2009) and Tsui (2011).
[9] See Mansurian (1991) and Manzano and Rigobon (2007).
[10] See Gylfason (2001).
[11] See Gylfason and Zoega (1999).

Recent events offer us an opportunity to reassess the validity of this thesis. It has for some time been well understood that foreign aid shares an important property with natural resource discoveries in that aid constitutes an unrequited transfer emerging like manna from heaven.[12] In the past, aid-receiving countries such as Zambia have seen their currencies appreciate as a result of aid inflows. Further, like resource windfalls, aid inflows have about them an aura of 'other people's money' which, like lottery winnings, as well as due to their transitory and often volatile nature, may seem easier to fritter away than one's own hard-earned incomes. This may explain why natural resource abundance does less harm to growth in democracies with good policies than elsewhere (Burnside and Dollar, 2000).[13]

Reputation mining as described by Akerlof and Shiller (2015) can be viewed the same way as other forms of resource depletion. During exuberant credit booms inflows of foreign credit can exert a similar manna-from-heaven effect on its recipients as resource windfalls and foreign aid.[14] Admati and Hellwig (2013, Ch. 9) describe the considerable hidden subsidies that banks deemed too big to fail extract from taxpayers through implicit or explicit government guarantees. With its gross foreign debt rising from 100% of GDP in 2002 to nearly 700% in mid-2008, Icelandic banks, aided and abetted by the government, used the sovereign's AAA rating to attract huge private capital inflows during 2003-2008 in the wake of their privatization of 1998-2003 followed by a sudden stop and a subsequent capital outflow.[15,16] The inflows, mostly in the form of short-term bank credits, were accompanied and, indeed, spurred by a persistent, policy-induced appreciation of the currency intended to keep a lid on domestic inflation through a high-interest-rate policy aiming also to attract foreign funds. While earlier work showed how abundant natural resources (or, specifically, a heavy reliance on natural resources) had the effect of slowing down investment and growth (Gylfason and Zoega, 2006), recent events offer an opportunity to analyze the effects of a

[12] See Younger (1992), Burnside and Dollar (2000), Svensson (2000) and Djankov, Montalvo and Reynal-Querol (2008) and also Deaton (2013, Ch. 7).
[13] Gylfason and Zoega (2003) and Goderis and Malon (2011) consider the relationship between natural resources and inequality.
[14] Benigno and Fornaro (2014) use the term 'financial resource curse' to describe episodes of abundant access to foreign capital coupled with weak productivity growth.
[15] See Gylfason *et al*. (2010), Benediktsdottir, Danielsson and Zoega (2011), Johnsen (2014) and Gylfason (2015, 2016).
[16] See Calvo (1998) and Calvo, Izquierdo and Mejía (2004) on how a sudden stop in international credit flows may cause financial and balance-of-payments crises. Calvo and Reinhart (2000) recommend dollarization as a way to eliminate the problems caused by the sudden reversal of capital inflows. Calvo (2007) argues that emerging economies should intervene in the credit market rather than relying solely on interest rates as a policy tool to reduce the likelihood of a sudden stop. Lane and Milesi-Ferretti (2008) discuss the impact of capital inflows on domestic variables.

capital outflow that offset the effects of the primary sector on the real exchange rate as well as on secondary output and growth by reversing the earlier appreciation of the currency.

Figure 1 shows the evolution of the nominal (trade-weighted) exchange rate, defined as the domestic currency price of foreign currency so that an increase in the index indicates depreciation. The gradual appreciation of the Icelandic króna until 2008 was interrupted in the spring of 2006 when the capital inflow stopped briefly, and was reversed in the spring of 2008 when the capital inflow suddenly turned into an outflow, followed by a collapse in October 2008. The sudden stop was triggered by the world financial crisis, in particular the collapse of Lehman Brothers. The collapse wiped out the foreign currency market by bankrupting all market participants; hence the exchange rate series in Figure 1 terminates in October 2008. Before and after the crash, the burden of the large foreign debt lowered the exchange rate by a half in nominal terms and a third in real terms,[17] offsetting some of the adverse effects of the primary sector on employment, investment and output in the secondary (i.e., non-primary) sector.

Our main aim here is to use Iceland's recent experience to illustrate the strong relationship between the real exchange rate and the current account of the balance of payments, a relationship that ´elasticity pessimists´ have often questioned. A subsidiary aim is to show how volatility in primary (i.e., natural-resource-based) exports as well as in foreign capital flows makes exchange rates volatile and thereby also other macroeconomic variables that depend on exchange rates. We do this by drawing a parallel between the way in which the exploitation of natural resources as well as of Iceland's high credit rating before the 2008 collapse increased the recorded value of the Icelandic króna and the way in which the collapse of the credit rating in 2008 (as if fish stocks had collapsed!) led to a sudden collapse also of the króna, which in turn facilitated a recovery of employment, investment and output. By 2016, output was at last restored to its 2007 level in terms of purchasing-power-parity-adjusted US dollars per capita.[18]

Meanwhile, the króna gradually regained lost ground. In 2015, the IMF considered the real exchange of the króna to be roughly in equilibrium (IMF, 2016, Box 2, p. 11). From mid-2015 until early 2017, the króna appreciated in real terms by 25% based on relative consumer

[17] Specifically, from 2007 to 2009 the real exchange rate fell by 35% based on relative consumer prices at home and abroad and by 50% based on relative unit labor costs. Source: Central Bank of Iceland, see http://hagtolur.sedlabanki.is/data/set/1wui/#!display=table&ds=1wui!1z9x=1.3.

[18] Source: World Bank, *World Development Indicators*.

prices and by 21% based on relative unit labor costs (source: Central Bank of Iceland), restoring the real exchange rate to its 2007 extent of overvaluation or thereabouts.

In the next section we briefly review the recent economic history of Iceland. We then present a simple stochastic model intended to capture relevant elements of the Dutch disease by showing how the volatility of primary output affects the real exchange rate and hence also total (i.e., primary plus secondary) output. The model sets the stage for – or, if you prefer, aims to illuminate – our empirical account of the encouraging effects of the collapse of the real exchange rate surrounding the financial crash of 2008 on secondary output, especially via foreign tourism which has expanded by leaps and bounds. The number of foreign tourist arrivals in 2016 was 1.8 million, more than five times Iceland´s population, up from 0.3 million in 2000 when the number of tourists bypassed the number of inhabitants.

1. Background

Iceland is unique among OECD countries in that the ratio of Iceland's exports of goods and services to GDP was stuck at about a third from 1870 (this is not a misprint) until 2008 when its three main banks collapsed. Why did Iceland's exports remain stagnant for so long at such a low level relative to GDP? All other OECD countries saw their exports grow more rapidly than GDP, especially after 1960 when liberalization of trade in goods and services gained momentum. For example, Denmark's export ratio rose from 32% in 1960 to 52% in 2007 while Iceland's export ratio remained stuck at about a third (Figure 2a). With a population that is just one-sixteenth of that of Denmark, Iceland, like other very small open economies, would need a much higher export ratio than Denmark to finance the importation of things that Iceland is too small to produce. Denmark is a significant high-tech producer, Iceland is not. Moreover, Iceland is marred by oligopolies unencumbered by foreign competition. For example, the combined market share of the three largest banks is still well above 90% and the same applies to the three largest insurance companies, oil retailers, and sellers of building materials.

Iceland was until 2008 a high-real-exchange-rate country, its overvalued currency holding back exports and thereby also imports except insofar as imports were financed by foreign borrowing. In 2007, a year before the crash, the IMF considered the króna overvalued by 15% to 25% in real terms (IMF, 2007). Even so, two months before the crash in September 2008, the IMF reported: "[t]he long-term economic prospects for the Icelandic economy remain enviable." The IMF overlooked the danger posed by the overvaluation of the króna as well as

by the huge inflows of capital before the eruption of the 2008 crisis. Looking back, the IMF´s Independent Evaluation Office (2011, Box 4, p. 15) was not amused.

The systemically high real exchange rate, a condition we associate with the Dutch disease, can be traced to several causes, including high inflation[19] and an abundance of natural resources, mainly fertile fishing grounds but also energy. Export subsidies to the fishing industry, direct at first through the government budget, then indirect through gratis allocation of highly valuable and macroeconomically consequential common-property fishing rights to select vessel owners, increased the supply of foreign exchange, lowering its price and increasing the real exchange rate. Other factors reinforced the effect of the primary sector on the real exchange rate, including the protection of agriculture against imported farm products, an arrangement that reduced the demand for foreign exchange, lowering its price and thereby exerting upward pressure on the real exchange rate. Further, the high real exchange rate skewed the composition of exports by hampering the development of, for example, high-tech export industries like those that emerged in Scotland, Ireland and Norway next door. Mostly, Iceland's exports were, and remain, resource-based (fish and aluminum) and thus mostly low-tech, a common symptom of the Dutch disease (Figure 2b).[20] A currency can remain overvalued for long periods just as a pendulum continues to tilt the same way as long as the wind blows from the same direction.

Recent events offer an opportunity to assess the effects of the collapse of the real exchange rate. Surrounding the financial crash of 2008 the collapse of the Icelandic króna made exports jump from a third of GDP to 60% of GDP (Figure 2a), and caused imports to plunge (Figure 3a) in keeping with the elasticity approach to the balance of payments (Goldstein and Khan, 1985). The fact that GDP fell by 8% after the crash shows that the hike in the export ratio stems mostly from a sharp increase in export earnings. Likewise, the fact that import volume contracted by 44% suggests a strong effect of the currency depreciation on imports on top of a much smaller income effect. Even so, the behavior of the real exchange rate of the króna before and after the crash accords well with the asset market approach to exchange rates

[19] Since 1960, Iceland has had the OECD region's second highest average rate of inflation, second only to Turkey. High inflation has often been seen to go along with high real exchange rates because the government hesitates to devalue the currency as expectations of inflation are not anchored and devaluation is likely to encourage inflation. As a result the government resorts to foreign borrowing instead, a common scenario in Africa and Latin America, for example.

[20] In 2012, fish products accounted for 27% of total export earnings in Iceland, aluminum for 22% and foreign tourism, 24% (source: Statistics Iceland). Kristjánsdottir (2012) describes the determinants of the geographical pattern of Iceland's export trade.

(Branson, 1977) which predicts that increased foreign borrowing to finance imports of goods and services causes the currency, on impact, to appreciate in real terms.

The reaction of Icelandic exports and imports to the large depreciation of the króna in 2008 resembles the response of exports and imports in South-East Asian countries to the collapse of their currencies in 1997. Figure 4 shows the evolution of export earnings and import volumes during a period spanning five years before and after the financial crisis in South-East Asia (t = 1997) as well as in Iceland (t = 2008).

The financial crash in Iceland was preceded by the privatization of the country's banking system and a subsequent capital inflow from 2003 to 2008 that propelled the real exchange rate to new heights and fueled the stock market and the housing market as well as a boom in consumption and investment through a current account deficit averaging 14% of GDP. Real equity prices increased by 35% per year during this period, a record surpassed only by Cyprus, and real estate prices rose by 12% per year.[21] The current account deficit rose from 5% of GDP in 2003 to 16% in 2007. The growth of per capita GDP went from 1.8% in 2003 to 6.6% in 2004, 6.0% in 2005, 1.8% in 2006 and 3.6% in 2007 before turning negative three years in a row, 2008-2010. Unemployment dropped to 2.3% of the labor force 2007. Gross foreign debt grew from a stable level of about 60% of GDP in the 1990s to nearly 700% before the collapse in mid-2008. Because the inflow of capital was unsustainable, and also because the Central Bank's foreign exchange reserves, in a violation of the Giudotti-Greenspan rule, had fallen to 7% of the short-term foreign liabilities of the banking system, the expansion was bound to end in a sudden stop. The reversal of capital flows in 2008 caused the currency to tank, consumption and GDP to fall, investment to plummet from 27% of GDP to 19% of a lower GDP,[22] real imports of goods and services to contract by more than 60% from 2006 to 2009 (recall Figure 3a showing the volume of merchandise imports), bank lending relative to GDP to contract by 54% from 2007 to 2012 (Figure 3b) and equity prices to plunge by, yes, 95% from peak to trough.[23,24] By 2011, real estate prices in the Reykjavík area had receded back to their 2004 level in real terms.[25]

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[21] The OMX15 covering the 15 largest corporations increased by a factor of six over the same period and nearly by a factor of nine from its bottom in 2001 to its peak value in 2007. See Aliber (2011) and Halldorsson and Zoega (2010).

[22] Net investment, i.e., gross investment minus depreciation, was negative from 2009 to 2012.

[23] Sources: *Statistics Iceland* (hagstofa.is), Central Bank of Iceland (sedlabanki.is), World Bank, *World Development Indicators*, and Trading Economics (tradingeconomics.com/iceland/stock-market). See also Halldorsson and Zoega (2010).

[24] Gylfason *et al*. (2010) and Gylfason (2015) compare economic conditions in the Nordic countries during these years.

[25] Source: Registers Iceland (skra.is/Markadurinn/Talnaefni).

The boom before the crash of 2008 masked an underlying structural weakness illustrated by a comparison between gross investment and adjusted net saving (Figure 5). As defined by the World Bank (2006), adjusted net saving aims to measure the real difference between production and consumption by adjusting net saving for changes in human capital (measured by spending on education and innovation) and depreciation or depletion of natural resources (e.g., through energy or mineral depletion). A comparison of the two panels of Figure 5 shows that, before the crash, despite Iceland's investment boom, adjusted net saving in Iceland was far below that of Denmark even without including estimates of natural resource depletion, a controversial subject. This finding reflects Iceland's long-standing aversion to saving and correspondingly strong propensity to borrow, a common characteristic of high-inflation countries.

In sum, Iceland´s experience before and after the fall mirrors the three-stage experience of many other countries in similar circumstances (Reinhart and Rogoff, 2009). First, large capital inflows, mostly bank credits, elevated the value of the currency well beyond its historical state of structural overvaluation. Second, the sudden reversal of capital flows and the associated debt overhang made the currency collapse. Third, the depreciation of the currency in real terms made imports plunge while providing a strong boost to exports, both old and new. The dramatic reversal of capital flows in 2008 offers us an opportunity to gauge the effects of a lower real exchange rate on the secondary sector. We revisit our stochastic model of the Dutch disease in Section 2 to describe the first two stages of the process and to prepare for the empirical account of the effects of the exchange rate on exports and output in Section 3.

2. A prototype model

Tradable output is produced in both the primary sector and in the secondary sector. The primary sector utilizes a natural resource and is subject to fluctuations. In Iceland, the natural resource is mainly fish stocks that yield an annual output that fluctuates from year to year, based mostly on natural factors. Further, there are capital inflows and outflows. Both fluctuations in primary output and in capital flows affect the secondary tradable sector, i.e., manufacturing and services. The volatility of the primary sector and capital flows makes the real exchange rate fluctuate, which affects the relative price of the secondary-sector tradable output, or secondary output in short, as we will show. Moreover, an abundance of natural

resources affects secondary employment, output and investment through wages.[26] The stock of external debt also has an effect on these variables through the real exchange rate. In a way, natural resource rents have an impact similar to the inflow of foreign capital while external debt works in the opposite direction due to the outflow of interest and amortization payments. Our main aim here is to show how the volatility of primary production causes exchange rate volatility which in turn makes secondary output and hence also total output volatile as well. This matters because output, especially in countries that depend significantly on volatile natural resources, needs, like assets, to be assessed in two dimensions: level and volatility.

2.1 Output and employment in the secondary sector

Profits in the tradable sector measured in terms of nontradables are

$$\Pi = \lambda_t K_t^{\alpha} (e(w_t/\overline{w_t})N_t)^{\beta} R^{1-\alpha-\beta} - w_t N_t \qquad (1)$$

where K is the stock of capital, N is employment, R denotes a fixed factor such as land and infrastructure, e is the level of industry-wide productivity and $\alpha < 1$ and $\beta < 1$.[27] The real exchange rate $\lambda = p^T/p^N$ is defined as the price of tradable goods in terms of nontradables. An increase in λ denotes a real depreciation of the currency.

Wages in the primary sector affect secondary-sector wages. The (strictly concave) function $e(w_t/\overline{w_t})$ measures worker effort as a function of the ratio of secondary-sector wages to wages paid in the primary sector, $\overline{w}$, which we take as given. We assume the following functional form for e, invoking Solow's elasticity condition (Solow, 1979)

$$e = \left(\frac{w - b\overline{w}}{b\overline{w}}\right)^{\kappa}, \ 0 < \kappa < 1 \qquad (2)$$

where b is a measure of the attractiveness of jobs in that sector; $b < 1$ suggests that jobs in the secondary sector are preferable to jobs in the primary sector.

The representative firm has to determine the optimal level of wages and employment at each point in time, w and N, and can costlessly hire or fire workers. The first-order condition for wages generates the following solution for secondary-sector wages

$$w = \frac{b\overline{w}}{1-\kappa} \qquad (3)$$

so that a higher primary-sector wage, a lower disutility of working in that sector and greater

[26] The model of this section differs from that in Gylfason, Herbertsson and Zoega (1999) by having two factors of production rather than only labor. Here, however, we do not derive the growth effect of the abundance of natural resources but only the effect on the level of primary and secondary output.
[27] Depreciation of capital is assumed away.

responsiveness of effort to relative wages as measured by κall make secondary-sector wages go up. The first-order condition for employment follows

$$N = \lambda^{\frac{1}{1-\beta}} K^{\frac{\alpha}{1-\beta}} w^{-\frac{1}{1-\beta}} Z \tag{4}$$

with $Z = \beta^{\frac{1}{1-\beta}} R^{\frac{1-\alpha-\beta}{1-\beta}} e^{\frac{\beta}{1-\beta}}$. The equation determines optimal employment for a given stock of capital, the real exchange rate and real wages, in addition to land, capital and productivity.[28]

Equation (4) and the production function (1) give short-run output supply as a function of the real exchange rate and primary-sector wages holding the stock of capital fixed. If primary and secondary-sector wages are initially equalized, the supply function is

$$Y^S = \lambda^{\frac{\beta}{1-\beta}} K^{\frac{1}{1-\beta}} w^{-\frac{\beta}{1-\beta}} B \tag{5}$$

where $B = R^{\frac{1-\alpha-\beta}{1-\beta}} \beta^{\frac{\beta}{1-\beta}} e^{\frac{1}{1-\beta}}$. It follows that secondary output depends on the real exchange rate, which, as we now will show, depends on the output of the primary sector as well as the real wage in the primary sector.

2.2 Primary output and capital flows

Primary output, including the inflow of foreign currency, is stochastic and follows a Brownian motion subject to random productivity shocks described by equation (6), and is independent of the real exchange rate;

$$dy^P = \eta dt + \sigma dW \tag{6}$$

Here dW represents the increment of a Wiener process $W = \epsilon_t \sqrt{dt}$, ε having a zero mean and a unit standard deviation, i.e., $E(dW) = 0$ and $V(dW) = dt$. The drift term ηdt reflects the growth of primary output or a rising level of capital inflows while the stochastic term σdW represents the vicissitudes of commodity prices that make primary output rise or fall at random and of international capital markets that can make a capital inflow quickly reverse itself during a sudden stop, thus creating uncertainty about output in the primary sector.

2.3 The intertemporal budget constraint and the real exchange rate

The external budget constraint equates the sum of the present discounted value of the difference between future output of primary goods Y^p and tradable goods from the secondary sector Y^S, on the one hand, and of tradable goods consumption C^T, on the other hand, to the

[28] Paldam (1994) describes the impact of the Dutch disease in Greenland through wages.

current stock of net foreign debt *D*. A capital inflow relaxes the constraint in the short run by enabling a country to service its short-term debt with a smaller current account surplus.

There is an infinite number of paths satisfying the intertemporal budget constraint. Instead of solving for the optimal path, we posit a simple rule that satisfies the constraint, making saving *r* a function of the sum of the output and foreign exchange earnings of the primary sector Y^P including net capital inflow (i.e., inflows of foreign currency) and output from the secondary sector Y^S less consumption *c*:

$$r_t = y_t^P + y_t^S - c_t \tag{7}$$

where $y^P = \log(Y^P)$, $y^S = \log(Y^s)$, $c = \log(C^T)$ and *r* is an exogenous parameter that depends on the level of net foreign debt. We then choose the value of saving *r* so that the external budget constraint is satisfied. Thus, the higher the level of external debt *D*, the greater is the external surplus *r* required to service the debt.[29] The choice of this saving rule simplifies the derivations to follow while making the real exchange rate appreciate when the foreign exchange earnings of the primary sector or capital inflows go up.

Taking the log of equation (5) gives the supply of secondary output as a function of the real exchange rate:

$$y^S = \alpha_0 + \alpha_1 log(\lambda) \tag{8}$$

where $\alpha_1 = \beta/(1-\beta) > 0$. Further, we assume that tradable goods consumption is a decreasing function of the real exchange rate, $c_t^T(\lambda_t)$. An appreciation of the currency in real terms, that is, a decrease in the relative price of tradable goods, makes λ fall. A log-linear demand function for secondary output gives

$$c^T = \beta_0 - \beta_1 log(\lambda) \tag{9}$$

where $\beta_1 > 0$. Combining equations (7), (8) and (9) gives

$$log(\lambda) = \frac{\beta_0 - \alpha_0 + r}{\alpha_1 + \beta_1} - \frac{y^P}{\alpha_1 + \beta_1} \tag{10}$$

Equation (10) shows that an increase in primary output (e.g., through resource depletion) or a net capital inflow (e.g., through reputation mining) makes the currency appreciate in real terms and that a higher level of foreign debt – requiring a higher value of saving, *r* – ultimately raises the relative price of the tradable good, countering the effect of primary output or the capital inflow y^P on the real exchange rate.

[29] Equation (6) implies that the sum of the growth rates of primary and secondary (tradable) output always equals the rate of growth of (tradable) consumption.

2.4 Volatility in the real exchange rate and secondary sector

It follows from equation (10) that the volatility of the primary sector affects the real exchange rate. Using Ito's Lemma, we can write the stochastic process followed by the log of the real exchange rate as follows:

$$dlog(\lambda) = -\frac{\eta}{\alpha_1+\beta_1}dt - \frac{\sigma}{\alpha_1+\beta_1}dW \tag{11}$$

Again using Ito's lemma, we can describe the evolution of the real exchange rate λ as

$$d\lambda = \underbrace{\left(-\frac{\eta}{\alpha_1+\beta_1} + \frac{1}{2}\left(\frac{\sigma}{\alpha_1+\beta_1}\right)^2\right)}_{\theta}\lambda dt - \frac{\sigma}{\alpha_1+\beta_1}\lambda dW \tag{12}$$

The drift term in the real exchange rate equation (12), with $\theta < 0$ denoting appreciation – a fall in the relative price of tradable goods – is what is usually meant by the Dutch disease. Notice that low volatility in the primary sector, that is, a low σ, makes the real exchange rate rise over time without fluctuating wildly. Medium primary-sector volatility, that is a middle-of-the-road σ, weakens the drift toward real appreciation while increasing volatility. High volatility in the primary sector, that is, a high σ, makes the real exchange rate fall over time combined with high volatility of the real exchange rate. Through its effect on investment, the induced volatility of the real exchange rate described by the stochastic term may be no less important than the real exchange rate drift for other export industries and import-competing industries.

Using Ito's lemma gives the following stochastic process for Y^S:

$$\begin{aligned} dY^S = \Bigg[\theta\left(\frac{\beta}{1-\beta}\right)\lambda^{\frac{\beta}{1-\beta}}K^{\frac{1}{1-\beta}}w^{-\frac{\beta}{1-\beta}}B \\ + \frac{1}{2}\left(\frac{\beta}{1-\beta}\right)\left(\frac{2\beta-1}{1-\beta}\right)\lambda^{\frac{\beta}{1-\beta}}K^{\frac{1}{1-\beta}}w^{-\frac{\beta}{1-\beta}}B\left(\frac{\sigma}{\alpha_1+\beta_1}\right)^2\Bigg]dt \\ -\left(\frac{\beta}{1-\beta}\right)\lambda^{\frac{\beta}{1-\beta}}K^{\frac{1}{1-\beta}}Bw^{-\frac{\beta}{1-\beta}}\left(\frac{\sigma}{\alpha_1+\beta_1}\right)dW \end{aligned} \tag{13}$$

Equations (9), (12) and (13) show that

- The real exchange rate depends on current and lagged shocks to primary output and capital flows;
- The output of the secondary tradable goods sector depends on the real exchange rate;
- Consumption of tradable goods also depends on the real exchange rate.

Notice also how an increase in the primary-sector wage, $\overline{w}$, by increasing wages, w, in the secondary sector (recall equation (3)) reduces the drift term in equation (13) while increasing

the stochastic term. In other words, a wage hike in the primary sector reduces secondary output and increases its volatility. A natural resource recovery which increases *B* via *R* (recall equation (5)) increases both the drift term and the stochastic term in equation (13). Thus, a resource boom increases secondary output at the cost of increased output volatility.

In view of these results we consider in the next section a system of four variables: the real exchange rate; the current account; tourism, which represents the secondary tradables sector that has expanded significantly in recent years; and other non-primary merchandise exports.

3. Empirical evidence

We employ a VAR model to describe the relationship between the real exchange rate (*E*), the current account of the balance of payments in proportion to GDP (*CA*), the number of tourists in proportion to the local population (*T*) and non-primary exports (*NP*) as a share of total merchandise exports.

Figure 6 presents these variables during 1960-2012. The top panel shows the real exchange rate – an increase indicates depreciation – and the current account surplus. There is a positive association between the two since the early 1990s when capital became mobile as permitted by law: a depreciation of the currency makes the current account improve, even if foreign borrowing makes the currency appreciate on impact; there is no inconsistency involved as laid out in Branson (1977) and Gylfason and Helliwell (1983). The middle panel shows the real exchange rate and the number of tourist arrivals where the latter series grows exponentially with a marked increase following the collapse of the currency. Finally, the bottom panel shows the real exchange rate and non-primary merchandise exports as a share of total merchandise exports; there is no apparent relationship between the two.

In Table 1 we present unit root tests for the four series, that is, the ADF test results where the null hypothesis is that the process contains a unit root. While the real exchange rate and the current account surplus do not have a unit root, we find a unit root in tourism as well as in non-primary exports. The first differences of these two variables are stationary. We can then estimate a VAR system for the four stationary variables using annual data ranging from 1960 to 2012. The general pth order VAR is

$$\boldsymbol{y}_t = \boldsymbol{\beta}_0 + \sum_{i=1}^{p} \boldsymbol{\beta}_i \, \boldsymbol{y}_{t-i} + \boldsymbol{\nu}_t \qquad (14)$$

where $\boldsymbol{y}_t' = (E, CA, \Delta T, \Delta NP)$, $\boldsymbol{\beta}_0$, ..., $\boldsymbol{\beta}_p$ are matrices of parameters and $\boldsymbol{\nu}_t$ is a vector of error terms. The Akaike Information criterion suggests two lags for the VAR (Table 2).

The results of estimating the VAR model are shown in Table 3.[30] The second column in Table 3 suggests that an increase of the real exchange rate index from 1 to 1.1, reflecting a 10% appreciation of the króna in real terms, will improve the current account by 3.2% of GDP in the following year and so on. The lag structure aims to forestall reverse causation.

Figure 7 shows the impulse responses to a shock to the real exchange rate – that is, an increase in the relative price of tradable goods, a real depreciation.[31] The upper left-hand panel shows that the real exchange rate is stationary, making it return to its initial level. The upper right-hand panel shows how a higher – i.e., depreciated – real exchange rate improved the current account for three to four years before the effect petered out. The effect is particularly clear in the year following the depreciation of the currency. The lower left-hand panel shows the response of changes – that is, the first difference – of the number of tourist arrivals per capita. There is a positive effect that peaks in the fourth year following the shock. This is consistent with Figure 6, which shows that the increase in the number of tourists after the financial crash in 2008 was not instantaneous. Even so, the real depreciation of the currency explains only part of the increase in the number of tourists since this was on the rise even before the financial crisis and the attendant collapse of the currency; hence the need to first difference the series before estimating the VAR. The bottom right-hand panel in Figure 7 shows the response of the change in the ratio of non-primary merchandise exports to total merchandise exports. This last response is weak and not statistically significant.

The initial impact of the real depreciation of the króna is found in the volume of imports, improving the current account in the first year after the depreciation. There follows a further positive effect on the number of foreign tourists raising export earnings. In terms of our model, tourism relies heavily on natural resources, R, which may explain why it is the first sector to benefit from the low real exchange rate, recall the links between Y^S, λ and R via B in equation (13). There is no evidence of a J-curve even if tourism responds with a lag. However, in terms of non-primary merchandise exports, there is an insignificant effect.[32] Yet,

[30] The VAR is stable because all roots of the characteristic polynomial lie inside the unit circle. The null hypothesis of the exclusion of real exchange rates from the current account equation and the change-in-the-number-of-tourists equation can be rejected at the 5% level of significance (probability = 0.0).

[31] The generalized impulses look identical to impulses derived with the Cholesky decomposition. The latter imposes an ordering on the variables in the VAR and attributes all of the effect of any common component to the variable that comes first in the VAR system, which in our case is the real exchange rate.

[32] Variance decomposition gives information about the relative importance of each of the random innovations for the forecast error for the four variables. The forecast error of the current account due to innovations to the real exchange rate is 9% in the first year after the innovation, 43.7% in the second year and then stabilizes at over 44%. The corresponding numbers for the number of tourists are 1.1% for the first year, 0.8% for the second year, then 7.9% for the third year, 18.9% for the fourth year before stabilizing at over 20%. In contrast to the importance of innovations to the real exchange rate for the

start-up firms in the technology sector initially gained from the currency collapse. However, their workers tend to be internationally mobile and several of these firms operate in many countries. For both reasons nominal wages started to rise rapidly after 2010, gradually erasing the competitive gain from the depreciation. Also, some local-cum-international non-primary exporters keep their accounts in euro and run their operations essentially as if they were foreign firms, and are thus impervious to the exchange rate except indirectly as victims of strict capital controls deemed necessary since the crash of 2008 to protect the króna from further depreciation if domestic and foreign capital were free to leave, especially if the controls were to be removed in a disorderly fashion.[33] The controls were relaxed for the most part in 2017 without weakening the króna.

The implication appears to be that the local labor market is dual in the sense that unskilled, low-paid workers in the tourism industry suffer a more prolonged decline in their real wages following the currency collapse than the higher-skilled workers in the technology sector. The former may face more limited opportunities when it comes to leaving the country and their employers have higher profits as a result.

The increase in the number of tourists relative to population has been quite sharp in Iceland, surpassing even such popular tourist destinations as France, Greece, Spain and Mauritius (Figure 8a). The comparison with Mauritius is especially notable for historical reasons. Until the 1980s, Mauritius was a natural-resource-based economy, its sugar cane industry being the country's main foreign exchange earner (Frankel, 2012). As tourism gained momentum, however, the weight of the sugar industry in economic activity declined and the political clout of the plantation owners declined accordingly. Even so, limits imposed by the government on the expansion of tourism in Mauritius stemmed the decrease in the share of food exports in total exports (Figure 8b).

4. Conclusion and discussion

We suggest that large capital inflows resemble natural resource windfalls in that both events flood the recipient country with easy money, are prone to quickly reverse themselves, and

standard error of the current account, innovations to the current account, number of tourists and other exports contribute much less to the standard error of the real exchange rate: the three innovations explain 2.3% of the standard error of the real exchange rate in the first year and just over 24% in year seven after the shock.

[33] Moreover, these firms require foreign investors who have been hesitant to invest in Iceland due to the capital controls in place since 2008. Some start-up firms have left the country for this reason and others are considering whether to do so.

may trigger similar reactions, including general euphoria, real appreciation of the currency and rent seeking. Likewise, large capital outflows can be viewed as a cause of the Dutch disease in reverse, triggering an economic downturn accompanied by real depreciation of the currency. This is what happened in Iceland after the financial collapse of 2008 when the króna lost a third of its value in real terms, stifling imports and contributing to an unprecedented expansion of foreign tourism, turning it into the country's chief foreign exchange earner in lieu of the once-overwhelming fishing industry. This kinship between capital inflows and resource windfalls and their reversibility and volatility has led us to rely on a familiar narrative about natural resources as a mixed blessing to describe also the links between capital flows and output, leaving for another day the full development of a dynamic stochastic macroeconomic model including both phenomena side by side. Such models do not generally lend themselves to direct econometric estimation, however, which is why we have used our simple theoretical model here just to try to illuminate rather than provide a concrete basis for our empirical exercise.

Further, Iceland's natural experiment before and after the crash of 2008 demonstrates the essential complementarity of the elasticities and asset market approaches to balance of payments analysis and exchange rate determination. The exchange rate of the króna climbed to unprecedented heights in response to the large capital inflows facilitated by trusting foreign bankers before the crash, an appreciation of the currency that was not caused by trade flows. Thereafter the currency collapsed as the capital flows were reversed improving the competitiveness of other tradable industries, in particular tourism, quickly turning the current account of the balance of payments to surplus. While it remains to be seen whether tourism will provide a more sustainable source of long-run growth than banking and fishing, our natural experiment has shown that the high real exchange rate prior to the crisis reduced the viability of tradable goods industries and that, in Iceland at least, the data do not support ´elasticity pessimism´, the view that real exchange rates do not significantly influence the current account of the balance of payments.

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Table 1. Augmented Dickey-Fuller Test Results

	E	CA	T	N^P	ΔT	ΔN^P
Test statistic	-3.928	-3.486	2.587	-2.240	-6.939	-4.807
Asymptotic p-value	0.02	0.05	1.00	0.46	0.00	0.00

Note: MacKinnon (1996) one-sided p-values. Constant linear trend.

Table 2. Akaike Information Criterion

No lags	17.01
1 lag	15.58
2 lags	15.18*
3 lags	15.25
4 lags	15.42

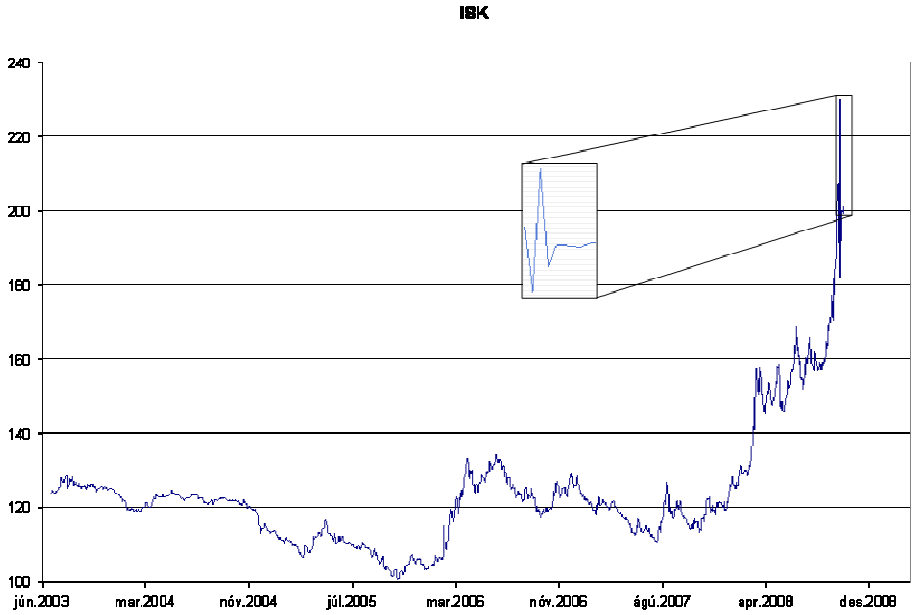
Note: * indicates lag order selected by the criterion.

Table 3. Estimation results for VAR (2) for 1960-2012

	E	CA	$D(T)$	$D(N^p)$
E(-1)	0.999*	32.256*	8.133	8.398
	(6.14)	(4.67)	(0.95)	(1.64)
E(-2)	-0.204	-29.119*	27.349*	-10.798
	(1.15)	(3.88)	(2.94)	(1.95)
CA(-1)	-0.005	0.485*	-0.526*	-0.222
	(1.35)	(3.16)	(2.76)	(1.96)
CA(-2)	0.001	0.135	0.212	0.160
	(0.42)	(0.97)	(1.22)	(1.55)
D(T(-1))	-0.000	-0.115	0.328*	0.128
	(0.14)	(1.03)	(2.36)	(1.54)
D(T(-2))	0.001	0.101	-0.589*	-0.101
	(0.35)	(0.74)	(3.47)	(1.00)
D(NP(-1)	0.002	-0.403	0.402	0.0358
	(0.35)	(2.04)	(1.64)	(0.24)
D(NP(-2))	0.005	-0.007	-0.420	-0.235
	(1.17)	(0.04)	(1.72)	(1.62)
Constant	0.200	-4.473	-33.865*	3.001
	(1.40)	(0.74)	(4.45)	(0.67)
R-squared	0.64	0.65	0.61	0.25
Akaike AIC	-1.78	5.72	6.15	5.11
Schwarz SC	-1.43	6.06	6.49	5.45

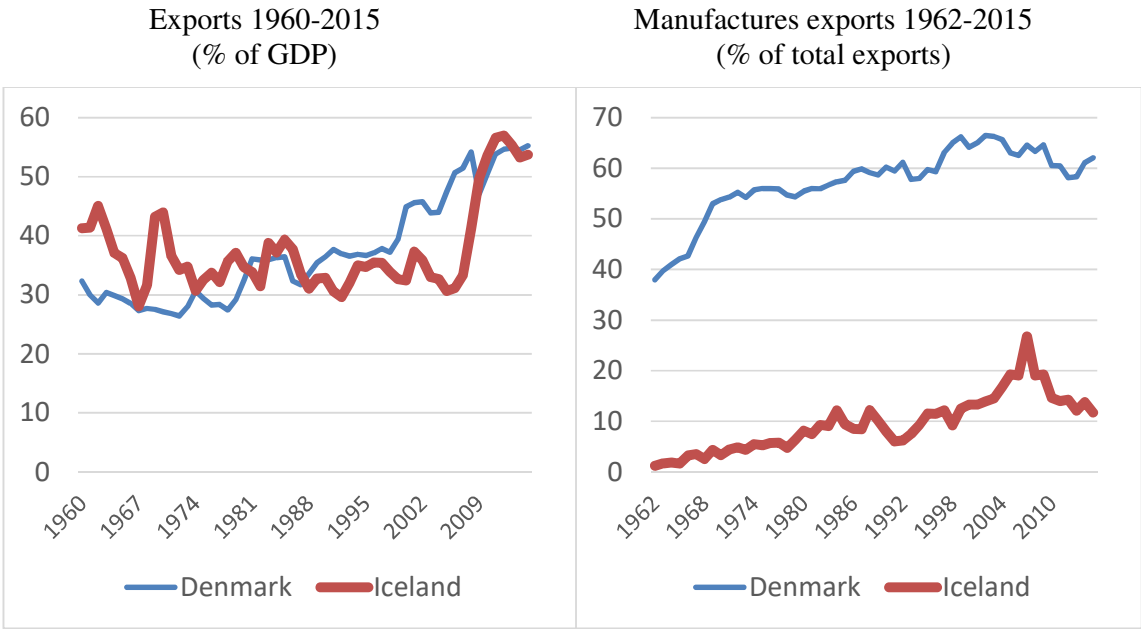
Note: Maximum likelihood estimates, 51 observations for 1960-2012, t-values within parentheses,
* denotes statistical significance at the 5% level.

Figure 1. Evolution of the nominal exchange rate 2003-2008



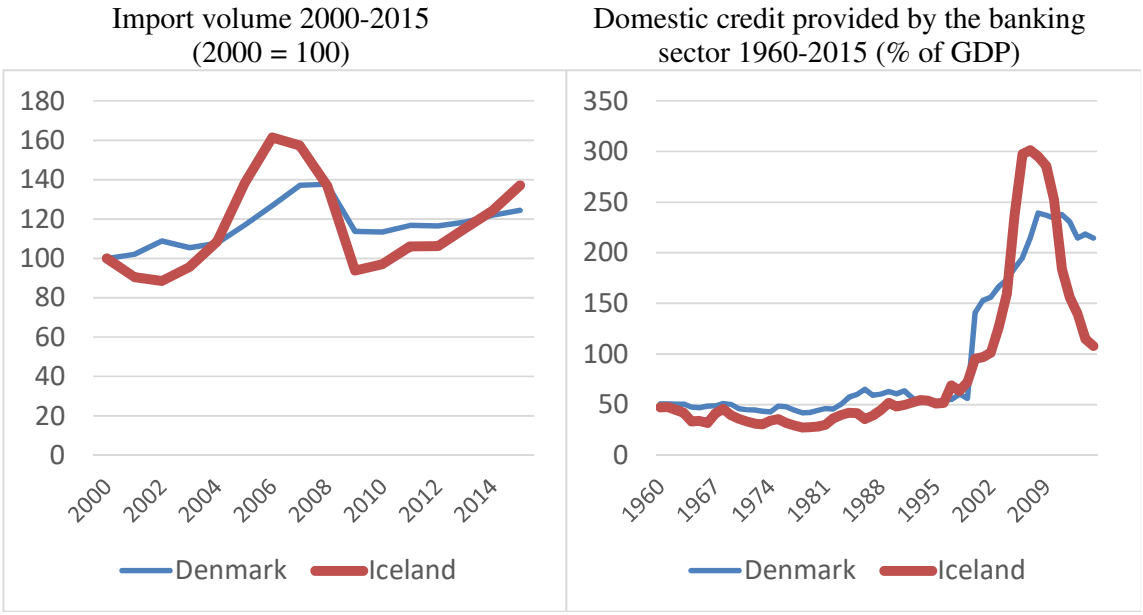
Source: Central Bank of Iceland.

Figure 2. Exports of goods and services and manufactures



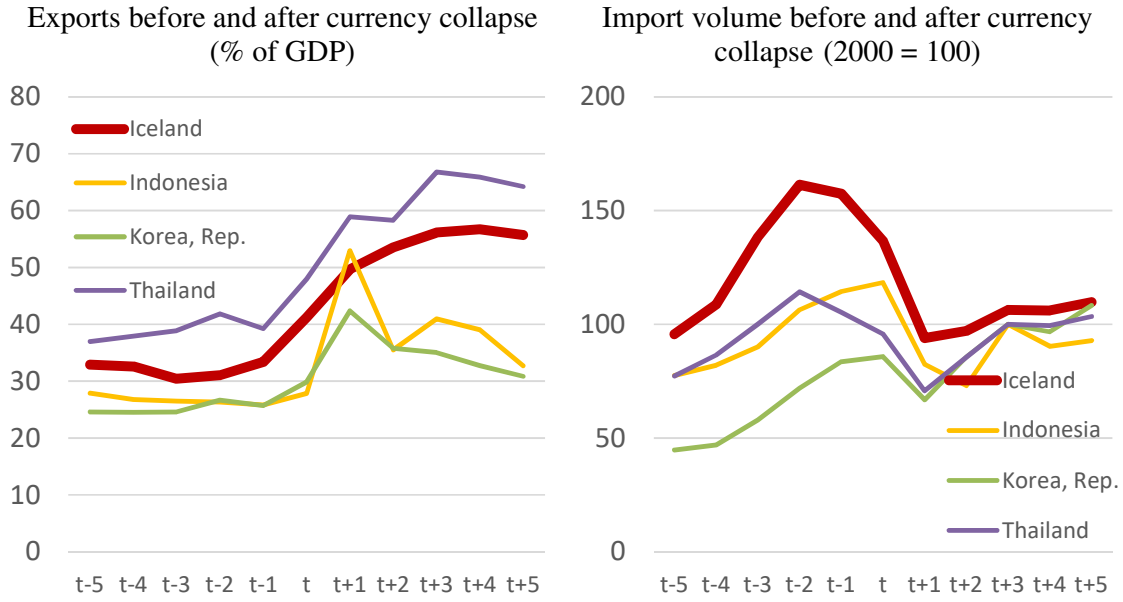
Source: World Bank, *World Development Indicators*.

Figure 3. Imports and domestic credit



Source: World Bank, *World Development Indicators*.

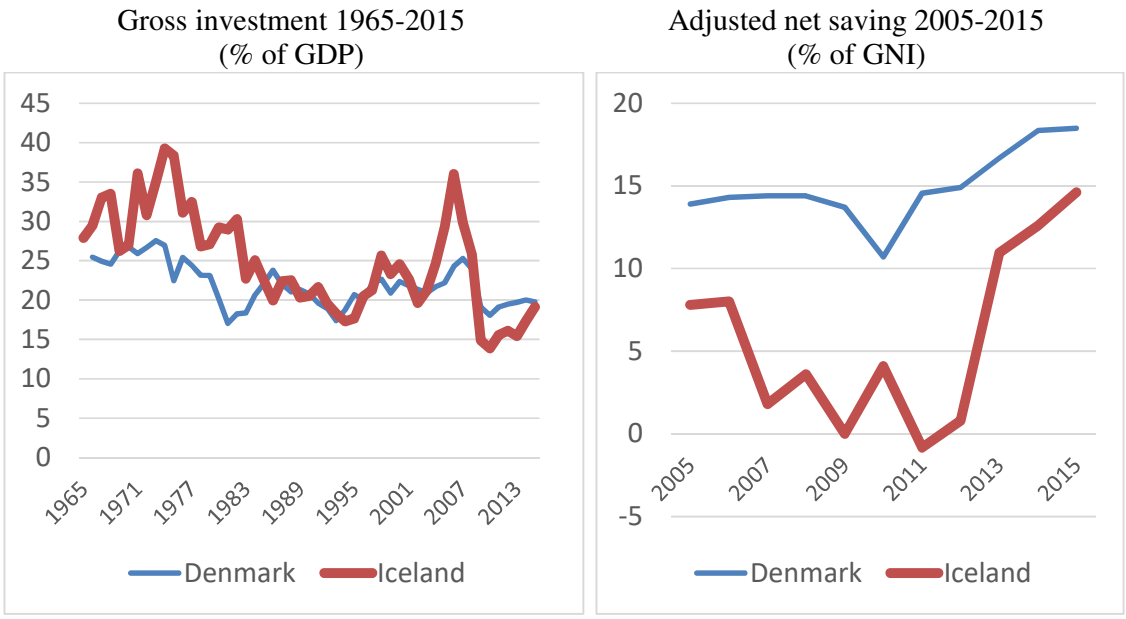
Figure 4. Exports and imports in Iceland and South-East Asia



Note: For Iceland, t = 2008, whereas for Indonesia, Korea and Thailand we set t = 1997.

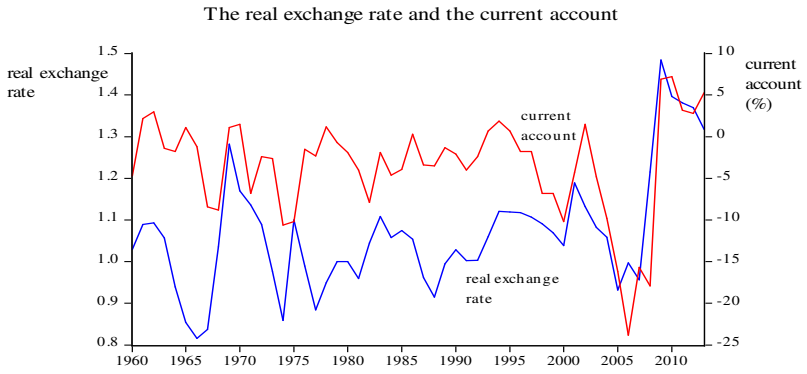
Source: World Bank, *World Development Indicators*.

Figure 5. Investment and adjusted net saving

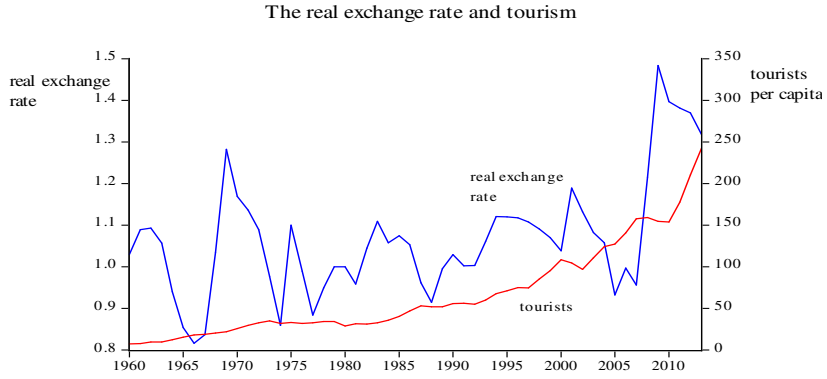


Source: World Bank, *World Development Indicators*.

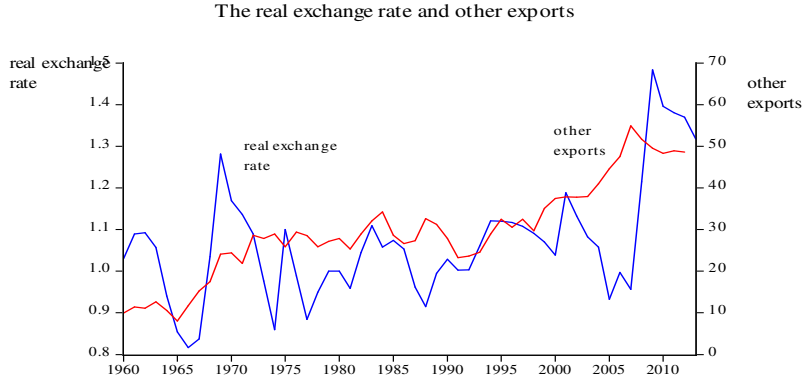
Figure 6. Real exchange rate, current account, tourism and non-primary merchandise exports 1960-2012



The current account measures the current account surplus as a ratio to GDP. The real exchange rate is defined as the relative price of tradables.



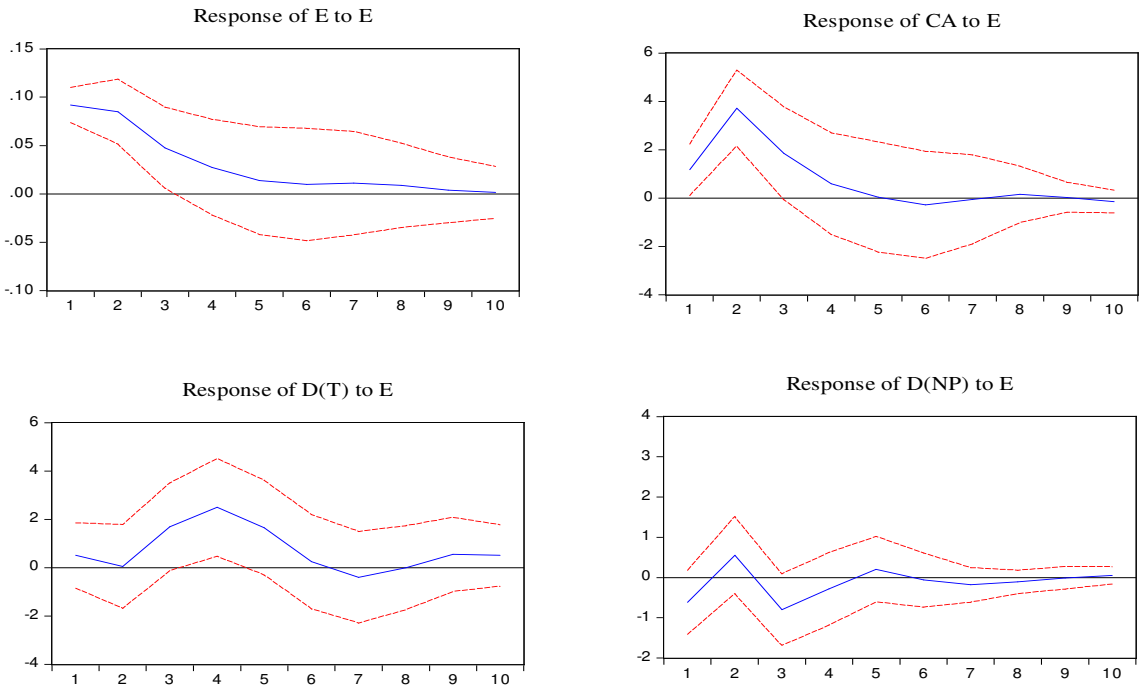
Tourism is calculated as the ratio of the number of foreign tourists and the population of Iceland. The real exchange rate is defined as the relative price of tradables.



Other exports are calculated as the ratio of non-primary merchandise exports to total merchandise exports. The real exchane rate is defined as the relative price of tradables.

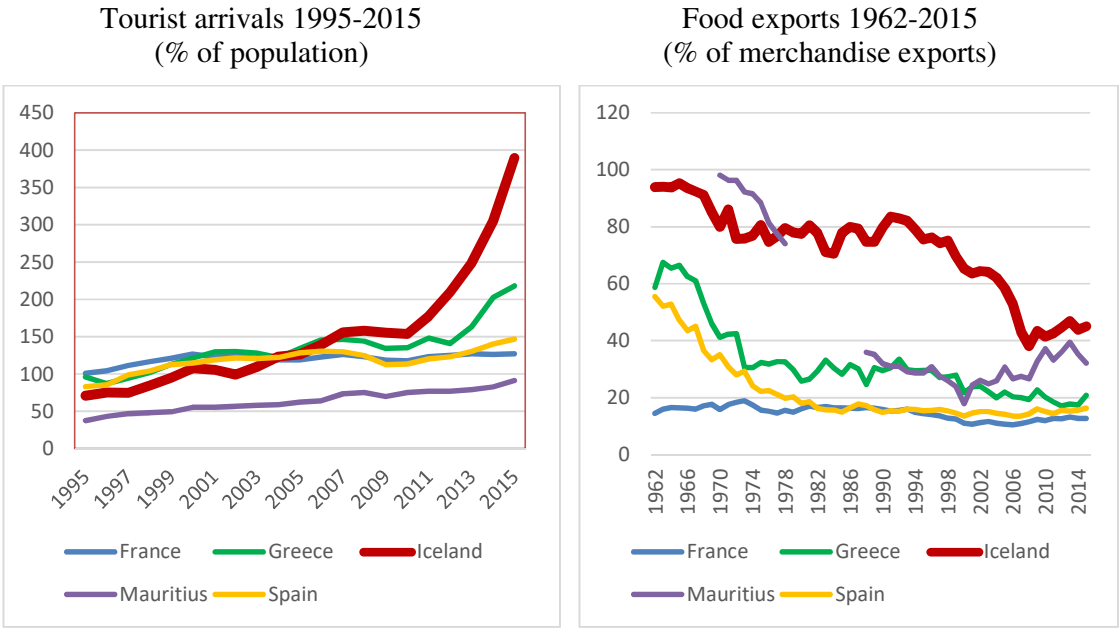
Source: Statistics Iceland (www.hagstofa.is) and the Icelandic Tourist Board (http://www.ferdamalastofa.is/is/tolur-og-utgafur/fjoldi-ferdamanna).

Figure 7. Impulse response functions to a rise in the price of tradable goods, i.e., real depreciation of the currency



Note: Generalized impulses (Pesaran and Shin, 1998). One S.D. Innovations ± 2 S.E.

Figure 8. Tourism and food exports



Source: World Bank, *World Development Indicators*.