

Baur, Dirk

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Monopoly in Real Life - The Housing Market, Finance and Inequality

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Monopoly in Real Life - The Housing Market, Finance and Inequality

Dirk G. Baur*

University of Western Australia Business School

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Abstract

This paper uses a simple model based on the board game *Monopoly* to analyze the drivers of house prices and wealth inequality. Simulations show that inequality generally builds up fast even if players have equal starting conditions and house prices are stable; rising house prices imply more extreme inequality. An extension of the classical game with interest rates and debt-financing further shows that low interest rates facilitate a property carry trade and increase house prices and inequality by more than high interest rates. The simulations also demonstrate a first-mover advantage both within a generation and between generations and the non-exogenous nature of wealth accumulation, i.e. without new money flowing into the housing market, house prices do not go up and wealth differences are less extreme. Overall, despite the model's simplicity it presents striking similarities with empirical evidence.

Keywords: house prices; debt; inequality; monetary policy; board game Monopoly; Cantillon effect; Ponzi scheme

JEL: D10; D31; D42; D63; E47; E58; R30

*Address: UWA Business School, 35 Stirling Highway, Crawley, Perth, WA6009, Australia. E-mail: dirk.baur@uwa.edu.au I would like to thank seminar participants at UTS Business School, Curtin Business School, University of Chemnitz, University of Hohenheim and UWA Business School for valuable comments and suggestions. I would also like to thank Adrian Lee, Gunther Schnabl, Kris Glover and Frank Liu for comments and suggestions.

“The disposition to admire, and almost to worship, the rich and the powerful, and to despise, or, at least, to neglect persons of poor and mean condition is the great and most universal cause of the corruption of our moral sentiments.”

Adam Smith (1723-1790)

The quote by Adam Smith is more than 200 years old but the issue of inequality is still relevant and only recently regained broader attention with the publication of the book “Capital in the Twenty-First Century” by Thomas Piketty. The work by Piketty (2014) and Piketty and Zucman (2014) has put wealth-to-income ratios and thus inequality on the agenda of both policy makers and academics. Whilst Piketty focusses on capital and does not explicitly discuss housing, Bonnet et al. (2014) argue that housing capital contributes to inequality. More recently, Knoll et al. (2017) show that land prices are of critical importance for the trajectory of wealth-to-income-ratios and refer to the work of Ricardo (1817) who predicted that owners of the fixed factor land would disproportionately benefit from economic growth. If the land was unequally distributed, the relative scarcity of land produced inequality.

This 200-year old prediction is not confined to any specific country and Knoll et al. (2017) show that there are significant variations across countries. For example, Australia has experienced the strongest increase in real house prices since 1870 whilst Germany experienced the weakest. Figure 1 preempts part of the empirical analysis of this paper and shows the evolution of monthly weighted house prices of Australian capital cities and an index of hourly wage costs excluding bonuses. The graph shows that house prices grew faster than wages over the 40-year sample period making it increasingly difficult to purchase a home with the average income. In other words, housing affordability and the income-to-housing-wealth ratio has deteriorated in Australia.¹

[Figure 1 about here.]

¹This finding is consistent with different age and family structures of regional populations and home-ownership. The Australian Bureau of Statistics reports for 2009-2010 that the states with the oldest age structures had the four highest rates of outright home ownership. Moreover, one of the poorest states (Northern Territory) has the lowest home-ownership rate (57%) and the highest proportion of renters (40%) across all states. <http://www.abs.gov.au/ausstats/abs@.nsf/Lookup/1301.0Main+Features1292012>

Whilst the problem of inequality or rising inequality is not an Australian issue but concerns many countries, there is controversy regarding both the causes and the remedies of inequality. Are the causes natural due to the fact that the supply of land is fixed, due to the government that regulates the release of land or the result of the economic and financial system or monetary policy? One answer we have is that monetary policy plays a big role particularly in a setting with significant household debt. Not surprisingly and consistent with Ricardo (1817) the distribution of home ownership is a fundamental component and the more uneven the distribution is the greater the potential for more extreme wealth inequality. For example, whilst there is always wealth inequality even in a “utopian” setting where every player owns exactly one house (because house values differ), inequality is significantly exacerbated if there is house price growth and interest rates are low.

The model is appealing because it is very popular and thus well known. Another important reason and related to the former is its simplicity.² Surprisingly perhaps, the model’s outcomes are in many scenarios a good reflection of empirical regularities despite its simplicity. The model simulations show that inequalities frequently arise in various scenarios (even if houses and land are not scarce) and that interest rates and the timing of property ownership are key drivers of this inequality. More specifically, the positive effect of excess money supply on house price growth and thus wealth inequality indicates that loose monetary policy (“Quantitative Easing”) plays a key role for rising house prices and inequality. Players with the ability to borrow engage in a property carry trade (“borrow low and invest high”) whilst players without an ability to borrow can neither profit from the carry trade nor significantly increase their savings. The findings are consistent with Schnabl (2016) who uses the Austrian overinvestment theory to argue that since the mid 1980s increasingly expansionary monetary policies have driven up real estate prices and thereby increased inequality.

The study also highlights the difference between income inequality (wages are equal among

²The model’s popularity and simplicity also address a criticism by Nobel Laureate Paul Romer (2016).

all players but capital gains and rental income can lead to income inequality) and wealth inequality and leads to the question which of the two is more important. Is it sufficient to reduce income inequality if wealth inequality is more extreme and not significantly reduced across generations? Recent studies indicate that wealth inequality is indeed extreme. For example, the wealth report by Credit Suisse (2018) states that “the top percentile alone accounts for almost half of all household wealth (47%)” (page 9) and a report by Oxfam states “Wealth is becoming even more concentrated - last year 26 people owned the same as the 3.8 billion people who make up the poorest half of humanity, down from 43 people the year before.” (Oxfam 2019, page 12). Assuming that the 26 people owned 40bn US dollars each and the 3.8 billion people 1,000 US dollars each, the resulting ratio is 40 million to 1. This wealth inequality ratio is significantly larger than an income inequality ratio of 1,000 to 1 based on the differences in income assuming that a CEO earns 15 million US dollar per year and the average worker only earns 15,000 US dollars per year. Taking into account that pre-tax income inequality (e.g. 1,000 to 1) is generally greater than post-tax inequality (e.g. 500 to 1), the post-tax differences between wealth inequality and income inequality are even larger.

This paper is structured as follows. First, we present the model that is the basis for the simulations. Second, we discuss the simulation outcomes for various scenarios followed by an extension of the model with interest rates and debt-financing. An empirical analysis of house prices and housing-wealth-to-income ratios for eight industrial countries illustrates that the simulations produce results that resemble “real” outcomes. Finally, the last section summarizes the main results and provides concluding remarks.

I Model

In this section we describe the basic simulation setting based on the classical board game Monopoly and an extension with interest rates and the possibility to finance the purchase of a house with debt. We also analyze the role of foreign investors and a “Utopia” setting where all houses are evenly distributed among all players so that each player owns exactly

one house.

We assume a city with four suburbs each populated with five streets as shown in Figure 2. There is one house in each street. The price of the houses (including the land) varies across streets and increases from 1 to 20 monotonically with the cheapest house being in the first street in the first suburb and the most expensive house being in the last street in the fourth suburb. The rental yield is assumed to be 5% and thus varies between 0.05 currency units for the cheapest house and 1 currency unit for the most expensive house.

[Figure 2 about here.]

There are N players of the game. Each of them sequentially roll a dice and buy the house (including the land it is built on). If the house has already been purchased by another player rent must be paid to the owner of the house.

If a player cannot purchase an available house or pay the rent the player is bankrupt and exits the game. The game is played with the remaining players until only one player is left. This “monopolist” wins the game. An alternative setting relaxes the bankruptcy condition and allows players to accumulate debt (initially interest-free), i.e. in this case a player is bankrupt only if the “savings” exceed a negative value of -200 . The softer bankruptcy condition generally leads to a significantly longer game duration and often leads to no winning “monopolist” and thus an atypical Monopoly outcome after 100 rounds. The game is stopped after 100 rounds if no Monopoly outcome is reached before. An alternative setting does not force a player to exit the game if the required rent cannot be paid but forces the player to sell the most valuable house in the player’s property portfolio at a 10% discount to the government (who holds all land and houses at the start of the game). The house can then be bought by any other player with sufficient amounts of cash as soon as they end up on that street. The game ends when all players except one have sold all their houses and have insufficient funds to cover any rental payments.

In the following we consider several scenarios ranked from rather simple to fairly complex with house price growth, borrowing (debt) and different interest rates. We look at four

measures: (i) Savings inequality defined as the maximum savings (non-housing wealth) over the minimum savings across all players; (ii) Housing affordability defined as median house price/ regular income (wage); (iii) Home ownership distribution across players and (iv) the relationship between final (last round) savings and house ownership.

A Basic Setting

- $N = 5$
- Each player receives an endowment/ starting capital equal to the median house price (10.5 currency units)
- Each player receives 1 currency unit of regular income (wage) in each round³
- Players are bankrupt (exit the game) if savings < 0
- The game ends when all players except one are bankrupt
- No house price growth

The simulation outcomes are presented in Figure 3. The game ends after five rounds with significant savings inequality where one player has seven times more savings than the player with the smallest amount of savings. The minimum savings are set to one to ensure comparability of this inequality measure. Player 2 owns two houses whilst all other players own no property in the final round. This increases wealth inequality further.

[Figure 3 about here.]

If the starting capital is significantly increased to half of the value of all houses (52.5 currency units) the simulations yield Figure 4.

[Figure 4 about here.]

³This assumption implies that there is no income inequality if capital gains (rental income) are excluded from the income definition. The focus of the paper is thus on wealth inequality defined by savings and home ownership.

This setting does not lead to the bankruptcy of any players and is played for the allowed maximum of 100 rounds. Savings inequality is low and decreasing over time, housing affordability is stable and similar to the setting with a lower starting capital and the house ownership distribution is skewed to the left towards “earlier” players.

An alternative to the increased starting capital is to relax the non-zero savings constraint and allow debt. This leads, again, to no bankruptcy and the maximum number of 100 rounds played even for 20 players as shown in Figure 5. Savings inequality increases, the house ownership distribution is skewed to the left and there is a positive relationship between house ownership and savings. The Figure also shows that an increase of the regular income (wage) from one to four units reduces inequality and increases affordability.

[Figure 5 about here.]

A variation of the number of players also affects wealth inequality. With $N = 5$ players, there are less rental cash flows to owners than with $N = 20$. The savings inequality is much larger with 20 players than with 5 players and the house ownership distribution is more unequal with 20 players than with 5 players. We specifically analyze the role of rental income on inequality by comparing two settings: one with rental income and the other one with rents assumed to be zero. Whilst the former produces significant wealth inequality both in savings and in house ownership the latter produces no savings inequality and a negative relationship between savings and house ownership.

B Extension 1 - House Price Growth

We now allow house prices to increase and compare the simulation outcomes to the outcomes with no house price growth. Figure 6 illustrates the role of house price growth under increasing regular income (wage).

We assume that house prices increase by 1% per round whenever all houses are sold. We have also considered certain measures of excess money in the economy to drive house price growth but realized that such measures renders the results very sensitive to the definition and the threshold for “excess” money.

[Figure 6 about here.]

The simulations show that house price growth leads to greater savings and house ownership inequality compared to no house price growth. Affordability is increasing with rising wages and savings inequality is decreasing with rising wages.

Figure 7 presents the simulation results for a larger number of players ($N=25$ and $N=30$) and illustrates that inequality increases with an increasing number of players for a fixed number of houses, i.e. more players lead to more inequality, lower affordability and a more extreme home ownership distribution.

[Figure 7 about here.]

C Extension 2 - Debt and Interest rates

In an extension of the model we include interest rates and debt and allow for 100% debt-financing (negative starting capital) and thus extremely leveraged property investments with no equity. Two different interest rate regimes are analyzed, a 10% interest rate regime and a 0% interest rate regime. We assume that borrowing and lending rates are equal within each regime and that all disposable income (cash) is invested at the prevailing interest rate.

[Figure 8 about here.]

Figure 8 shows that low interest rates lead to higher house price growth than high interest rates if the majority of housing is debt-financed since high interest rates increase the likelihood of bankruptcy which slows house price growth. The simulation outcomes also show that housing affordability is improved and inequality lower with high interest rates than with low interest rates. The main reason for this result is that high interest rates do not allow a property carry trade (“borrow low and invest in higher-yielding housing”) for the more wealthy players but allow a significant increase in savings for the less wealthy players. Consequently, the house ownership distribution is less skewed to the left and the relationship between house ownership and savings is essentially zero indicating that the

usual high savings - high house ownership relationship is broken improving equality. The game duration or number of rounds is significantly shorter with positive interest rates and excess debt compared to low interest rates emphasizing that high debt is unsustainable in high interest rate regimes.

The setting also allows an analysis of the question if a central bank is facing a “debt trap”, i.e. excess debt is reducing a central bank’s flexibility to increase interest rates even if deemed necessary due to inflationary or other economic indicators. Figure 9 shows that a move from a low interest rate regime to a high interest rate regime with significant household debt leads to falling house prices (house prices are assumed to fall by 1% if a player is bankrupt and all houses are transferred back to the central authority (state)) and less inequality as home ownership distribution and the relationship with savings wealth clearly improves in a high interest regime compared to a low interest rate regime. Finally, the game duration is relatively short, i.e. the game ends quickly if the central bank increases interest rates with high household debt. Falling house prices and an abrupt stop of the game can explain the term “debt trap”.

[Figure 9 about here.]

Why do low interest rates lead to increased inequality? If interest rates are below the rental yield (e.g. $0\% < 5\%$), property owners with the ability to borrow benefit from a property carry trade (“borrow low and invest high”) but renters without the ability to borrow lose as they have to pay rent but cannot grow their savings. In contrast, if interest rates are above the rental yield (e.g. $10\% > 5\%$), property owners and debt holders do not benefit but the other group of players benefit as their growth in savings is greater than the rental costs. It can also be argued that interest rates are more binding for some “players” than for others. For example, it is possible that interest rates are binding as a borrowing rate but to a lesser extent as a lending rate as capital can be invested in higher-yielding assets such as equity or property. For example, the 0% low interest regime allows for a “carry trade” where investors borrow at the low interest rate and invest at much higher

rates in the property or equity market.

The results show that the game is longer with 0% interest rates than with 10% interest rates as the high debt level grows too fast and becomes unsustainable at high interest rates. In addition, lower interest rates lead to higher house prices since the game is played more rounds and the eventual bankruptcy comes later. The results also suggest that it may be optimal to switch to lower rates if system-wide bankruptcies of players or a drop in house prices is to be avoided.

D Extension 3 - Utopia

In this section we analyze how a potentially utopian regime in which every player owns exactly one house affects house price growth and inequality. Figure 10 shows that savings inequality is close to one but not exactly one as the value of house prices still differs. House ownership is equally distributed and the relationship of house ownership and savings is zero, i.e. the amount of savings or capital accumulation is not related to the house ownership distribution but to the value of the house and its rental yield.

[Figure 10 about here.]

Destroying “Utopia” by restricting one player to own a house increases inequality as one other player can now own two houses and thus accumulate wealth more quickly than all the other players. In this case savings inequality monotonically increases to levels around 2.5 after 100 rounds. The restricted player cannot cover any rental costs with rental income and will suffer decreasing wealth during the game increasing the difference with the player who owns two houses throughout the game.

E Discussion

The model setup described above is rather simple but covers a range of additional institutional settings and factors. For example, even the basic model proxies for the supply of money and thus the cost of money (interest rates) through different values for the starting

capital. A relatively high starting capital implies low borrowing costs and thus high potential debt levels.⁴ Since the starting capital and the regular income (wage) are coming from an implicit central bank, high starting capital or high wages can also be interpreted as a form of quantitative easing. In other words, the more money is in circulation, the more players can buy houses and thereby push up prices potentially increasing inequality. Also, the higher the starting capital and regular income the higher the house price appreciations and the longer the game. This may be interpreted as a good outcome and would be indeed if the players represented an entire society or nation and multiple generations. However, the players only represent one generation and neglect future generations. An example clarifies the importance of this issue. If a player is assumed to enter a game at a later stage and after strong increases in house prices with most properties already sold, the player would be unlikely to win the game and in fact be more likely to lose the game as the price of properties and rental costs would be prohibitively high.

Recent empirical work (Agarwal et al., 2015) also suggests that property buyers respond to rising house prices by buying early. This “rushing into the American dream” is consistent with the simulation outcome that the order in which players roll the dice matters with the first player more likely to win the game. The more players participate in the game, the more likely it is that all houses are sold in the first round leaving the last players with no or very limited opportunities to buy property.

The variations in the simulation settings even allow an analysis of a scenario consistent with Ricardo (1817) in which land (and houses) is fixed in the game (at 20 streets and houses) but the population grows. The effects can be examined by comparing the “utopian” (equal house ownership distributions) model results with results based on unequal house ownership distributions. The distributions of property ownership and final capital clearly show that the differences between players are larger for 20 players than for 5 players. This finding fully replicates the predictions of Ricardo (1817).

The extension of the classical model and the introduction of interest rates and debt demon-

⁴Borrowing constraints or “mortgaging” is analyzed in Jorda et al. (2016).

strated the flexibility of the basic model framework. The analysis of negative interest rates is straightforward and would show that high-debt players benefit from negative rates whilst high-equity players lose. The implications regarding inequality depend on the composition of high-debt and high-equity players, i.e. if high-debt players have no properties and high-equity players hold all the properties the level of inequality will fall.

What is not analyzed is the relationship between house prices and rents as this relationship is fixed in the model. For example, we do not allow a decoupling of house prices from rents so that there is a natural tendency for house prices to revert to their fundamental value determined by the future expected cash flows or the rental yield. More specifically, foreign investors may increase house prices and inequality but also lower rents by increasing the supply of rental properties. If the number of players is smaller than the number of houses, rental yields should be lower relative to a situation where the number of players is larger than the number of houses implying that there is a shortage of rental properties.

Finally, we have abstracted from taxes (e.g. stamp duty, capital gains tax) and subsidies such as the first home buyers grant and negative gearing to keep the model relatively simple. The explicit inclusion of such factors would not pose a challenge but also render the model and the simulations more complex.

II Empirical Analysis and Comparison

Figure 11 presents the evolution of real house prices from 1975 to 2016 for eight industrial countries and reveals significant differences across countries.⁵ Australia, Ireland, Switzerland, the UK and the US show a positive price trend over the 40-year period whilst Germany, Italy and Japan display no growth in house values or negative growth as in the case of Japan. The more recent evolution starting about 2009, after the Global Financial Crisis, show positive trends for all countries except for Italy and Japan.

[Figure 11 about here.]

⁵We acknowledge use of the dataset described in Mack and Martinez-Garcia (2011).

Figure 12 presents the ratio of real house prices and real disposable income for the same set of countries and shows that this ratio is on a positive long-run trajectory for Australia, the UK and Ireland and on a zero or negative long-run path for the other countries. Germany and Japan stand out with clear negative long-run trends of the ratios. Similar to the different short-run trends for real house prices after 2009, the ratios also show positive trends starting about 2009 for Australia, Switzerland, Germany, the UK, Ireland and the US.

[Figure 12 about here.]

A comparison of the evolution of house prices and the ratio of house prices and disposable income indicates that changes in house prices are in most cases stronger than changes in disposable income and thus drive the ratios and inequality.

In countries in which the ratio is increasing and house prices increase faster than disposable incomes, it is likely that house price ownership per person is falling due to the increasing gap between house prices and wages and thus the affordability of housing.

A comparison of the house price - wage ratio for Australia (Figure 1) with the real house price - disposable income ratio (Figure 12) reveals that the former is larger than the latter. Whilst small differences are not surprising given differences in the definitions of the average wage and disposable income, the discrepancy between the two graphs warrants further discussion. Since disposable income also includes capital income (interest) and not only wage income, disposable income is a broader measure and more likely to produce differing evidence for inequalities if capital income is unequally distributed in a society and inflates the average income by the capital income of a higher income group.⁶

⁶There are also significant variations in wage growth based on the type of wage that is considered. For example, the US “full time employed median usual weekly real earnings (Wage and salary workers: 16 years and over)” increased from 339 in 1979 to 351 in 2016 (US Bureau of Labor Statistics). This wage growth of less than 10% over 35 years is in stark contrast to another wage statistic: The “Average Hourly Earnings of Production and Nonsupervisory Employees (Total Private)” increased from about 6 US dollars per hour in 1979 to about 21 US dollar per hour in 2016, a 250% wage growth. Clearly, the two wage statistics would produce very different housing-wealth-to-income ratios. The former would indicate a strongly decreasing housing affordability whilst the latter would indicate an increasing housing affordability.

III Summary and Concluding Remarks

This paper uses a simple model based on the original design of the board game *Monopoly* to analyze drivers of housing wealth and inequality. The model simulations show trends that are remarkably similar to empirical evidence in industrial countries regarding house prices, disposable income and wealth inequality but are surprising given the model's simplicity. One of the most interesting findings is based on an implicit assumption regarding future generations. Whatever the dynamics of the inequality among the players of the game are, the inequality measured with those that are not part of the game, i.e. future players and thus future generations in a real life context, almost always increases and can easily reach extreme values. Such values result from high house price growth caused by excess money in the economy. This suggests that loose monetary policy or "Quantitative Easing" has an effect on housing affordability and inequality and thus effects well beyond consumer price inflation. Interestingly, high interest rates lead to less inequality than low interest rates both with debt and with no debt and the stronger house price growth at lower interest rates is only observed for a high debt regime.

Whilst the inter-generational inequalities that may arise are only an implicit finding, intra-generational inequalities among players are explicit and also show that the timing and sequence is crucial. Despite the random component introduced by the dice and the equal starting conditions of all players, simulations show that players who are among the first to roll the dice and thus start the game generally finish the game as richer players with respect to the number of properties owned and the capital accumulated on average. This finding can be linked to the "Cantillon effect" which states that new money does not flow evenly into the economy.⁷

We also show that ultra-low interest rates enable a carry trade strategy in the property market which further exacerbates inequality. A simulation setting in which no "new" money flows into the economy yields stable house prices and no inequality illustrating that wealth accumulation is not exogenous and not independent of other people's choices.

⁷E.g. see Cantillon (1755) and Cachanosky (2017).

In other words, without the demand for houses of other players, neither housing wealth nor inequality increases. The model also produces a prediction by David Ricardo (1817) who argues that because the supply of land is fixed and land is unequally distributed, economic and population growth will produce rising inequality. The random component in the game leads to an unequal distribution of land which implies inequality. This inequality is exacerbated if there are more players in the game, if the game is played longer or if there is strong house price growth.

What can be done about inequality? The model suggests that restricting house price growth, e.g. by releasing more land, is one way to reduce extreme inequalities. A new start of the game can, of course, also eliminate any inequalities but is not a feasible scenario in real life. Tax policies that ensure a more equal wealth distribution across generations may be the closest analogy to a game restart.

This paper highlights the importance of the housing market for wealth inequality and uses a simple model to describe its causes and implications.

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R Code

```
# Number of players
N=5

# house prices and rents
s = array(0,c(20,2))

s[,1]=1:20
s[,2]=s[,1]/20

# starting capital
wstart=1*median(s[,1])

# regular income
inc=1

# player characteristics (ownership) *****
p = array(0,c(20,N))
p2 = array(0,c(20,N,100))

# wealth/ savings
w=array(wstart,c(100,N))
hown=array(0,c(100,N))

inequ1=rep(1,100)
m=median(s[,1])/inc
inequ2=rep(m,100)
pos=rep(0,N)

flag=0
iter=2

# minimum capital threshold th
th=0

# loop *****
while (flag==0) {
  w[iter,]=w[(iter-1),]

  # loop *****
  for (k in 1:N) {
    if (w[iter,k]>th) {
      if (sum(w[iter,]>th)>1) {
        # Roll the dice and move forward by d
        d=sample(1:6,1,replace=T)
        pos[k]=pos[k]+d
        if (pos[k]>20) {pos[k]=pos[k]-20}
        w[iter,k]=w[iter,k]+inc

        # if property available buy, if not pay rent/ receive rent
        if (sum(p[pos[k],])==0) {
          p[pos[k],k]=1
          w[iter,k]=w[iter,k]-s[pos[k],1]
        }

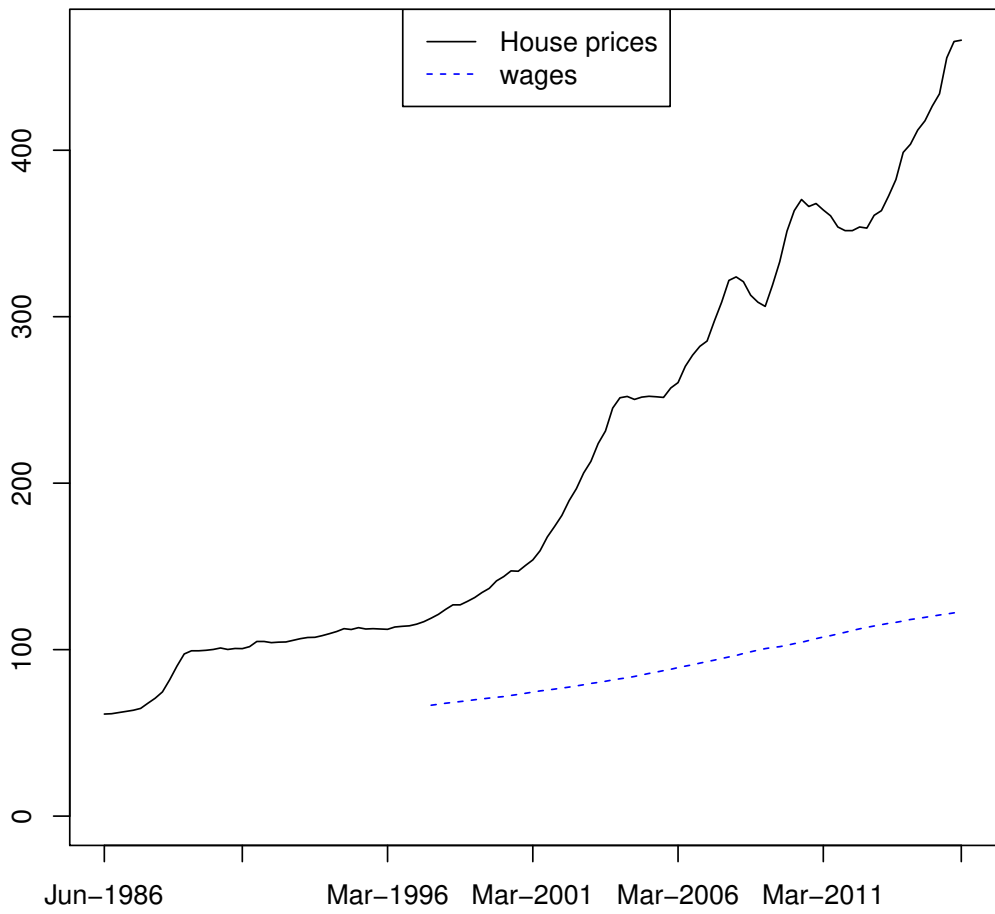
        if (sum(p[pos[k],])==1) {
```

```

w[iter,k]=w[iter,k]-s[pos[k],2] # pay rent
owner=which(p[pos[k],]=1)
w[iter,owner]=w[iter,owner]+s[pos[k],2] # receive rent
}
if (w[iter,k]<=th) {
  w[iter,k]=th
  p[,k]=0 # housing wealth transferred to state
}
}} # loop for k 1: N *****
p2[, ,iter]=p
a=max(w[(iter),]); b=max(median(w[(iter),]),1)
inequ1[iter]=a/b
inequ2[iter]=median(s[,1])/max(inc,1)
if (sum(w[iter,]>th)<2) {flag=1} else {iter=iter+1}
if (iter>100) {flag=1; iter=iter-1}
}
*****
par(mfrow=c(2,2))
hpg=0; r=0
txt=paste("income(wage)=",inc,"; wstart=",wstart,"; house price growth=",hpg,"; interest rate r=",r,"; th=",th," ",sep="")
plot(ts(round(inequ1[1:iter],1)),xlab="round",ylab="savings inequality",main=txt)
txt=""
plot(ts(round(inequ2[1:iter],1)),xlab="round",ylab="house price/ income (wage)",main=txt)
fma=apply(p2[, ,iter],2,sum)
plot(fma,xlab="players",ylab="house ownership",axes=F)
tr=1:N
fit=lm(fma~tr)
abline(a=coef(fit)[1],b=coef(fit)[2],lty=2,col="red")
z1=1:N; lab=1:N
axis(1,at=z1,labels=lab); axis(2); box()
plot(w[iter,],fma,xlab="savings",ylab="house ownership")
fit=lm(fma~w[iter,])
abline(a=coef(fit)[1],b=coef(fit)[2],lty=2,col="red")

```


Figure 1: Australian house price index and wage index



Source: Australian Bureau of Statistics

Figure 2: Model

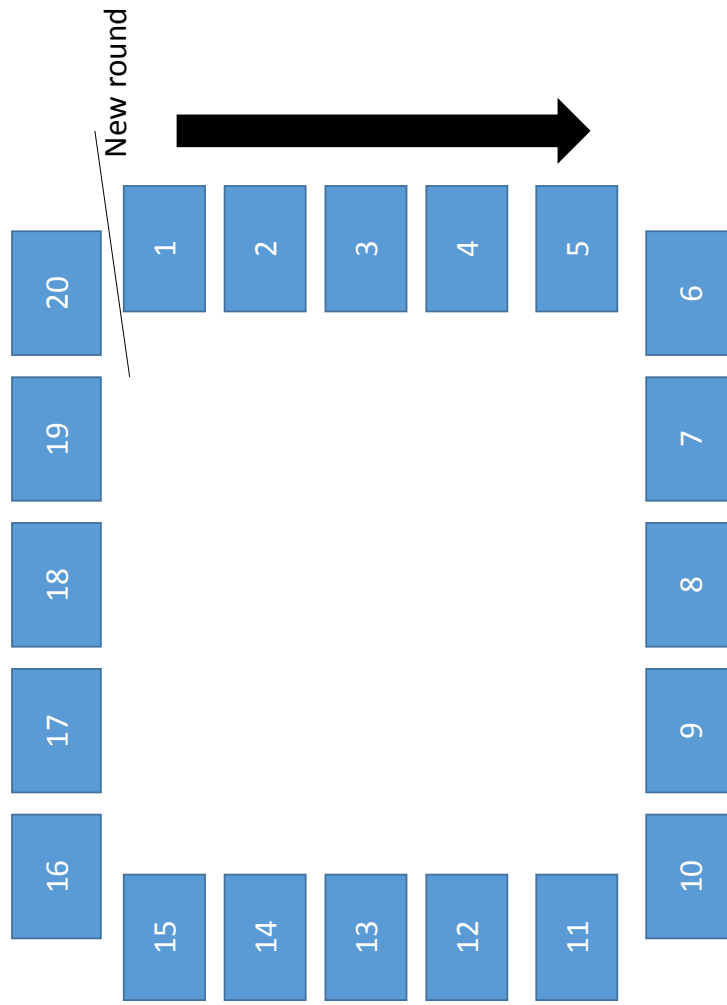
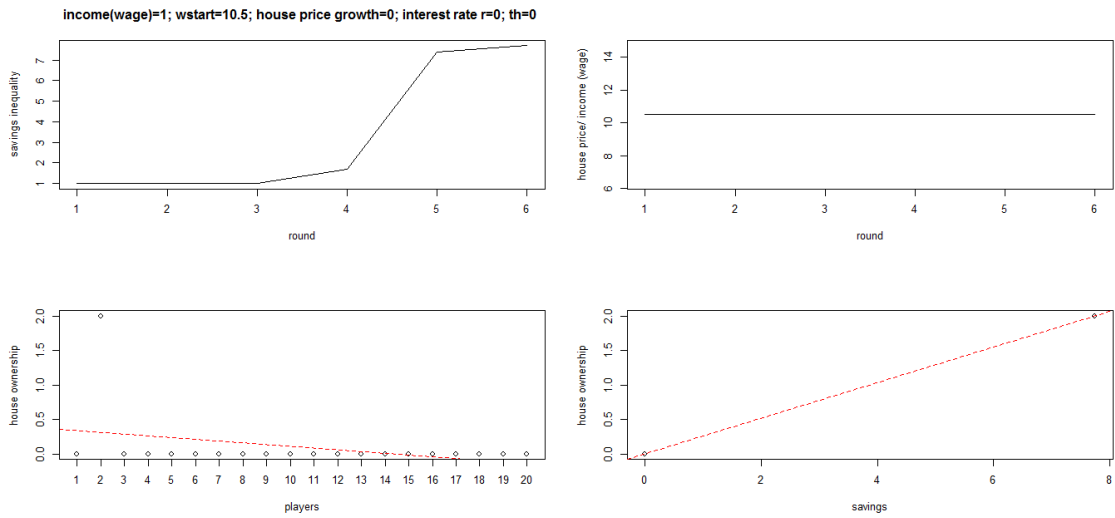


Figure 3: Simulation Result - Basic Setting

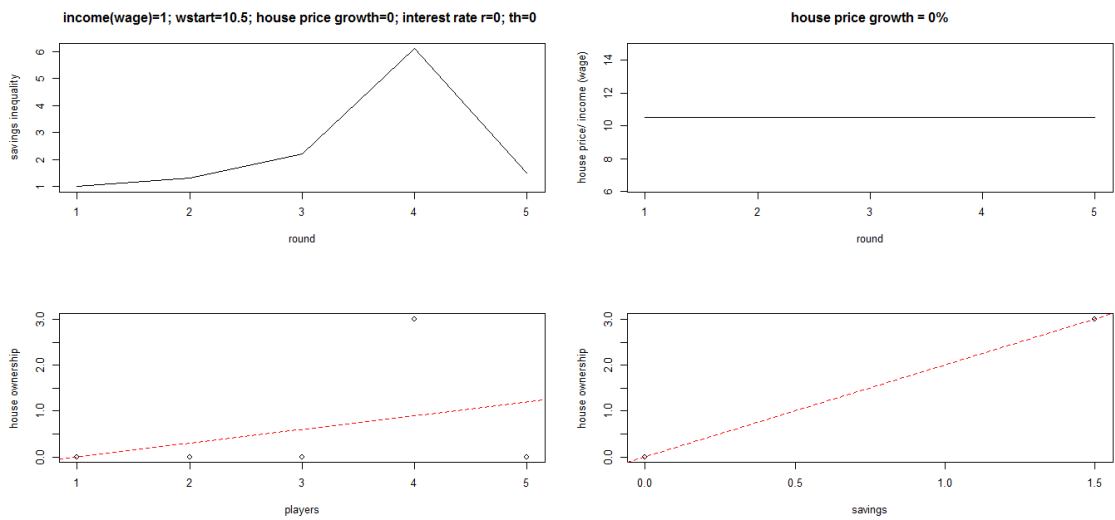
Monopoly outcome for $N = 20$ players and $N = 5$ players, no house price growth and no borrowing ($th=0$)

Monopoly outcome (1)



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Monopoly outcome (2)



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Figure 4: Simulation Result - Basic Setting

Increased starting capital (wstart) for $N = 5$ players, no house price growth and no borrowing ($th=0$)

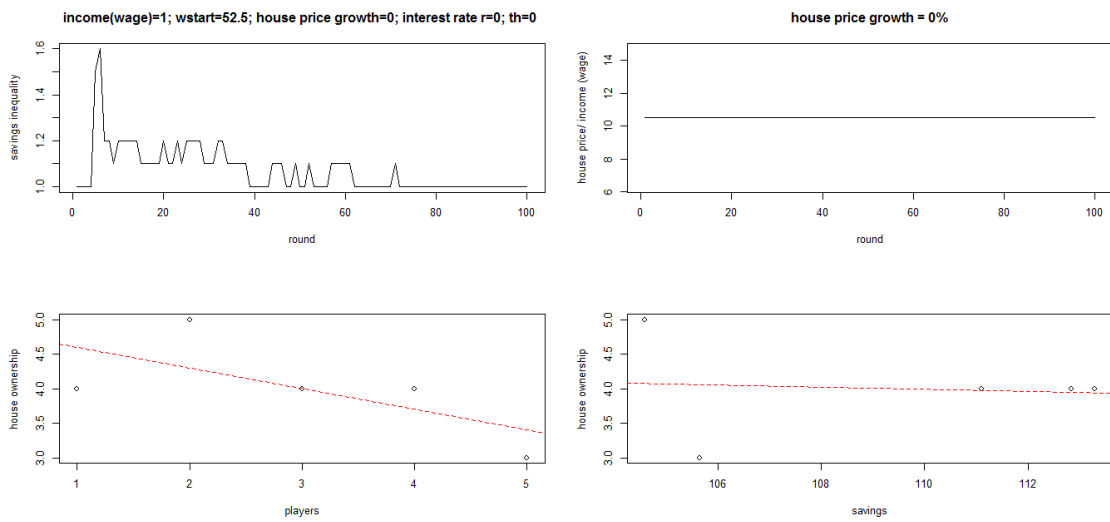
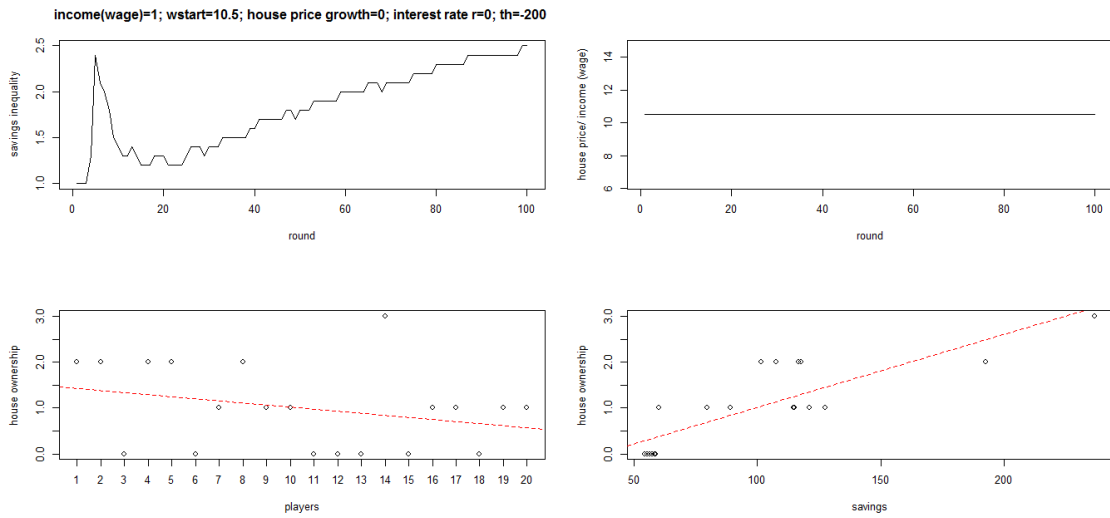


Figure 5: Simulation Result - Debt

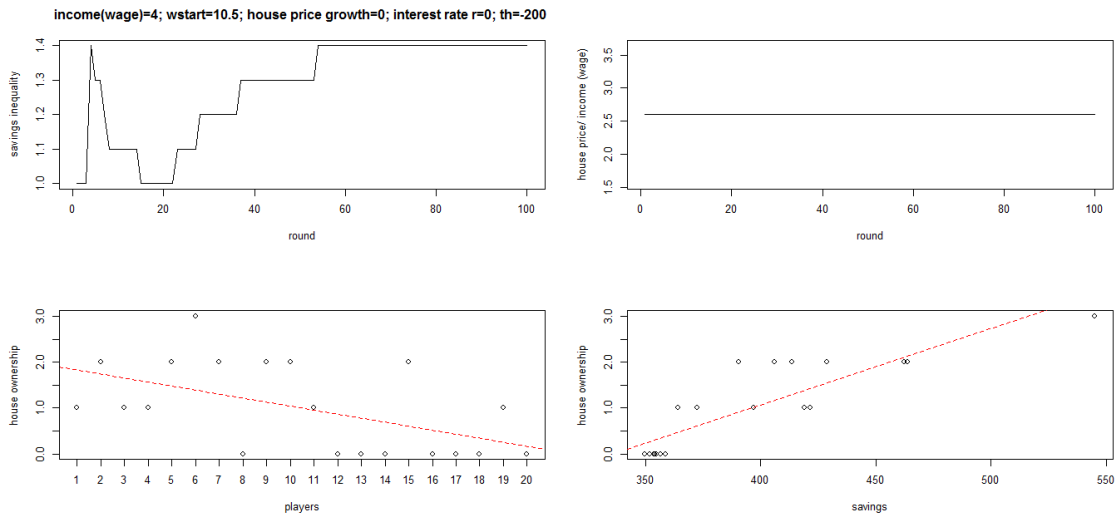
Regular income (wage) varied top panel (=1) versus bottom panel (=4), relaxed borrowing constraints (debt allowed, $th = -200$)

Increasing income



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Increasing income



17

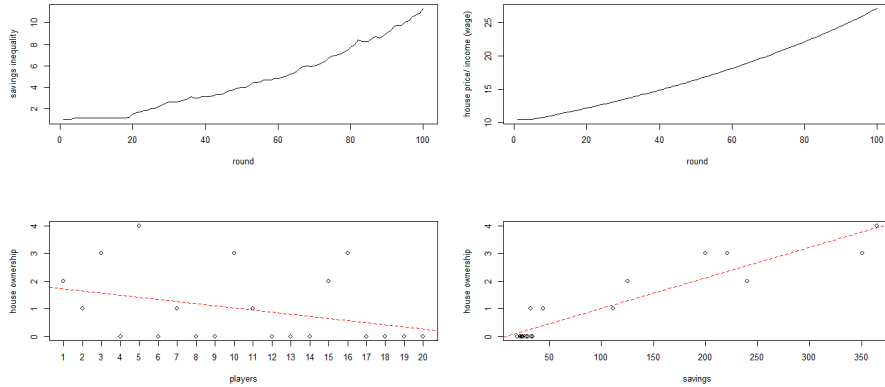
Figure 6: Simulation Result - House Price Growth

Regular income (wage) varied across settings

The simulations show that increased wage income lowers savings inequality but does not significantly affect the house ownership distribution and the positive relationship between savings and house ownership

Adding house price growth (1)

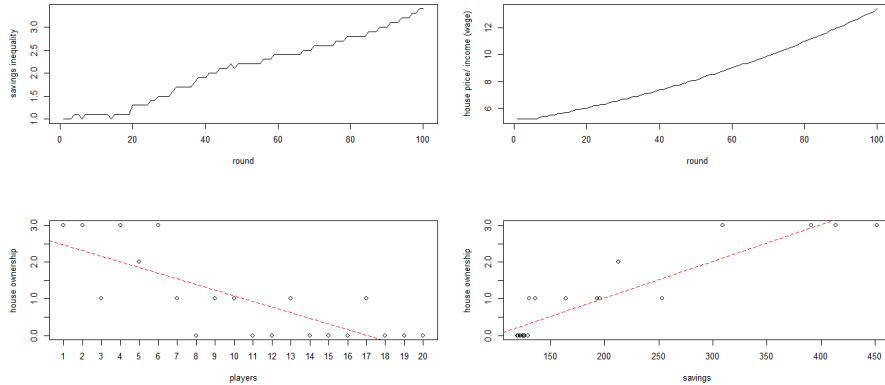
income(wage)=1; wstart=10.5; house price growth=0.01; interest rate r=0; th=-200



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Adding house price growth (2)

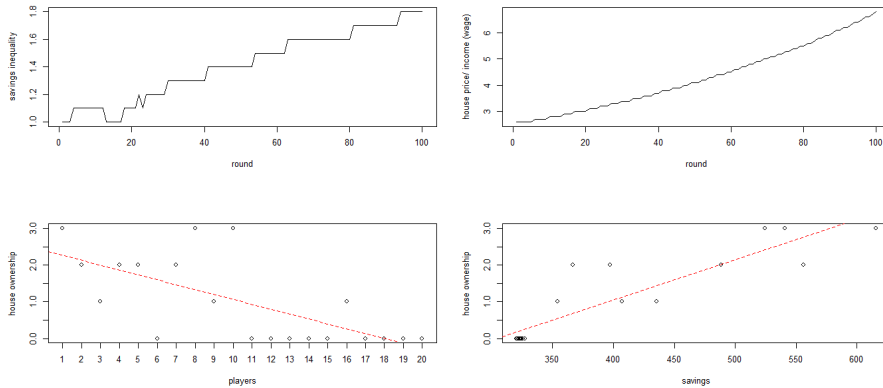
income(wage)=2; wstart=10.5; house price growth=0.01; interest rate r=0; th=-200



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Adding house price growth (3)

income(wage)=4; wstart=10.5; house price growth=0.01; interest rate r=0; th=-200

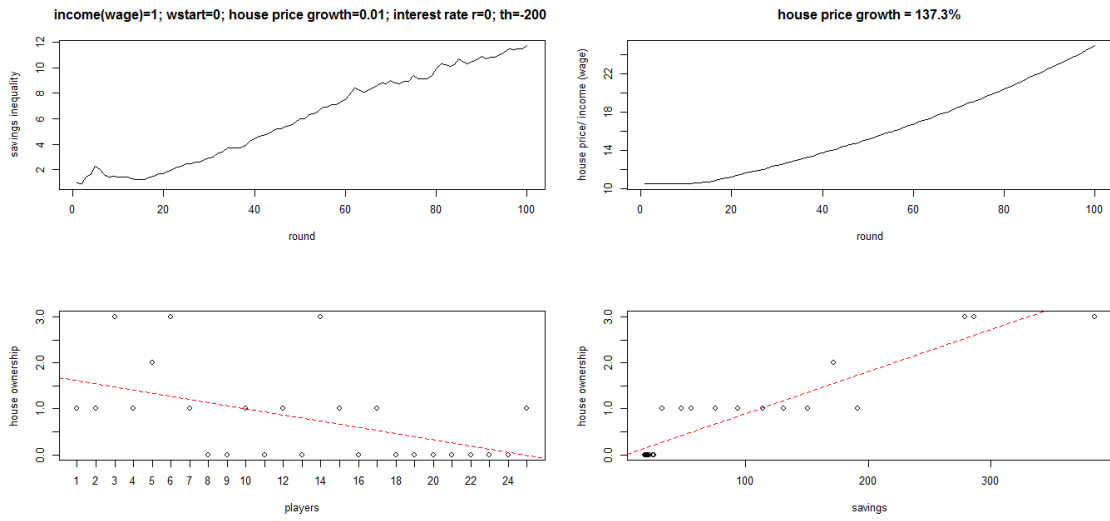


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Figure 7: Simulation Result - Large number of Players

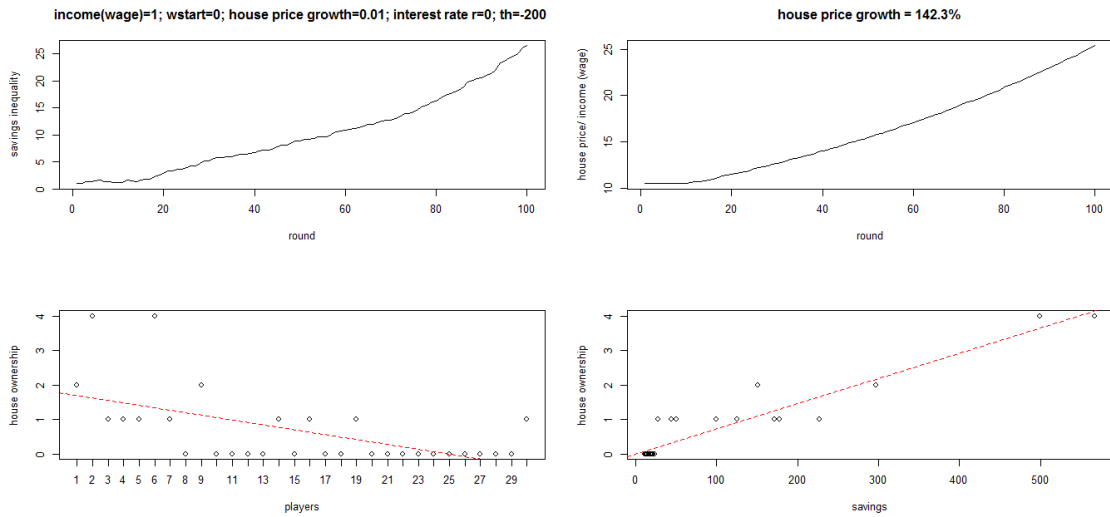
Number of players N varied across settings. The larger number of players ($N=30$, bottom panel) leads to more pronounced inequality measures than the smaller number of players ($N=25$ top panel).

N=25



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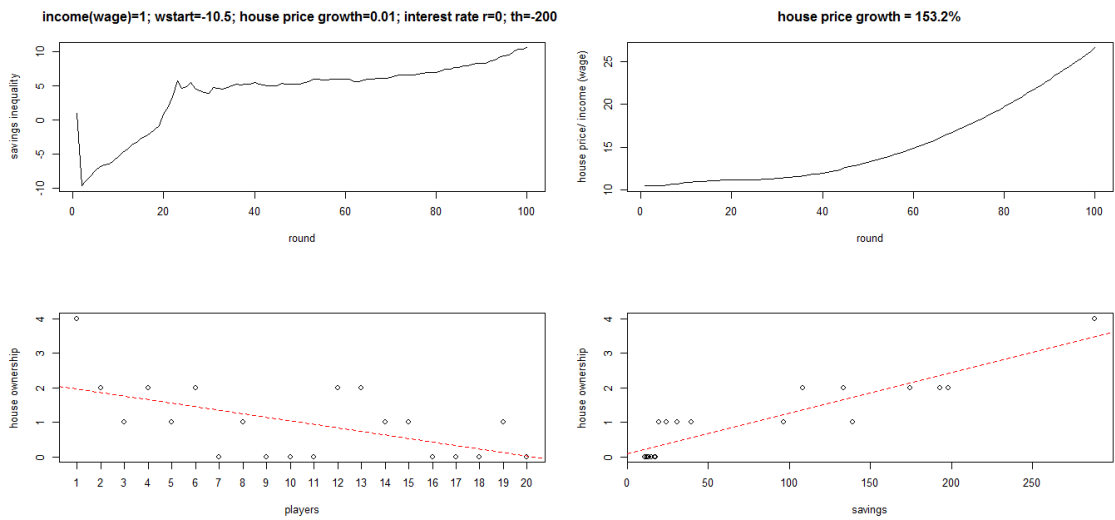
N=30



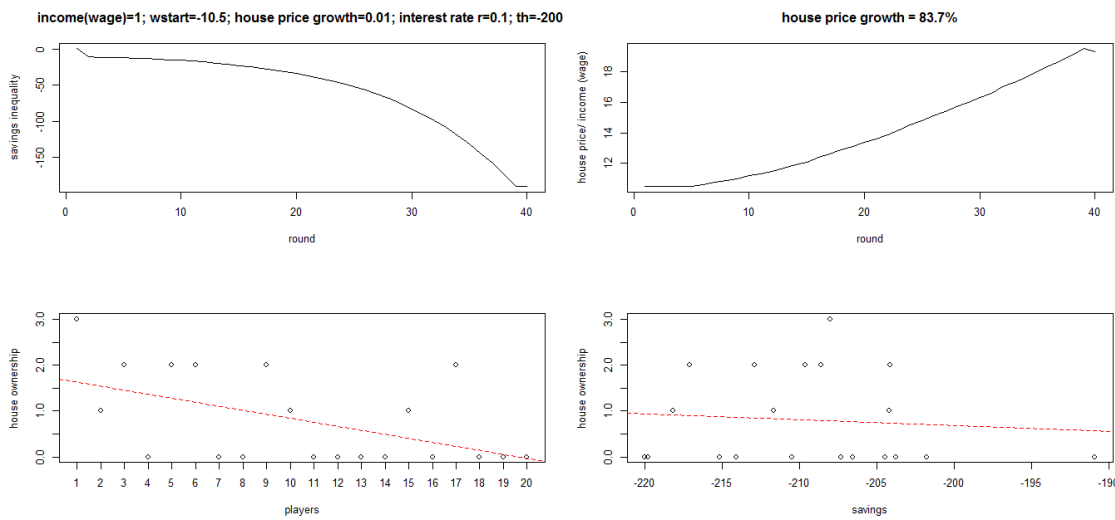
22

Figure 8: Debt and interest rates

Interest rates varied across settings (0% versus 10%). House price growth and inequality measures are larger with 0% interest rates (top panel) than with 10% interest rates (bottom panel).



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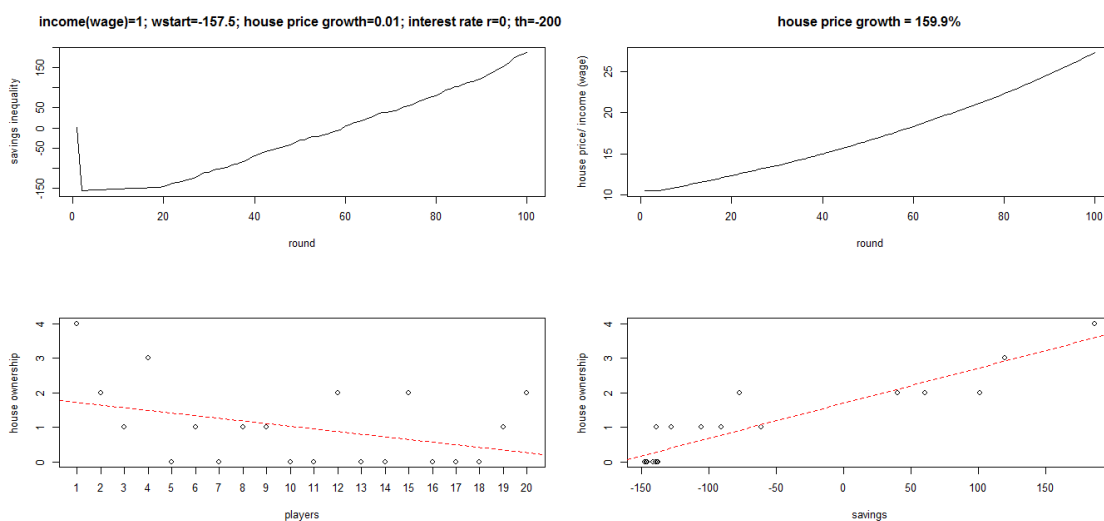


30

Figure 9: Debt trap

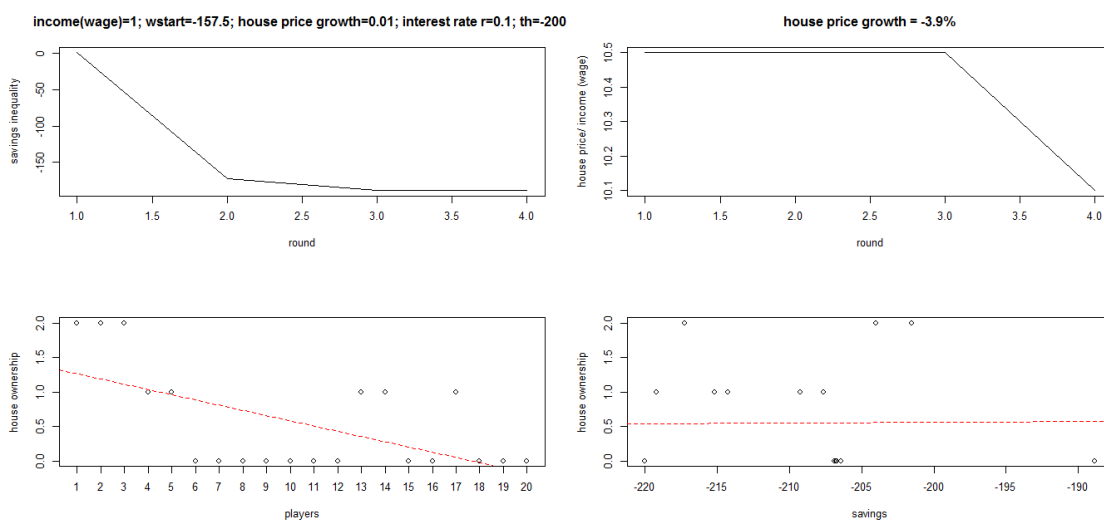
Interest rates varied across settings (0% versus 10%), all players have significant debt. Increasing interest rates (bottom panel) lead to a comparably short game duration (four rounds), negative house price growth and lower inequality compared with a low interest rate setting.

Debt trap (1)



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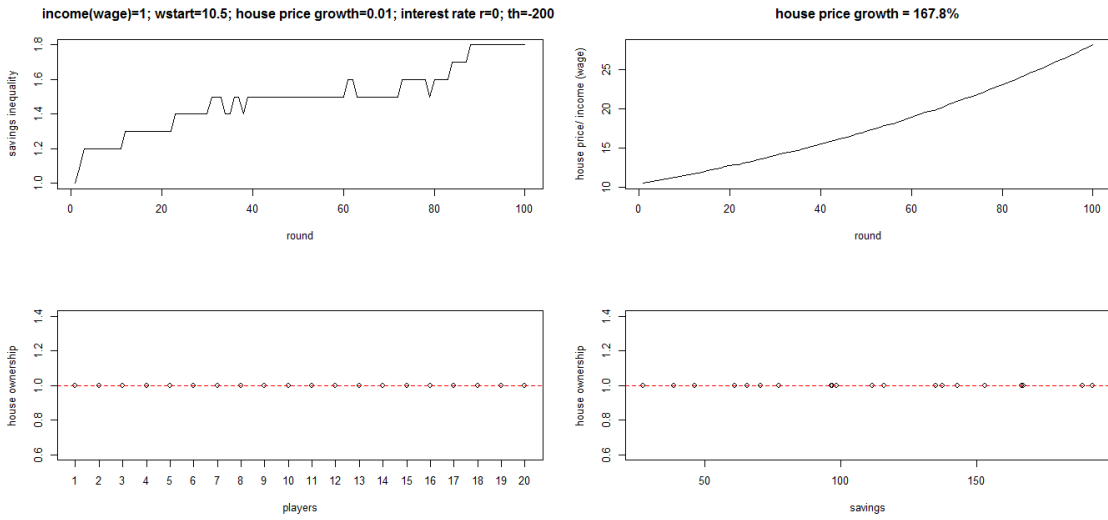
Debt trap (2)



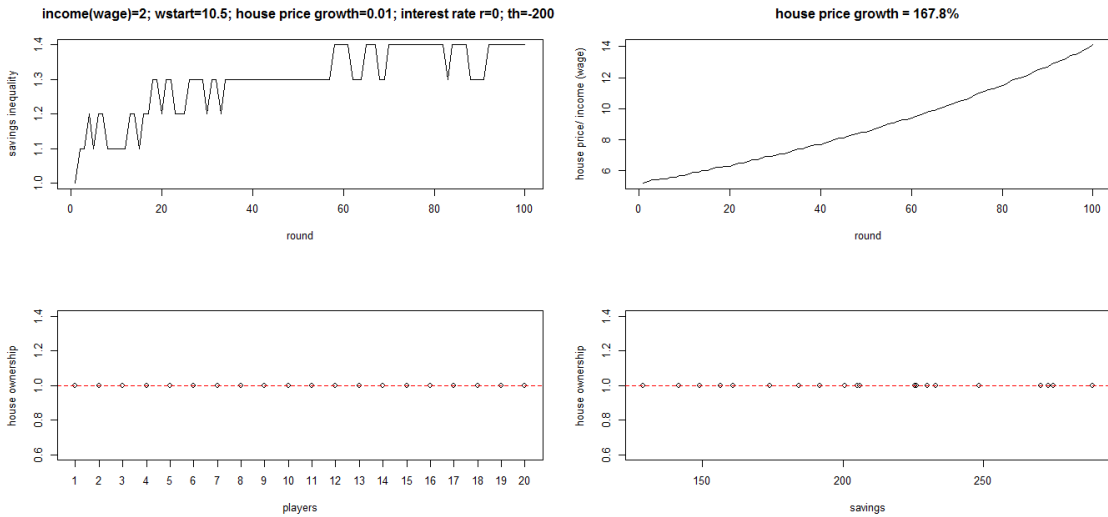
32

Figure 10: Utopia
 Regular income (wage) varied across settings

Utopia

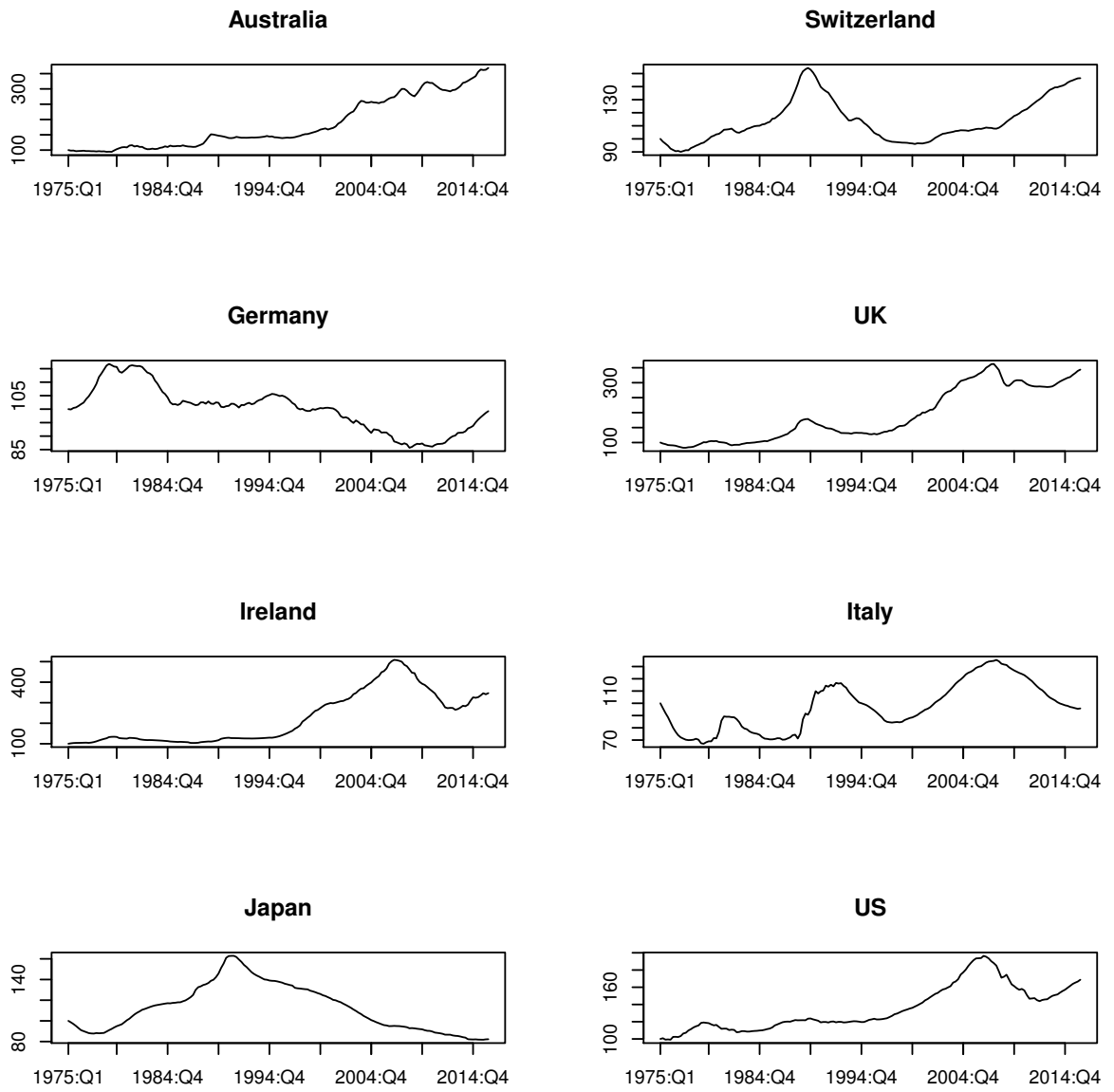


37



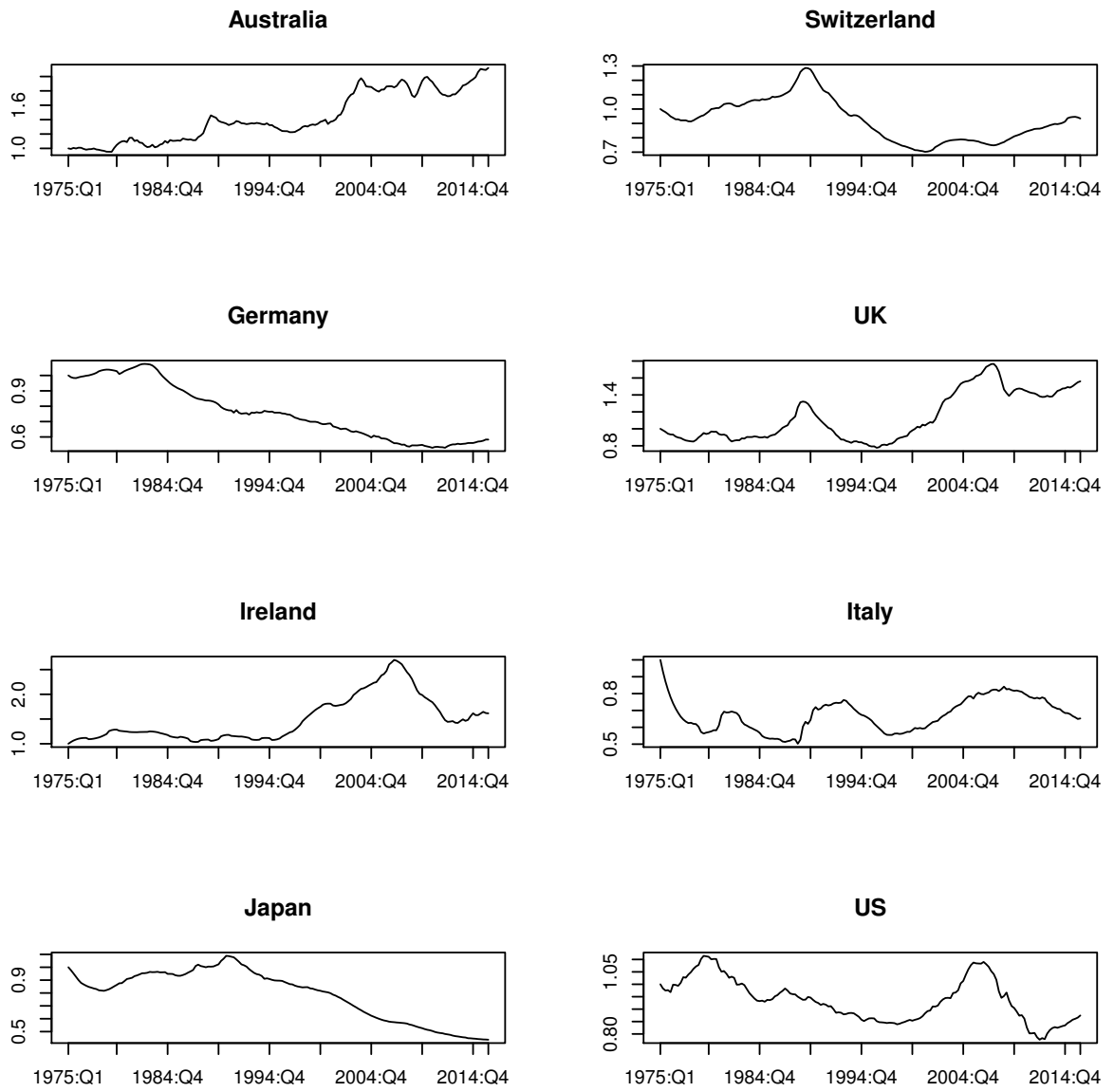
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Figure 11: Real house prices



Source: Mack and Martinez-Garcia (2011)

Figure 12: Ratio - Real house prices over real disposable income



Source: Mack and Martinez-Garcia (2011)