HÁSKÓLINN Í REYKJAVÍK
REYKJAVIK UNIVERSITY

Macroeconomic effects of varied mortgage instruments studied using agent-based model simulations

Þórir Bjarnason

Thesis of 30 ETCS credits
Master of Science in Financial Engineering

December 2014

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Þórir Bjarnason

Thesis of 30 ECTS credits submitted to the School of Science and Engineering at Reykjavík University in partial fulfillment of the requirements for the degree of
Master of Science in **Financial Engineering**

December 2014

Supervisors:

Dr. Hlynur Stefánsson, Supervisor
Associate Professor, School of Science and Engineering, Reykjavik University, Iceland

Einar J. Erlingsson, Co-Supervisor
Macroprudential Supervisor, The Financial Supervisory Authority, Iceland

Dr. Marco Raberto, Co-Supervisor
Associate Professor, University of Genoa, Italy

Examiner:

Dr. Sverrir Ólafsson, Examiner
Professor, School of Science and Engineering, Reykjavik University, Iceland

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Date

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Abstract

This thesis was originally written as a paper to be published in the online journal Economics[1]. It has been somewhat modified for this stylesheet.

Mortgage instruments differ in many respects. Their microeconomic effects might be easily calculated but their effects on a macroeconomic level are not always easily understood. Agent-based models can be used to study the macroeconomic effects that emerge from the microeconomic behavior of multiple interacting agents. Using a macroeconomic model of a credit network economy we have found that inflation-indexed mortgages can mislead households' expectations of risk, encouraging them to buy more housing due to their low initial amortizations which, in turn, stimulates housing prices. We also find that the effectiveness of standard monetary policy tools is diminished when inflation-indexed mortgages are used. Banks partake in the interest rate risk with fixed rate mortgages but bear little or no risk with adjustable rate or inflation-indexed mortgages.

We have seen in this study that mortgage types, macroprudential tools and other policy tools can be experimented on, give insights into the interplay between agents and insight into the effects that certain policy settings may have on a macroeconomic level.

[1]http://www.economics-ejournal.org/

Þjóðhagsáhrif mismunandi lánategunda rannsökuð með agent-based þjóðhagslíkani

Þórir Bjarnason

Desember 2014

Útdráttur

Verkefnið var skrifað sem grein til birtingar í vefritinu Economics[2]. Greininni var lítillega breytt til að passa inn í þetta sniðmát.

Hvernig sem lánafyrirkomulag er þá er í flestum tilvikum hægt að segja til um hver áhrif lánana eru á hvern aðila hagkerfisins um sig. Ef litið er á hagkerfi í heild og áhrif mismunandi lánategunda þá vandast málið töluvert. Hægt er að nota hermilíkön á borð við agent-based líkön til að skoða hvernig þjóðhagur þróast útfrá fjárhagssamskiptum margra aðila. Þjóðhagslíkan sem byggir á tengslum efnahagsreikninga allra þátttakenda hagkerfis leiddi í ljós að verðtryggð lán geta skekkt væntingar heimila á áhættu sem ýtir undir meiri lántöku fyrir kaupum á húsnæði vegna lágrar greiðslubyrði í upphafi lánstímans sem síðan hefur áhrif á húsnæðisverð. Líkanið gefur einnig til kynna að skilvirkni stýrivaxta sé lægri á lánamarkaði þar sem verðtryggð lán eru ríkjandi. Bankar taka meiri þátt í vaxtaáhættu þegar óverðtryggð fastvaxtalán eru notuð en litla sem enga áhættu þegar verðtryggð lán og lán með breytilegum vöxtum eru notuð.

Rannsóknir okkar sýndu að með notkun agent-based þjóðhagslíkans er hægt að skoða lánategundir og verkfæri sem styðja við fjármálastöðugleika hagkerfis og hvernig hagkerfi hegða sér við breytingar á þessum þáttum. Hægt er að öðlast innsýn í hvaða áhrif samverkandi aðilar innan hagkerfis hafa á hagkerfið sjálft og niðurstöðurnar eru ekki fjarri raunveruleikanum.

[2] http://www.economics-ejournal.org/

Acknowledgements

I would like to thank my supervisor Dr Hlynur Stefánsson for his guidance and help through this work. I would also like to thank Einar Jón Erlingsson for his help and guidance. I would also like to thank my supervisor Dr Marco Raberto for his comments and guidancee.

I would also like to thank Einar J. Erlingsson and Bulent Ozel for their help in modifying the model and helping me understand how it works.

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Chapter 1

Introduction

Standard mortgage instruments have been criticized in the past for not incorporating the problem of inflation (Lessard and Modigliani (1975) and Shiller et al. (1997)). The so-called tilt effect[1] may result in higher payments on new mortgages and mortgages with variable rates, lowering demand for housing which in turn may decrease the relative price of housing, lowering construction of new housing due to a higher cost to price ratio (Kearl (1979)). In other words it can result in frictions and mismatches in the economy (Barrull and Dorse (2011)) causing stress in the housing market. Iceland is one of a handful of countries where inflation indexed mortgages have been implemented to counter these effects.

Historically inflation has been high in Iceland. Over the past 15 years it has been 5.57% per annum and in 2009 it peaked at roughly 18.5% per annum causing all inflation indexed mortgages to increase in nominal value. Table 1 shows the average 12 month inflation rate over different time periods in Iceland. In the year 2001 the Central Bank of Iceland set an inflation target defined as 12 month rise in the consumer price index. Figure 1.1[2] shows the inflation rate per annum calculated monthly using the consumer price index (CPI)[3] and the inflation target including the tolerance limits. Table 1.2[4] shows that some of Icelands neighboring countries have similar targets but the inflation is not close to what is known in Iceland.

The most common mortgage type in Iceland is the inflation-indexed mortgage (IIM) which is linked to the CPI. Because of how the mortgage is constructed an increase in the CPI causes an increase of the remaining principal and thus an increase in the monthly

[1] The payment stream of non inflation indexed mortgages decreases, in real terms, as inflation rises.
[2] http://www.cb.is
[3] http://www.statice.is
[4] https://www.cia.gov and https://www.imf.org

payment. Shiller et al. (1997) observe that people agree with the principle of inflation, yet the general population is resistent to inflation indexation, one reason supposedly being money illusion, i.e. people want to know how much money they will receive disregarding the distinction between nominal and real value. This seems in line with the ongoing discussion in Iceland, whether to keep inflation-indexation or not.

Campbell and Cocco (2003) use a life-cycle model of mortgage choice to examine what type of mortgage is preferrable, the adjustable rate mortgage (ARM) or fixed rate mortgage (FRM). Also, they look into the inflation-indexed FRM. Results from their simulations suggest that welfare benefits such as wealth stability of an ARM and income stability of FRM are combined in the inflation-indexed FRM which in turn yields a lower risk for both households and financial institutions. Alm and Follain (1984) find in their simulation results that borrowers are willing to pay more to use price-level adjusted mortgages (PLAM). PLAMs have a stimulating effect on the mortgage market when inflation is high and when taking out a PLAM, rather than a FRM, the borrower can always purchase a house of more than 30 percent greater value.

Furthermore, Cocco (2013) and Lunde (1997) both point out that additional mortgage instruments in the market allow for greater diversification of portfolios using real mortgage market data from the United Kingdom and Denmark. The banks in Iceland offer mixed mortgages, i.e. non inflation indexed and inflation indexed mortgages, to borrowers which might be beneficial as the household portfolio is somewhat more diversified, although IIMs continue to be the dominant form of mortgages in Iceland.

This paper focuses on the differences of the mortgage types discussed thus far, i.e. FRM, ARM and IIM, and how they affect the economy. We use the Iceace model (Erlingsson et al. (2014)), an agent-based computational macroeconomic model, to simulate possible evolutions over a 15 year period. The Iceace model utilizes the balance sheet accounting of economic agents, introduced by the EURACE model (Cincotti et al. (2012) and Raberto et al. (2012)). This gives us the opportunity to study in detail the balance sheet of every agent in the artificial economy at every time step of the simulation.

The rest of the paper is organized as follows. In Chapter 2 we look at the calculations behind the common mortgage types that are found in Iceland and a brief comparison of the Icelandic mortgage market with neighboring mortgage markets. In Chapter 3 a brief overview of the Iceace model is given followed by a detailed description of the housing and mortgage market in the model. In Chapter 4 initialization of the model and the different cases that we study are stated and the results from the simulations are analyzed and compared. Finally, we conclude in Chapter 5.

Time period	5 years	10 years	15 years
Average inflation per annum	4.43%	6.13%	5.57%

Table 1.1: Average inflation per annum measured from March 2014 back to March of the year for the respective period using the Icelandic consumer price index.

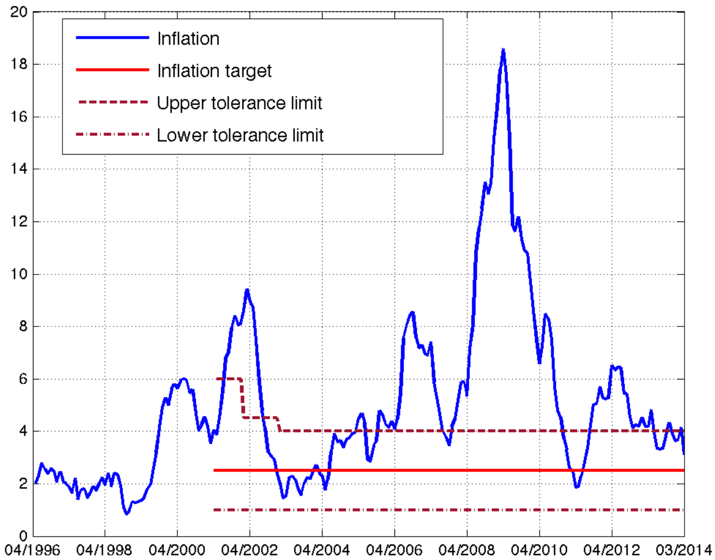

Figure 1.1: 12 month inflation rate calculated monthly for the period April 1996 - March 2014 and inflation target with tolerance limits. The blue line is the inflation rate per annum calculated monthly using the CPI. The red solid line is the inflation target set at 2.5% and the maroon dashed lines are the upper and lower tolerance limits. The lower tolerance limit was set at 1.0% and has not changed while the upper tolerance limit was set at 3.5% until the end of 2001 when it was lowered to 2.5%. Then in 2003 the upper tolerance limit was set at 1.5% corresponding to an upper limit of 4.0%.

Country	Inflation rate	Inflation target
Iceland	3.66%	2.5%
Denmark	0.8% (2013 est.)	None
Germany	1.6% (2013 est.)	None
United Kingdom	2.7% (2013 est.)	2.0%
United States	1.5% (2013 est.)	2.0%

Table 1.2: Inflation rates and targets in Iceland and four neighboring countries.

Chapter 2

Mortgage loans

Loans secured against real estate are called mortgage loans or mortgages. The two main categories of mortgages are the adjustable rate (or variable rate) and fixed rate mortgages, ARM and FRM respectively. FRMs have a fixed rate throughout the loan term whereas the ARMs have an adjustable rate, often linked to some known rate, e.g. LIBOR or Central Bank rate. Many loan markets offer ARMs with the options of an initial fixed rate for up to 10 years. These kinds of mortgages are often called short, medium or long term fixed ARMs. The loan term of a mortgage varies from a few years up to 40 years, or more in some cases. Table 2.1 lists a number of amortization schedules commonly available to mortgage borrowers.

2.1 Annuity loan

A mortgage with an annuity amortization schedule, henceforth annuity, is designed so that each payment is equal. Of course, the payment amount will change if the interest rate, loan term or principal changes. The payment amount is calculated using Eq. 2.1.

$$A = \left(\frac{r}{n}\right) \frac{\left(1+\frac{r}{n}\right)^{nT}}{\left(1+\frac{r}{n}\right)^{nT} - 1} X, \tag{2.1}$$

where A is the payment amount, r is the interest rate per annum, n is the number of payments per year, T is the loan term in years and X is the principal. Since each payment is the same amount at every payment date the tradeoff is that the principal is repaid very slowly in the beginning and the asset formation is therefore slow. To get the total interest paid, denoted by I, on an annuity loan, just multiply the annuity with the number of

Amortization schedule	Explanation
Annuity	Every payment is the same amount
Balloon	The principal is not fully amortized at the last payment date leaving a large end payment
Bullet	The entire principal is due at the last payment date and sometimes the entire interest payment as well
Equal installment	Principal payments are the same amount at every payment date

Table 2.1:

payments, then subtracting the result with the original principal,

$$I = AnT - X. \tag{2.2}$$

If we divide A by X we get the annuity factor inversed, or $1/A_f$, for which the formula is, with a little reordering of the terms,

$$A_f = \frac{n}{r} - \frac{n}{r\left(1+\frac{r}{n}\right)^{nT}}. \tag{2.3}$$

2.2 Mortgages in Iceland

The most common mortgage type in Iceland is the inflation indexed mortgage (IIM) which is linked to the Icelandic CPI, and consequently directly linked to the calculated inflation. Other loans are the ARM with the option of fixing the interest for up to five years at the beginning of the loan. The maximum loan term is 40 years, the loan-to-value (LTV) ratio is set at 80% with the exception of Landsbankinn who offers mortgages with an LTV ratio of 85%, the interest rate is set with respect to the loan taken and the central bank rate. Early repayment fees may apply to loans with a fixed interest rate and anyone looking to take out a mortgage has to pass a credit assessment, present income must cover payments of all liabilities as well as cost of living plus a buffer. An overview of the Icelandic mortgage market can be found in Gunnarsson (2013) and Lúðvíksdóttir (2012) and in Icelandic law on consumer loans (no. 33/2013[1]).

The mortgage payments for an annuity IIM are as in Eq. 2.1 added the index adjustment, yielding

$$A_i = \left(\frac{r}{n}\right)\frac{\left(1+\frac{r}{n}\right)^{nt}}{\left(1+\frac{r}{n}\right)^{nt}-1}X_i\frac{P_i}{P_0}, \tag{2.4}$$

where A_i is the index adjusted payment number i, t is the remaining loan term in years, n is the number of payments per year, X_i is the remaining principal at payment number

[1] All Icelandic law can be found online at: http://www.althingi.is.

i, P_0 is the base index value, P_i is the index value at payment number i and $i \geq 1$, see Elíasson (2014).

The way that Eq. 2.4 is written suggests that the index adjustment is made to the remaining principal rather than the payment, in fact it does not matter which is done first. The effect of each index adjustment to the principal is spread across all remaining payments, yielding higher (lower) payments in case of inflation (deflation). The index adjustment is a negative (positive) amortization in case of inflation (deflation) and the principal is adjusted in nominal terms to preserve the value of the debt in real terms, payments are then adjusted accordingly.

There is however another amortization schedule for loans that are inflation indexed, not available to borrowers in Iceland, where the index adjustment is payed in full at every payment date. The annuity is the same as a non inflation indexed mortgage and the index adjustment, V_i, is calculated as

$$V_i = X_i \left(\frac{P_i - P_{i-1}}{P_{i-1}} \right) \tag{2.5}$$

where P_i is the index value at payment number i and P_{i-1} is the index value at the previous payment. The total payment is then the sum of the index adjustment V_i and the non inflation-indexed mortgage payment A_i.

2.2.1 Comparison to mortgages in neighboring countries

It is interesting to see how different loan markets between countries can be. The differences vary from choice between ARM and FRM, loan term and how the mortgages are funded. Table 2.2 shows that the maximum loan term is most often no more than 30 years compared to 40 years in Iceland. In Denmark mortgages are funded almost entirely with covered bonds whereas in Iceland, just as in the german, british and US mortgage markets, mortgages are funded mostly with deposits. The choice of interest rate in Denmark ranges from short term to entire loan term fixed interest rate but in the United Kingdom short term fixed or variable rates are the most frequent. In Germany it is close to an even 25% split between fixed, medium term, short term and variable interest rate and in USA the FRMs are dominant (Fernández de Lis et al. (2013)). In Iceland the mortgage rates are most often fixed in the case of IIMs and variable or short term fixed in other cases.

In 1982 Denmark introduced inflation-indexed mortgages although the success was short-lived due to a number of reasons such as tax rules, restrictions and the complication of early repayment. IIMs are still available to borrowers in Denmark but very few borrowers choose those mortgages (Lunde (1997)).

2.3 Analytical Comparison of mortgages

Table 2.3 shows total nominal repayments of the different annuity mortgages mentioned earlier. The indexed mortgage has higher totals than the other and the jump is almost 4.7 million when the loan term is changed from 25 to 40 years. This large difference stems from the structure of the indexed mortgage, where the index adjustment is not payed in full at every payment date so the remainder of the index adjustment is added to the remaining principal.

Table 2.4 contains the first, average and maximum monthly payments of the same mortgages discussed in Table 2.3. The calculations show that the indexed annuity has very low payments in the beginning compared to the other loans but both the average and maximum payments are higher. This kind of mortgage might be appropriate for those who expect an increase in income in the future and need the extra buffer of low mortgage payments to use their liquidity elsewhere. From the viewpoint of the risk averse borrower a non indexed annuity FRM seems the best choice since the payments do not change over the entire lifespan of the mortgage.

Figure 2.1 shows the evolution of the remaining principal of two indexed annuities where the green solid line is the remaining principle of a 40 year mortgage with 4.15% inflation per annum whereas the red solid line depicts the same mortgage following a different inflation estimate, the first part of the curve follows the inflation in Iceland from the first of January 2007 until March 2014 and after that it follows the same estimate of 4.15% as the other mortgage. The point here is to show that if inflation is high in the beginning of the mortgage then the remaining principal increases substantially and it follows that the total repayment of the mortgage becomes higher. The payment stream grows just as the principal increases but note that the increases in the payment are relatively small, smoothing over the effects of the index adjustment to the remaining principal. The difference in monthly payments just after the first 48 months is approximately 1.220 but in the end it is closer to 16.270 for the read dashed line.

	Iceland	Denmark	Germany	UK	USA
Loan term (years)	≤ 40	≤ 30	≤ 30	≤ 30	≤ 30
Max LTV ratio	80%	80%	80%	110%	100%

Table 2.2: Note that in this table common values are recorded, no extremes or exceptions pertaining to one or a few financial institutions. Fernández de Lis et al. (2013), IMF (2011)

Mortgage type	Loan term	Total nominal repayment	Interest rate
ARM	25 years	3, 115, 164	Variable
FRM		1, 753, 770	5.0%
IIM		3, 614, 227	2.5%
ARM	40 years	4, 790, 432	Variable
FRM		2, 314, 544	5.0%
IIM		8, 268, 798	2.5%

Table 2.3: Comparison of nominal total repayment amounts of annuity mortgages. The initial principal is $1,000,000$ and payments are monthly. The interest rate curve used to calculate the ARM was created with the Iceace model, simulating over $9,600$ iterations to create a curve for 40 years. The same was done for the inflation curve to calculate the IIM.

Mortgage type	Loan term	First	Average	Max
ARM	25 years	5, 278	10, 384	13, 605
FRM		5, 846	5, 846	5, 846
IIM		4, 486	12, 047	24, 765
ARM	40 years	4, 179	9, 980	13, 725
FRM		4, 822	4, 822	4, 822
IIM		3, 307	17, 227	48, 981

Table 2.4: Comparison on first, average and maximum monthly payments. The same prerequisite values as were used in the calculations for Table 2.3 are used here. The difference is rather substantial between FRM and the other mortgages types due to the fact that it has a comparatively low and fixed interest rate.

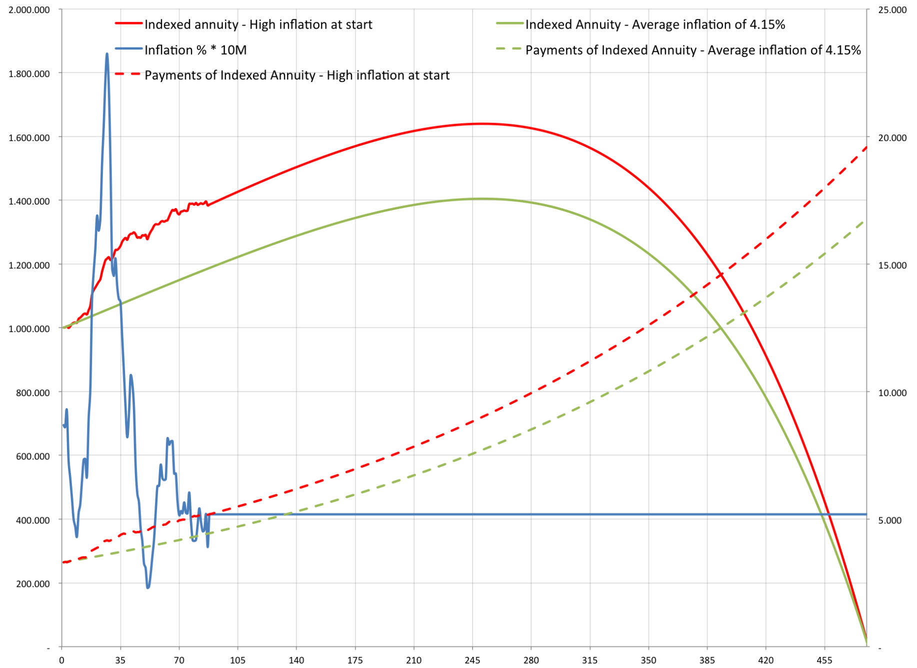

Figure 2.1: Remaining principal with index adjustment and payment stream of inflation indexed annuity mortgages with a 40 year loan term. The x-axis is in number of months, the left y-axis is the remaining principal (solid lines) and the right y-axis is the total payment (dashed lines). Both mortgages are calculated using the prerequisite information in the caption of Table 2.3 with the difference that the red lines (solid and dashed) follow the CPI from 1.1.2007 and after that it follows an average inflation of 4.15% while the green lines follow the average inflation of 4.15% throughout the loan term. The darker blue solid line is the inflation rate used for mortgage represented by the red line. The dashed lines represent the payment streams for the respective loans.

Chapter 3

Iceace model

In this section an overview of the Iceace model will be given. For a more detailed description of the model please refer to Erlingsson et al. (2014). Naming convention of variables given will be in accordance with the previously mentioned paper. The Iceace model is built-up of various types of heterogeneous agents; banks, construction firms, firms, households, a government, a mutual fund and a central bank. To use this model in computational experiments the model was based on FLAME[1] multi-agent simulation framework, where FLAME is short for flexible large scale agent modelling environment.

Banks provide firms and construction firms with loans and households with mortgages and if the aforementioned agents have any liquidity, that amount is deposited into the banking system. Firms and construction firms produce consumption goods and housing units respectively, employing labor from a decentralized labor market. Households provide the labor market with a labor force, consume goods produced by firms and buy housing units produced by construction firms or sold by other households.

The equity fund owns all the equity shares in banks, firms and construction firms. Dividends are collected by the equity fund and redistributed equally among households owning shares. If one or more firms have requested financing from the equity fund the equity fund may retain a part of the dividends for financing, given that two conditions pertaining to the financing are fulfilled. A firm must apply for financing and only do so when in need of financing and it must have exhausted every possibilty to get a loan from the banking system.

The government collects taxes on labor and capital income which together with net earnings from the central bank is used to pay unemployment benefits to households in need

[1] For more information on FLAME, go to their website flame.ac.uk

and general transfer benefits to households. General transfer benefits are in the interval $0 - 40\%$ of average household labor income and may vary throughout the simulation. Labor and capital income tax is set in the interval $10 - 50\%$. Unemployment benefits are set to 50% of average household labor income. In addition the government is responsible for the fiscal policy of the artificial economy, setting the level of income tax and general transfer benefits, always aiming at a zero deficit. The exonegously set parameter Γ, defined in the interval $(0, 1)$, is used to determine to what extent income tax versus benefits is to be used to reach zero deficit. A higher value of Γ means that income tax is used to a larger extent to maintain a balanced budget.

The Central Bank in the model provides a standing facility to the banking system to fulfill its liquidity needs, without limit. The second task appointed to the Central Bank in the model is setting the policy rate, r_{CB}, according to a Taylor rule, where inflation and unemployment rate are both considered. r_{CB} can never be lower than 0.5% and there is no cap.

Each iteration or time step, in the model, is considered to be one day. A week is set to five days, a month is equal to four weeks and one year is equal to twelve months. Agents in the model are set to act on the first day of a week, month or quarter. Every week households use a weekly ration of their monthly consumption budget on the homogenous goods produced by firms. Every month firms and construction firms set the prices for the coming month and employ or fire labor depending on their production plan. Households decide if they want to enter the housing market or not. Households may be forced to enter the housing market in case of a fire sale due to a high debt-to-income ratio, i.e. high ratio between mortgage payments and income. The fire sale threshold is set exogenously.

Every quarter, before the monthly activities, balance sheets are calculated for the agents and their accounts are balanced. The government sets the income tax and the general transfer benefit rates and the Central Bank collects interest on outstanding loans and sets the policy rate r_{CB}.

Table 3.1 shows the balance sheets of the agents in the Iceace economy. Notice that all agents have an equity entry in the liability column. For households, firms, construction firms and banks, if the equity becomes negative it means that the liabilities are greater than the assets and the agent is bankrupt. In the case of firms, bankruptcy leads to a restructuring process that can involve debt write-off.

3.1 Household Credit Market

The housing market in the Iceace model was built up adhering to empirical facts from the Icelandic housing market and the behaviour of Icelandic households, modeling the household mortgages with ARM, Erlingsson et al. (2013). For this paper that implementation was changed with the addition of two mortgage types, IIM and FRM, and there are no speculative trades in the housing market.

Banks provide mortgages to households who are in the process of buying new housing units and do not possess the needed liquidity. There are three types of mortgages in the model to choose from and the choice is made exogenously prior to the start of a simulation. The loan term is the same for all mortgages and is also set exogenously prior to the start of a simulation. Table 3.2 lists the mortgage types available in the model, with a brief explanation. IIM is inflation indexed and the annual interest rate is fixed throughout the life of the mortgage. When a new mortgage is created the interest rate is set as r_{CB} plus a fixed premium. FRM has a fixed rate but since it is not inflation indexed the rate, r_{fM}, is set as r_{CB} plus a fixed 3% spread. For the ARM the interest rate r_M follows r_{CB} plus a fixed 2% spread. Every quarter, i.e. every 60^{th} iteration, after the Central Bank has adjusted r_{CB}, the mortgage payments are calculated. In the model initialization, mortgages can be set as either a ratio of total assets or adjusted so that the payments are set to a ratio of total income after tax. In addition the initial remaining loan term is set randomly in the interval $[2, 40]$ years, the mortgage amount adjusted accordingly. All new mortgages during simulation get a remaining loan term of 40 years.

The equations used in the model should be familiar as they were presented in Chapter 2. For the balance sheets the model keeps track of all interest payments as well as principal payments. Interest payment for mortgage m, R_r^m, for each quarter is calculated as follows:

$$R_r^m = U^m \frac{1}{4} r_M, \tag{3.1}$$

where U^m is the remaining principal of mortgage m and r_M can be interchanged with r_{IIM} or r_{fM}.

To find the principal payment for mortgage m, R_U^m, the annuity factor, A^m, has to be calculated. Using Eq. 2.3 we get the following with the annotation as in Erlingsson et al. (2014):

$$A^m = \frac{1}{\frac{1}{4} r_M} - \frac{1}{\frac{1}{4} r_M \left(1 + \frac{1}{4} r_M\right)^n}, \tag{3.2}$$

where r_M is interchangeable with r_{IIM} or r_{fM} and n is the number of quarters remaining of the loan term. Now the quarterly mortgage cost (interest and principal repayment), R^m,

Agent	Assets	Liabilities
Household *abbrev.*: Hous *index*: $h = 1, \ldots, N_{Hous}$	housing X^h liquidity, M^h equity fund shares, V_d^h	mortgages, U^h *equity*, E^h
Firm *index*: $f = 1, \ldots, N_{Firm}$	capital goods, K^f inventories, I^f liquidity, M^f	debt (loans from banks), D^f *equity*, E^f
Construction firm *abbrev.*: TFirm *index*: $s = 1, \ldots, N_{TFirm}$	capital goods, K^s inventories, I^s liquidity, M^s	debt (loans from banks), D^s *equity*, E^s
Bank *index*: $b = 1, \ldots, N_{Bank}$	loans, $\mathcal{L}^b = \sum_{f,s} D_b^{f,s}$ mortgages, $U^b = \sum_h U_h^b$ liquidity, M^b	private sector[2] deposits, $\mathcal{D}^b = \sum_{h,f,s} M_b^{h,f,s}$ debt with the central bank, D^b *equity*, E^b
Equity Fund *abbrev.*: Fund *index*: e	liquidity, M^e firms' shares, V_f^e construction firms' shares, V_s^e banks' shares, V_b^e	*equity*, E^e
Government *abbrev.*: Gov *index*: g	liquidity M^g	debt to the central bank, D^g *equity*, E^g
Central Bank *abbrev.*: CB *index*: c	liquidity, M^c loans to banks, $\mathcal{L}_b^c = \sum_b D^b$ loans to the government, $\mathcal{L}_g^c = D^g$	outstanding fiat money banks liquidity, $\sum_b M^b$ government liquidity, M^g fund liquidity, M^e *equity*, E^c

Table 3.1: Balance sheets of agents populating the Iceace economy. Notice, for instance, the connection between agents such as banks, where mortgages are assets, and households, where mortgages are liabilities. From this table it is possible to map the flow of money in the system and some of the interactions between agents.

[2] The private sector refers here to households, firms and construction firms. Banks' liquidity is deposited at the central bank.

Mortgage type	Abbreviation	Short explanation
Variable rate annuity mortgage	ARM	Interest rate follows the rate of the Central Bank plus a fixed 2% spread
Fixed rate inflation indexed annuity mortgage	IIM	Interest rate is fixed throughout the term and principal indexed to CPI
Fixed rate annuity mortgage	FRM	Interest rate set as the rate of the Central Bank plus a fixed 3% spread

Table 3.2: Mortgage types available in the Iceace model.

of mortgage m is as follows:

$$R^m = \frac{U^m}{A^m}. \tag{3.3}$$

The interest payment of the annuity is given by Eq. 3.1, thus the principal repayment, R^m_U, is given by

$$R^m_U = R^m - R^m_r. \tag{3.4}$$

These equations can be used for the ARM and FRM. In the case of the IIM, before calculating the quarterly repayment costs the remaining principal is adjusted for inflation and then the above equations are used. Let us denote this adjusted remaining principal by $U^m_{adj} = U^m(1 + I)$ where I is the quarterly change in prices, i.e. quarterly inflation, and in the equations above we use U^m_{adj} instead of U^m.

The process of getting a mortgage is subject to three constraints, the first being that there must be a bank whos equity base will be greater than a fraction χ of the sum of its loans to firms and mortgages to households. The second constraint is that the net wealth of a household taking a new mortgage must be greater than or equal to a fraction ϕ of its total wealth. The third constraint is that the total quarterly mortgage cost $R^h = \sum_m R^m$, where R^h denotes the total quarterly mortgage cost of household h, must be less than or equal to a fraction β of its quarterly net income, i.e. labor income Z^h_l and capital income Z^h_e after tax deduction. If these constraints are not met then that household will not get a mortgage and will not be able to buy a new housing unit. Note here that the fraction β works as a macroprudential tool known as debt-to-income ratio (DTI) and will henceforth be referenced as such. DTI in this paper is defined as the parameter β above, i.e. mortgage payments divided by total income after taxes per quarter may not exceed the fraction β. The difference here is that we use net income instead of gross income but the main purpose of the tool is the same, to limit the mortgage payments of households.

Households selling a unit of household will use the money gained to repay all or part of their mortgages, starting with the oldest mortgage. If all mortgages are repayed and there is still money left from the sale, that money is kept as liquidity. If the remaining principal of a mortgage is higher than what is left of the money gained from the sale then the principal will be lowered by that amount and new quarterly costs of that mortgage are calculated.

If a household is spending more than a fraction θ_{high} of its disposable income on mortgage payments then that household is considered no longer able to service the debt. This leads to a debt write-off, lowering the quarterly mortgage cost down to a fraction θ_{low} such that $R^h = \theta_{low}\left(Z_l^h\left(1-t_l\right)+Z_e^h\left(1-t_e\right)\right)$, where t_l is the labor income tax rate and t_e is the capital income tax rate. A debt write-off affects banks as a loss of assets which is reflected in their income statement and in turn their balance sheet.

Chapter 4

Results and discussion

The macro economic effects of three different mortgage types, ARM, FRM and IIM as described in Chapter 3.1, were studied using the Iceace model. Each simulation featured only one of the mortgage types with a set DTI ratio. The DTI ratio was set to one of the three values $\{25\%, 30\%, 40\%\}$ resulting in a total of nine simulation scenarios. Every scenario was simulated using 50 different random seeds, for aggregation and analysis to see if the model behaves the same for different random seeds. The number of iterations per simulation was $3,600$, equal to fifteen years in model time.

The number of agents was set as follows: 3200 households, 50 firms, 10 construction firms, 2 banks, 1 government, 1 central bank and 1 equity fund. The number of households is just 40% of the number of households used by Erlingsson et al. (2014), the reason being that the simulation results using 8000 versus 3200 households are very close to the same, underlining the stability of the model, and the simulation time was drastically shortened. Erlingsson et al. (2014) used four values for DTI and the mortgage type used was the ARM. To get a greater appreciation of the macro economic effects of FRM and IIM, three values for DTI were used, leaving out the 20% ratio which was used in the aforementioned paper.

First a summary of the initial model state will be given followed by an outline of the results, starting with households and the housing market and then banks and the Central Bank and lastly the economy and the government.

4.1 Initial model state for simulations

The initialization of the model is largely based on the work of Erlingsson et al. (2014) and therefore only a few variables have been altered. Some new variables were added to the model to accomodate for the simulation cases for this paper. The main idea of the initialization is to set up the balance sheet for every agent.

Inflation is set at 3.5% so that the Central Bank rate calculates to 2% given an unemployment rate of 5%. To account for the unemployment, households' liquidity is set at random as the sum of three months worth of average wage, $W(0) = 5$, and unemployment benefits, $\xi_U W(0)$ where ξ_U is the initial unemployment benefit rate. Each household gets five housing units, each one worth $20W(0)$. Households start out with a mortgage load U^h such that 15% of their total income is the payment amount on their mortgages and the lifetime of the mortgages is set randomly in the interval $[2, 40]$ years to get a more distributed set of mortgages but new mortgages get a loan term T_M of 40 years. The initial interest rate on the mortgages is set in accordance with the Central Bank rate as described in Section 3.1. Only 10% of households hold shares and receive dividends from the equity fund throughout the simulation.

Both firms and construction firms are assigned employees randomly so that 7.5% of households are employed by construction firms and the remaining employed households work at firms. The initial debt load of firms and construction firms, $D^{f,s}$ is set as 20% of labor cost and equity $E^{f,s}$ is set as debt divided by the initial startup leverage of firms, $\frac{D^{f,s}}{v^{f,s}}$.

After initializing the balance sheets of households, firms and construction firms it is possible to initialize the balance sheets of banks. Mortgages U^b and loans $\mathcal{L}^b$ are set to equal the total amount of mortgages on the balance sheet of households and loans that firms and construction firms have. Banks' total assets are made up of risky assets, mortgages and loans, and liquidity M^b which is set to 10% of the value of risky assets, $M^b = 0.1\left(\mathcal{L}^b + U^b\right)$. Banks equity E^b is set to 10% of total assets. Liquidity held by households, firms and construction firms is deposited in banks. To balance the assets and liabilities a Central Bank debt is set for the banks.

Please refer to the appendix for a complete list of initialized parameters.

4.2 Households and the housing market

Households enter the housing market with an exogenously given probability whereupon they either sell or buy a housing unit. The use of IIM makes it easier for households to buy more housing due to the initial low amortization. Figure 4.1 shows the distribution of housing wealth among households.Notably the distribution looks log-normal, regardless of mortgage type, and the log-normal distribution is often used to show distribution of wealth (Gibrat (1931)). Figure 4.2 shows the distribution of households paying more than 32 local currency units (LCU) in mortgage cost per quarter. The figure shows that more households pay more each quarter when using IIM. The low initial amortization of IIM may mislead households' expectation of risk, like increasing mortgage cost or a dive in equity ratio because of falling house prices.

Tables 4.1-4.3 show a selected set of parameters and their mean value of all the 50 seeds and iterations. Each table shows values with respect to different values of the parameter β. Variables holding nominal values are generally higher in the case of IIM than the other two mortgage types for all values of β and with increasing value of β we see an increase in the nominal values for all mortgage types.

As seen in Tables 4.1-4.3, average housing prices, both real and nominal, are higher when IIM is used rather than FRM and ARM. The same is to say for average total assets per household and also the total amount of mortgages in the artificial economy.

Both IIM and FRM have fixed interest rates resulting in more stable housing payments than in the case of ARM. This can been seen by comparing the subplots of Figure 4.3, notably the second and third subplots. showing how the interest rate fluctuates. The last subplot in the Figure 4.3 shows the effects that the policy rate level has on the housing market turnover and, as with housing payments, FRM and IIM are less affected by the changes in policy rate than ARM. The turnover in the housing market for IIM is higher than for FRM and does not dip as low as for ARM showing more activity in the housing market even when the policy rate is set high, see Figure 4.3, subplot 4, the 20^{th} quarter for instance.

The first subplot of Figure 4.3 shows the normalized amounts of mortgages in the economy and Tables 4.1-4.3 show the total amounts of mortgages on average in the economy. When using IIM the amount of mortgages is higher as households have a greater margin with respect to the DTI ratio due to the low initial amortization unlike FRM and ARM. Using FRM yields the lowest mortgage amount in the system on average but households keep their asset value at par compared to simulations with ARM. This holds true for nominal and real housing prices as well, as can be seen in Figure 4.4.

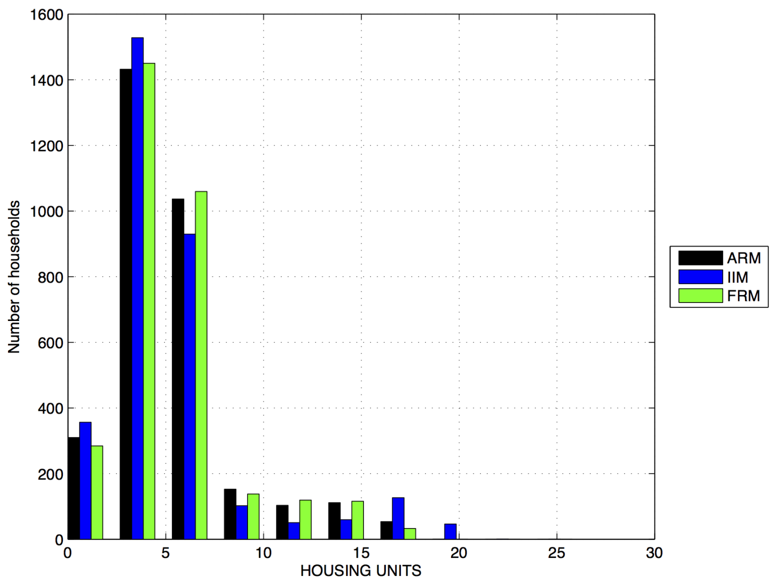

Figure 4.1: Histogram plot showing the distribution of housing wealth defined as households over housing units in the last state of the model and DTI ratio is set to 30%.

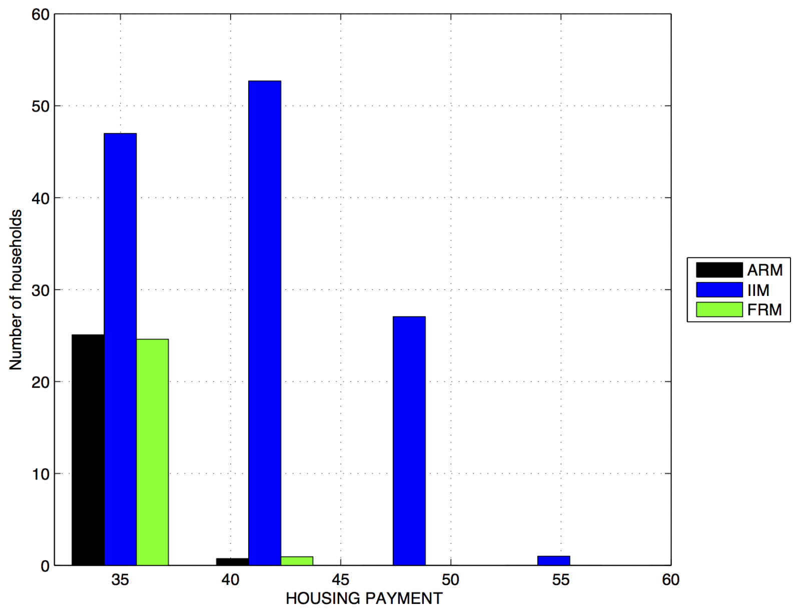

Figure 4.2: Histogram plot showing the distribution of housing wealth as households over housing payments when DTI ratio is set to 30%, note that not all households are shown and the x-axis starts at value 32.

Housing prices start out at 100 in all simulations. When the DTI ratio is set to 25% real housing prices fall for both ARM and FRM after a short lived rise but the fall seems to turn around close to the end of 15 years. The same is to say for IIM only the fall is short and the real housing price oscillates around 100 initially before starting to increase at a steady rate towards the end. With increasing DTI ratio real housing prices increase for all

	ARM	IIM	FRM
Total real GDP	$17,917$ (81)	$17,863$ (62)	$18,026$ (68)
Real economic growth per annum (%)	0.58 (0.01)	0.48 (0.01)	0.59 (0.01)
Total GDP	$32,137$ $(1,422)$	$31,874$ $(1,316)$	$31,949$ $(1,332)$
Economic growth per annum (%)	7.90 (0.03)	7.68 (0.02)	7.71 (0.03)
Central Bank rate (%)	9.62 (0.43)	9.54 (0.44)	9.41 (0.44)
Inflation rate (%)	7.11 (0.25)	6.99 (0.27)	6.91 (0.27)
Total mortgages	$422,263$ $(3,312)$	$565,791$ $(6,366)$	$383,138$ $(3,010)$
Average housing price	170.8 (6.7)	192.3 (8.5)	169.7 (6.3)
Real average housing price	96.5 (0.6)	107.1 (0.4)	96.8 (0.5)
Average mortgage payment per household	1.68 (0.06)	1.67 (0.08)	1.52 (0.07)
Average housing value per household	921.6 (40.1)	$1,042.3$ (51.1)	916.1 (38.0)
Average total assets per household	975.0 (43.7)	$1,111.3$ (55.6)	971.5 (41.5)
Banks' total assets	$523,773$ $(3,275)$	$672,838$ $(6,761)$	$484,821$ $(3,000)$
Banks' total Dividends	$6,778$ (465)	$14,407$ (828)	$5,715$ (509)
Banks' net earnings	$6,964$ (464)	$14,934$ (822)	$5,894$ (561)
Banks' retained earnings	9.7 (9.6)	163.8 (45.0)	159.2 (54.5)

Table 4.1: Each row shows a variable from the model with its value for each of the mortgage types. The values are calculated using all seeds as the mean over the entire life time of the model, i.e. a 15 year period. DTI ratio is set to 25% and the standard error is in parenthesis.

mortgage types and the nominal housing prices rise by more than 350% for all mortgage types when DTI ratio is set to 40%. Just as Erlingsson et al. (2014) showed, higher DTI ratios lead to higher housing prices especially when using IIM.

4.3 Banks and the Central Bank

The turnover in banks is significantly higher in the case of IIM. All nominal values in banks' balance sheets are higher for all DTI ratios compared to ARM and FRM, see Tables 4.1-4.3. The reason is that households can borrow more due to lower initial mortgage cost as mortgage interest rates are lower for IIM and, as was shown in Section 2.3, in case of inflation the principal, and payments, of IIM increase meaning that banks stand to gain the index adjustment on all outstanding mortgages in addition to the regular mortgage payments from households.

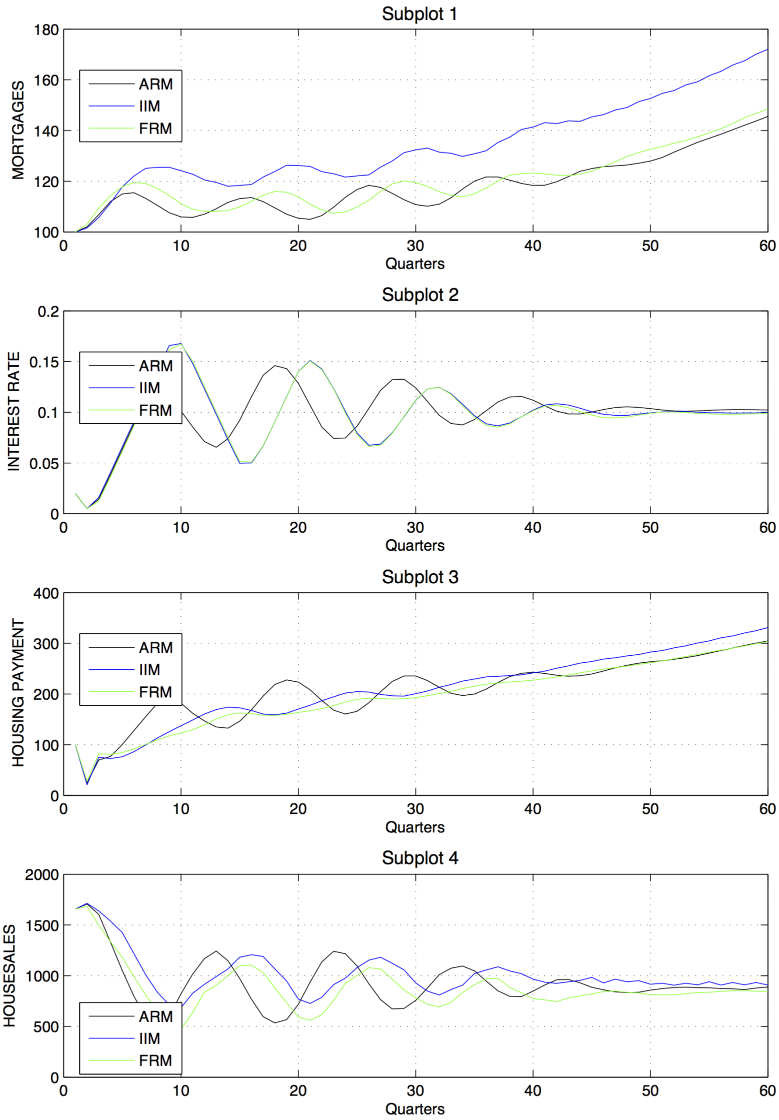

Figure 4.3: All data in these subplots have been aggregated from 50 seeds and DTI ratio is set to 30%. Subplot 1 shows the normalized mean of all outstanding mortgages in the model owned by banks. Subplot 2 shows the Central Bank rate. Subplot 3 shows how normalized quarterly housing payments grow over time on average for households in the Iceace economy, except in quarter number 2. What happens there is that almost all households who enter the housing market can buy or sell, meaning that all households who sell will repay as much of their mortgages as they can while those who buy more housing will get mortgages with very low interest rate compared to the mortgages that were repayed. The dive is the difference between interest payments on mortgages repayed and new mortgages acquired. Subplot 4 shows number of housing units bought per quarter.

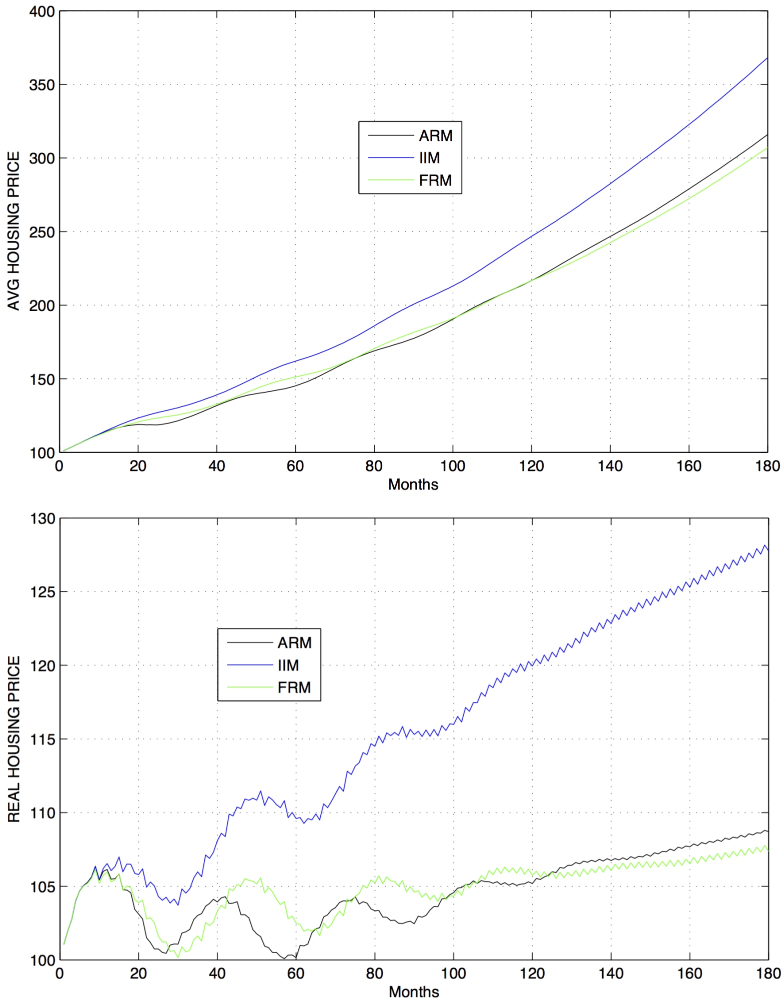

Figure 4.4: Average nominal and real housing prices when DTI ratio is set to 30%. The nominal housing prices are in the upper subplot and the real housing prices in the lower subplot.

With ARM and IIM there is very little risk for the banks. An increased (decreased) Central Bank rate means higher (lower) interest payments for banks on their Central Bank debt but it also means higher (lower) interest payments on ARM and in the case of IIM, with higher (lower) Central Bank rate there is inflation (deflation) in the system and mortgages need to be adjusted for inflation (deflation) which reflects in the asset side of banks balance sheets and in the income statement as the mortgage payments are adjusted as well.

In all scenarios banks' net earnings are great enough to repay their debt to the Central Bank and subsequently lower the interest payments to the Central Bank. In the case of FRM and IIM, banks retain more of their earnings to sustain the capital adequacy ratio, the main reason being new mortgages when using IIM and greater writeoffs on loans to firms and construction firms when using FRM. Banks pay dividends in all scenarios except for a few times when using FRM, the reason being a combination of high interest

	ARM	IIM	FRM
Total real GDP	17,783 (75)	17,750 (61)	17,890 (65)
Real economic growth per annum (%)	0.48 (0.01)	0.39 (0.01)	0.49 (0.01)
Total GDP	32,216 (1,422)	32,094 (1,338)	32,263 (1,358)
Economic growth per annum (%)	7.89 (0.04)	7.73 (0.02)	7.79 (0.02)
Central Bank rate (%)	9.78 (0.43)	9.76 (0.45)	9.65 (0.45)
Inflation rate (%)	7.21 (0.25)	7.15 (0.28)	7.09 (0.27)
Total mortgages	470,379 (6,337)	622,621 (10,765)	432,987 (5,806)
Average housing price	189.9 (8.7)	212.7 (10.7)	189.5 (8.2)
Real average housing price	104.6 (0.5)	115.5 (1.1)	104.9 (0.3)
Average mortgage payment per household	1.90 (0.08)	1.91 (0.09)	1.80 (0.08)
Average housing value per household	1,028.6 (51.7)	1,156.2 (63.8)	1,026.5 (49.1)
Average total assets per household	1,092.5 (56.2)	1,238.2 (69.6)	1,092.3 (53.4)
Banks' total assets	571,551 (6,337)	729,999 (11,231)	534,243 (5,819)
Banks' total Dividends	8,360 (571)	17,292 (1,019)	7,732 (634)
Banks' net earnings	8,742 (584)	18,081 (1,020)	8,120 (673)
Banks' retained earnings	132.6 (40.5)	340.4 (65.5)	207.5 (47.0)

Table 4.2: Each row shows a variable from the model with its value for each of the mortgage types. The values are calculated using all seeds as the mean over the entire life time of the model, i.e. a 15 year period. DTI ratio is set to 30% and the standard error is in parenthesis.

rate, increasing writeoffs resulting in a lower equity ratio and mortgage income from households being lower than the banks interest payments to the Central Bank.

In more detail, using FRM, banks' equity ratio dips down below the capital adequacy ratio, more often for a lower DTI ratio, due to a very high Central Bank rate at times meaning higher interest payments on the debt and writeoffs on loans to firms and construction firms. FRMs already in the economy are not affected by the increase in the Central Bank rate, very few new mortgages are being created and therefore banks do not create new mortgages with the ensuing payments during times of high Central Bank rate. Banks partake in the interest rate risk and as a result their net earnings are negative at times which leads to a dip in their equity ratio.

The Central Bank policy rate fluctuates much more for IIM and FRM than for ARM. IIM and FRM have fixed interest rates making it harder for the Central Bank to use its monetary policy tool to have an impact on the housing market. For IIM the effect of a high policy rate is less direct than for the other mortgage types as shown in Figure 4.3,

	ARM	IIM	FRM
Total real GDP	17,636 (75)	17,649 (63)	17,738 (64)
Real economic growth per annum (%)	0.40 (0.02)	0.34 (0.02)	0.40 (0.02)
Total GDP	32,457 (1,451)	32,671 (1,399)	32,819 (1,413)
Economic growth per annum (%)	8.00 (0.04)	7.95 (0.02)	7.97 (0.03)
Central Bank rate (%)	10.04 (0.43)	10.14 (0.46)	10.05 (0.47)
Inflation rate (%)	7.40 (0.25)	7.41 (0.28)	7.37 (0.29)
Total mortgages	556,277 (13,638)	722,309 (19,687)	525,753 (12,334)
Average housing price	218.9 (12.1)	244.0 (14.3)	224.2 (11.9)
Real average housing price	116.3 (1.4)	127.3 (2.1)	118.6 (1.3)
Average mortgage payment per household	2.27 (0.11)	2.34 (0.12)	2.27 (0.12)
Average housing value per household	1,190.3 (71.4)	1,330.2 (84.1)	1,220.1 (70.3)
Average total assets per household	1,274.0 (77.7)	1,433.0 (91.6)	1,307.3 (76.5)
Banks' total assets	656,851 (13,613)	830,370 (20,245)	626,375 (12,321)
Banks' total Dividends	11,045 (849)	22,128 (1,359)	11,306 (906)
Banks' net earnings	11,803 (875)	23,437 (1,379)	12,076 (932)
Banks' retained earnings	418.2 (76.1)	696.7 (109.3)	408.4 (66.8)

Table 4.3: Each row shows a variable from the model with its value for each of the mortgage types. The values are calculated using all seeds as the mean over the entire life time of the model, i.e. a 15 year period. DTI ratio is set to 40% and the standard error is in parenthesis.

subplots 2 and 4. Even with high interest rates more households are buying new housing with IIM than the other mortgage types and the low initial mortgage cost of IIM makes it possible.

4.4 Economy and the government

This closed economy thrives in a high inflation environment and in a short time, being 15 years, all nominal values increase by up to almost 400% with a high DTI ratio. Regardless of the DTI ratio the inflation rate and the policy rate stay at approximately the same level when the rates level out around the 50^{th} quarter. The system seems to find some equilibrium state and only small adjustments to the policy rate are needed to keep it there.

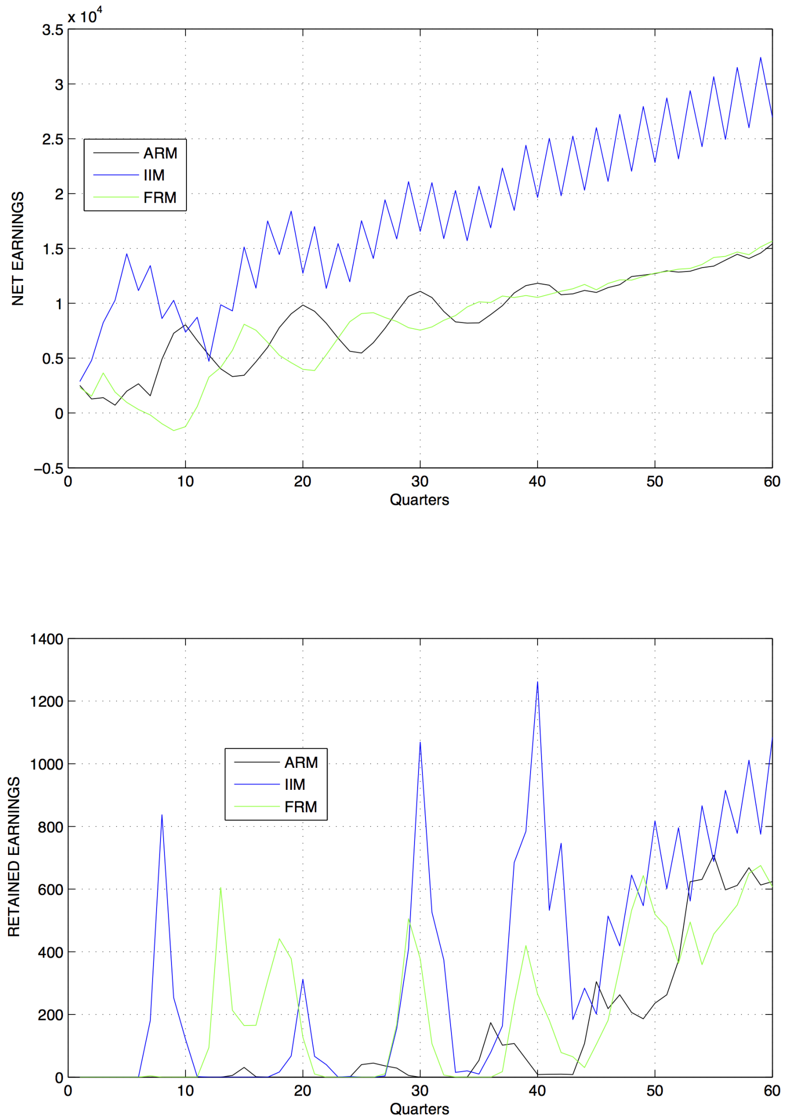

Figure 4.5: The upper subplot shows banks' nominal net earnings and the lower subplot shows how much banks retain of those earnings, DTI ratio is set to 30%.

The nominal growth of the economy is greater for high DTI ratio. Even though the difference is small, FRM seems to give the best economic growth in terms of real GDP whereas IIM has the weakest growth and this holds true in nominal terms except when DTI ratio is set to 40%, then IIM has the highest nominal value. Increasing the DTI ratio decreases the value of real GDP for all mortgage types. Figure 4.6 shows the yearly real GDP where it seems as though all lines are sloping downward at the end of 15 years but the line for IIM is sloping just a little bit more than the other two lines.

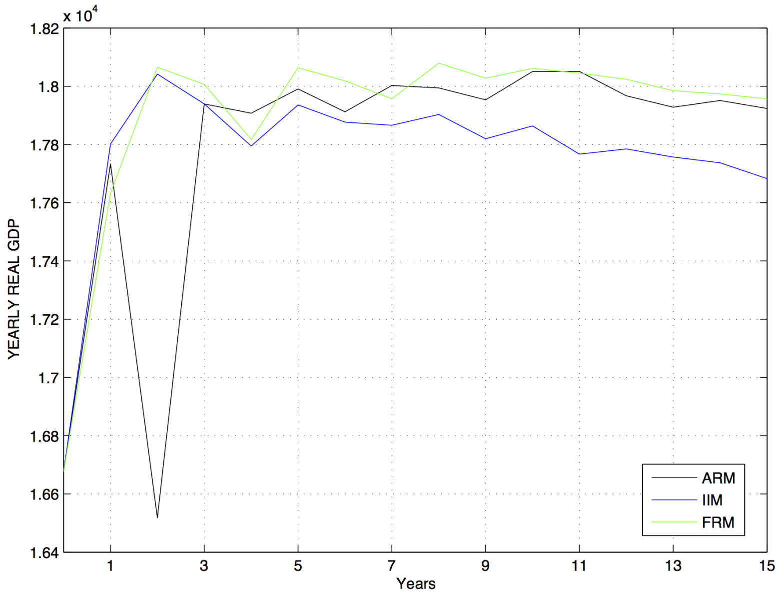

Figure 4.6: Real GDP in the Iceace model at the end of each year for the different mortgages and DTI ratio is set to 30%. When using ARM, there is a dip in the second year and why is it there? At the start, almost all households who enter the housing market sell or buy housing increasing demand, pushing housing prices skyward which in turn affects the inflation. In Figure 4.3, subplot 2, we see that the interest rate shoots high in the first 8 quarters as a result of the inflation spike. With rising interest rates, more households have higher mortgage cost resulting in less goods bought and fewer households buying more housing resulting in a stagnation in prices of housing and goods. Firms lay off workers to lower labor cost to meet lower production plans and revenues. This stagnation in prices and production also stagnates the GDP and therefore when we look at the real GDP we get this dive.

Using IIM yields higher income for the government in the form of capital tax income and Central Bank income, lower debt burden and higher liquidity. Central Bank income comes from the banks in the form of interest payments.

4.5 Discussion

The Iceace model used for this paper represents a closed economy which thrives even during times of high inflation. Without any shocks to the system that an open economy might introduce via exchange rates and import export markets the closed economy does not show any bubbles bursting, i.e. household bankruptcies, the collapse of one or both banks in the artificial economy. There is no unemployment, firms are producing at max capacity and construction firms are constructing and selling new housing units. Trials

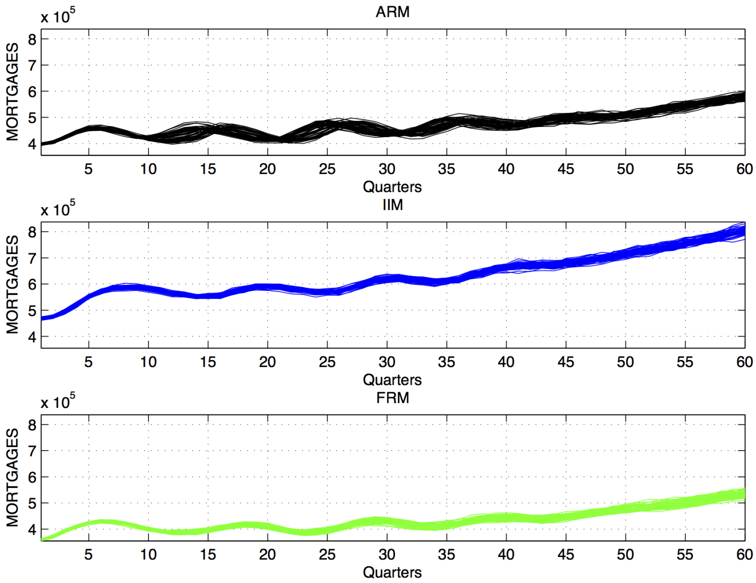

Figure 4.7: Each subplot shows the different paths taken by each of the 50 seeds for the three mortgage types when DTI ratio is set to 30%.

were run with $7,200$ iterations, equal to 30 years of model time, showing ever increasing numbers and no bubbles bursting.

Another point to be made is that in this paper DTI is set exogenously but it should preferably be set endogenously in sync with the policy rate so that the economy can perhaps sustain economic growth without the volatility in the policy rate.

What can be learned from these experiments is that ABM is a well suited tool to test macroeconomic effects of different mortgage types and may be useful in testing applications of economic policies.

Some of the challenges of using ABM are related to the initialization, calibration and validation of such models. The Iceace Closed Market Economy is far from perfect and there is still work to be done in calibration and validation. The model is stable and consistent, tested with different seeds for the pseudo random number generator and for different number of agents, the greatest differing factor being the count of households in the model. Figure 4.7 serves as an example plot to show the consistency of the model and as can be seen the paths do not differ by much.

Other implementations for the Iceace model is to open up the economy and to implement the other inflation-indexed mortgage mentioned in Section 2.2 along with equal installment mortgages. The Central Bank should be able to set the DTI ratio endogenously, giving it more tools to adjust the housing market.

Chapter 5

Concluding remarks

The average inflation in Iceland has been above the Icelandic Central bank's inflation target the better part of the last 10 years. The most common mortgage instrument in Iceland is the inflation-indexed mortgage. Because inflation has been high the remaining principal of many IIMs has increased in nominal terms, much to the dissatisfaction of borrowers in Iceland.

In this paper the focal point was to compare different mortage instruments and how they affect the economy. The three mortgage instruments studied were ARM, FRM and IIM. To get our results we used an agent-based computational macroeconomic model of the Icelandic economy, Iceace. Adjustments were made to the model, adding functionality to calculate IIM and FRM.

In this study we saw that inflation-indexed mortgages can mislead households' expectations of risk with the low initial monthly mortgage payments and encourage households to purchase more housing which stimulates housing prices. Further, IIMs seem to increase the profits and reduce the risk for banks and diminish the effectiveness of standard monetary policy tools, i.e. the policy rate, and seem to cause a decline in real GDP in the long-term.

The Iceace model was created in the likeness of the Icelandic economy and for this paper it was used to compare different mortgage instruments. Erlingsson et al. (2014) used the model to study the effects of different values of DTI as a creditworthiness condition for lending to househholds. This model might provide some help to policy makers with regard to future policy changes regarding IIM and setting laws for the use of the macroprudential tool that is DTI.

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Appendix 1

Parameter	Description	Value
Time constants		
T_D	Loan duration	$+\infty$
T_M	Mortgage duration in years	40
T_H	Housing construction time in months	12
Housing market		
ϕ	Minimum equity ratio of mortgage borrowers	$-\infty$
λ_H^{rnd}	Seller price interval for housing	0.025
$\lambda_H^{firesale}$	Fire sale price reduction interval	0.05
Households		
ω	Households wealth effect	0.075
ς	Households labor turnover probability	0.1
ν^h	Households starting debt-to-ratio	0.15
ζ_{min}	Minimum amount of housing units	1
θ	Households budget threshold for fire sale	0.6
θ_{high}	Households budget threshold for mortgage write-off	0.7
θ_{low}	Households budget ratio for mortgage write-off	0.5
α_C	Speed of adj. of Household savings	0.1
ρ_C	Households target ratio of liquid wealth over disp. income	1

Table 1: Table of general parameters for time constants, the housing market and households in the Iceace economy.

Appendix 2

Parameter	Description	Value
Firms and construction firms		
ν^f	Firms starting leverage	4
μ	Firms markup on consumption goods	1.1
γ_L	Firms labor productivity	1000
γ_K	Physical capital utilization of firms	$+\infty$
ν^s	Construction firms starting leverage	1
ψ_L	Construction firms labor productivity	0.8
ψ_K	Physical capital utilization of construction firms	0.7
δ^s	Labor force share of constr. firms	0.075
ϱ^s	Maximum yearly growth rate of housing stock	0.015
Banks		
χ_{min}	Minimum capital adequacy ratio of banks	0.085
r_{Disc}	IIM rate discount	0.015
Government and Central bank		
Γ	Tax and benefit ratio policy parameter	0.9
$\mathcal{I}_{CB}$	Central bank inflation target	0.02

Table 2: Table of general parameters of firms, construction firms, banks and policy agents in the Iceace economy.

Appendix 3

Variable	Description	Value
Price and interest rates		
$P_H(0)$	Initial price of a housing unit	$20\,W(0)$
$P_C(0)$	Initial price of consumption goods	0.0056
$P_K(0)$	Initial price of capital goods	$100 * P_C$
$r_{CB}(0)$	Initial Central Bank interest rate	0.02
$r_L(0)$	Initial bank loans interest rate	$r_{CB} + 0.01$
$r_M(0)$	Initial bank Mortgage interest rate	$r_{CB} + 0.02$
$r_{IIM}(0)$	Initial bank Mortgage interest rate	$r_{CB} - r_{Disc}$
$r_{fM}(0)$	Initial bank Mortgage interest rate	$r_{CB} + 0.03$
Firms and Construction firms		
$W^{f,s}(0)$	Initial wage of firms and construction firms	5
Households		
$X^h(0)$	Households initial amount of housing units	5
$M^h(0)$	Households initial liquidity	$3\,W(0)$
Banks		
$\chi(0)$	Initial capital adequacy ratio of banks	0.1
$M^b_{init\ ratio}$	Initial liquidity ratio of banks	0.091
Government and Central bank		
$t_\ell(0)$	Initial income tax	0.2
$t_e(0)$	Initial capital income tax	0.2
$\xi_U(0)$	Initial unemployment benefit ratio	0.5
$\xi_T(0)$	Initial general transfer benefit ratio	0.3
$\mathcal{U}(0)$	Initial unemployment level	0.1

Table 3: Table of initial values for some of the variables of the artificial economy.

School of Science and Engineering
Reykjavík University
Menntavegi 1
101 Reykjavík, Iceland
Tel. +354 599 6200
Fax +354 599 6201
www.reykjavikuniversity.is
ISSN 1670-8539