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The Housing Market in Israel: Long-Run Equilibrium and Short-Run Dynamics

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Abstract

The housing market is characterized by persistent deviations from the long-run equilibrium, and these deviations affect market dynamics in the short run. Therefore, any empirical analysis of the housing market must identify these long-run relations. This paper estimates an econometric model for the housing market in Israel for the years 1980–2019, where the long-run relations are estimated based on the theoretical model of DiPasquale and Wheaton (1992). We utilize the model to learn about the characteristics of the Israeli housing market and about the factors driving home prices, rents, and construction activity during the sample period. The model sheds light on the interaction between home prices and rents: A rise in rents pushes prices higher as it increases the return from home ownership. In contrast, an increase in home prices reduces rents because it stimulates housing supply. We also find that both demand and supply are inelastic in the long run; as a result, external shocks to the market are mainly manifested as changes in prices rather than quantities. As for the factors behind the surge in home prices that started in 2008, the estimation of the model suggests that about half of the rise in prices during 2008–11 was driven by undervaluation of homes in the preceding period. Monetary policy also supported prices during that period, though our estimates suggest that it played a minor role. Supply-side shortage had a moderate but persistent effect on house prices, and starting in 2012 supply shortage alongside rising household income are the main factors supporting prices. The acceleration in construction activity in recent years closed much of the supply shortage toward the end of the sample period.

Keywords: Housing Market, Home Prices, Cointegration, Error-Correction Model

JEL Classification: C22, R21, R31

ניתוח שוק הדיור בישראל:
קשרי הטווח הארוך והדינמיקה של הטווח הקצר

יוסי יכין וינון גמרסני

תקציר

שוק הדיור מאופיין בסטיות ממושכות משיווי המשקל של הטווח הארוך, ואלה משפיעות על הדינמיקה בשוק כבר בטווח הקצר. לכן, בכל ניתוח אמפירי של שוק הדיור יש לזהות את קשרי הטווח הארוך. עבודה זו אומדת מודל אקונומטרי לשוק הדיור בישראל לשנים 1980–2019. קשרי הטווח הארוך נאמדים על בסיס המודל התיאורטי של DiPasquale and Wheaton (1992), ובאמצעותו אנו מבקשים ללמוד על מאפייני שוק הדיור בישראל ועל הגורמים שתרמו להתפתחות מחירי הדירות, שכר הדירה והיקף הבנייה בתקופת המדגם. המודל שופך אור על הדינמיקה שבין מחירי הדירות לשכר הדירה: עלייה של שכר הדירה פועלת לעלייה של מחירי הדירות, משום שגידול התשואה מהבעלות מביא לגידול הביקוש לרכישתן; כנגד זאת, עלייתם של מחירי הדירות פועלת לירידה של שכר הדירה, משום שעליית מחירן תומכת בגידול של היצע הדירות. עוד אנו מוצאים כי הן הביקוש והן ההיצע קשיחים בטווח הארוך, ועל כן זעזועים בשוק מתבטאים בעיקר בשינוי של המחירים. אשר לגורמים לעליית מחירי הדירות שהחלה ב-2008 – מאמידת המודל עולה כי כמחצית מעליית המחירים בשנים 2008–2011 נבעה מתמחור חסר של הדירות בתקופה שקדמה לכך. המדיניות המוניטרית תרמה גם היא לעליית המחירים בתקופה זו, אך להערכתנו תרומתה הייתה משנית. למחסור בדירות תרומה מתונה אך מתמשכת לעליית המחירים, והחל מ-2012 המחסור בדירות לצד גידול הכנסתם של משקי הבית הם הגורמים העיקריים לעלייתם. הבנייה המואצת בשנים האחרונות הביאה לצמצום המחסור בסוף המדגם.

מילות מפתח: שוק הדיור, מחירי הדירות, קואינטגרציה, מודל תיקון-טעות

סיווג JEL: C22, R21, R31

1. Introduction

Current housing expenditure is the largest component in households' expenditure, purchasing a home is typically the largest transaction households make during their lifetime, and homes make up a substantial portion of their asset portfolio.[1] Moreover, rising home prices and rents in Israel for over a decade have placed them at the center of the public debate and government policy. All these point to the importance of understanding the developments in the housing market. To that end, this paper develops an econometric model for analyzing the housing market in Israel, and uses it to reveal the factors driving the rise in prices that started in 2008. In addition, the model sheds light on the short- and long-run interactions among the variables acting in the market, e.g., between home prices and rents, on the effect of monetary policy, and on demand and supply elasticities.

The housing market reacts slowly to shocks, and as a result, deviations from the long-run equilibrium can persist for many years.[2] These deviations affect market dynamics in the short-run, and hence any empirical analysis must attempt to identify them. To that end, the analysis must use a sample long enough to include several cycles. Relying on a structural model may also help. The sample in this paper spans over four decades, 1980–2019, in annual frequency, and the econometric specification of the long-run equations is motivated by the theoretical model of DiPasquale and Wheaton (1992)—hereinafter, "DW". Hence, our analysis utilizes both a long sample that covers several cycles and a structural model. We estimate the short-run dynamics using an error-correction model, which explicitly accounts for the effect of deviations from the long-run equilibrium.

The DW model provides a simple and convenient framework for analyzing the housing market. It has four components: (1) the market for housing services, (2) an asset-pricing equation, (3) construction supply, and (4) a stock-flow equation that ties the flow of construction activity to the stock of dwellings. The endogenous variables in the model are rents, home prices, construction activity and the stock of dwellings. Given an initial stock and exogenous demand factors, rents are determined in the market for housing services. Given rents and financial asset returns, the asset-pricing equation pins down home prices. The scale of construction activity is

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1 In Israel the value of homes is about 52 percent of the total value of households' assets (2018 figures), Bank of Israel (2020). Arrondel, et al. (2016) review 15 Euro-area countries and find that, on average, homes make up 51 percent of the value of households' assets (2013 figures). In the US this share is lower, around 31 percent (2016 figures), Bricker, Moore and Thompson (2019).

2 See Bar-Nathan, et al. (1998) for Israel, and Adams and Füss (2010) for a panel of 15 OECD countries.

determined by home prices and construction cost. These represent the long-run equilibrium relations in the housing market.

We find that deviations from these relations have a crucial effect on the dynamics in the short run. In particular, supply shortage (or excess supply) relative to long-run demand affects rents, home prices and construction activity; over- or under-valuation of homes relative to their value implied by the asset-pricing equation affects home prices and construction activity; and excessive (or under) construction relative to long-run supply affects the scale of construction activity in the following period.

Several indications suggest that undervaluation was the main factor behind the surge in home prices during 2008–11, similar to the finding of Dovman, et al. (2012). The asset-pricing equation suggests that on the eve of the rise in home prices, in 2006–07, prices were lower by 13.7 percent, on average, relative to their implied long-run value. Dynamic simulation, evaluating prices solely on the basis of exogenous variables (and initial conditions from 1980) indicates a somewhat larger undervaluation. We note that the model does not track price data during that period well, and in the years 2008–11 the model produces a large residual. However, this outcome followed a large residual in the opposite direction during the preceding three years. Such a residual structure is unusual during the sample period, and hence it seems supportive of the view that the rise in home prices was mainly driven by undervaluation at the beginning of the period. Overall, we assess that about half of the rise in prices during 2008–11 was driven by undervaluation.

Nagar and Segal (2011) emphasize the contribution of monetary policy to the rise in home prices that started in 2008. We find that the short-term real interest rate (the monetary rate net of expected inflation) explains about a quarter of the rise in prices during 2008–11. This is an economically significant effect; however, it is not the main driver. Furthermore, it is important to distinguish between the short real rate and monetary policy, since the former is affected by various factors, in addition to monetary policy. We assess the effect of monetary policy to be around 45 percent lower than that of the short real rate.

We define housing shortage as the gap between demand and the existing housing stock, where demand depends on demographic needs as well as on households' income and the price of housing services (rents). We find that starting in 2007 there is a persistent shortage, though not so large in magnitude—up to 0.7 percent of the stock (around 16,000 units in 2008).

Nevertheless, due to the high sensitivity of prices to housing shortage, starting in 2008 it raised prices consistently at an average rate of 1.8 percent per year (in real terms).

The model sheds light on the interaction between home prices and rents. Both variables affect each other, but in opposite directions. An exogenous rise in rents leads to an increase in home prices, as it raises the return on homeownership. In contrast, an exogenous rise in home prices pushes rents downward, because it stimulates supply. Both the theoretical model and the empirical estimation support this result, and it is consistent with the findings of Rubinstein (1998).

Further we find that both long-run demand and long-run supply are inelastic, similar to the finding of Bar-Nathan, et al. (1998). This result is not surprising, as the raw data mainly display variation in prices and less so in the stock of dwellings.

Several contributions have analyzed the Israeli housing market, where the closest to ours is that of Bar-Nathan, et al. (1998) who estimate a structural model for the years 1974–90. Similar to us, the DW model motivates their econometric specification, though they put a special emphasis on the description of the process of homebuilding in the short-run. Bar-Nathan, et al. (1998) find that shocks have long-lasting effects on the housing market, and convergence back to equilibrium takes 15–20 years. As a result, they argue that proper estimation of long-run relations using reduced-form equations, as attempted in several papers[3], requires very long sample periods, because such estimation assumes that throughout the sample period the market fluctuates around the long-run equilibrium. Additionally, and as mentioned above, they also find that both demand and supply are inelastic in the long run.

Nagar and Segal (2011) and Weiner and Fuerst (2017) use more recent data, and examine the factors behind the surge in prices that began in 2008. Nagar and Segal (2011) estimate the dynamics of home prices and rents. They use the asset-pricing equation as the only cointegration relation that governs the long-run equilibrium. Similar to our results, they find that a rise in interest rate reduces prices and raises rents. Nevertheless, several of their results are inconsistent with ours. In particular, they emphasize the role of monetary policy as the main factor raising home prices starting in 2008, while we find it had a secondary effect; in addition, they find a positive effect of prices on rents while we find an opposite effect. Weiner and Fuerst (2017) only estimate a price equation. They consider a single cointegration equation for a

[3] See, for example, Mankiw and Weil (1989) for the American housing market, and Nagar and Segal (2011) and Weiner and Fuerst (2017) for the Israeli market.

relatively large group of variables, though without providing an economic motivation for its specification. Their work focuses on the effect of risk factors from the financial markets on house prices, and they use the VIX as representative of that risk. They find a positive effect of financial risk on home prices, and argue that when the risk in the financial markets rises, investors shift asset demand to the housing market, and as result home prices rise.

In addition to these papers, Dovman, et al. (2012) and Rubinstein (1998) have also examined the development of home prices in Israel, though the analysis in both cases was carried through the lens of an asset pricing equation and focused on the question whether a financial bubble had evolved in house prices. Dovman, et al. (2012) study home prices over the period of 1996–2010. They do not find evidence for a financial bubble, and argue that a considerable portion of the rise in prices starting in 2008 stemmed from their low level at the beginning of the period, similar to our finding. Rubinstein (1998) estimates an asset pricing equation for the period 1974–96, and focuses on the effect of inflation variance on home-price risk premium. He finds a positive correlation between the level of inflation and its variance, and a negative effect of inflation variance on home prices. He explains that homeownership provides insurance against unexpected inflation, and argues that during the high inflation years in Israel, a decline in the risk premium supported home prices (in real terms). Our results support his finding, and in particular we find that controlling for the volatility of inflation in the asset-pricing equation improves its estimation. In addition, and similar to our results, he finds that higher rents raise home prices, but not vice versa.

The rest of the paper is organized as follows. The next section presents stylized facts on the Israeli housing market since the 1960s, and discusses the considerations for the choosing the sample period for the econometric analysis in this paper. Section 3 presents the theoretical model of DW. Section 4 presents the data for our analysis. Section 5 estimates the long-run equations, derives the error-correction factors, and presents estimates of the long-run elasticities. Section 6 estimates the short-run dynamics. Section 7 presents dynamic simulation of the model and the contributions of the various factors to the development of home prices, rents and construction activity. Section 8 presents impulse response functions, and Section 9 concludes.

Figure 2.1: Home prices net of CPI excluding housing
log index, 1961-2019

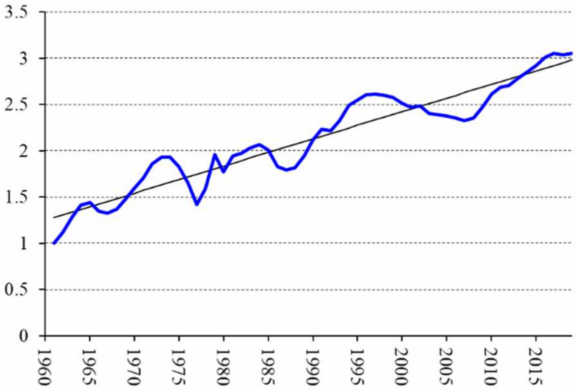
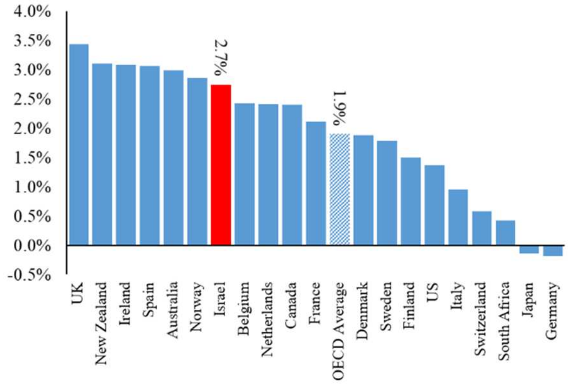


Figure 2.2: Rate of home price increase in OECD countries
Annual rates, real terms, 1970-2019*



Source: OECD Analytical House Price Database and authors' calculations.
* Slopes of linear trend lines of the log of real house prices. Prices are deflated by consumption prices from the National Accounts. Data for Spain start at 1971, for all other countries data start at 1970.

2. Long-term view of the housing market: The stylized facts

In this section, we present central housing-market indicators for a period spanning over six decades, from the beginning of the 1960s to 2019; these include home prices in real terms, price-income and rent-price ratios, and the development of the housing stock relative to demography. In particular, we attempt to characterize the housing market through the stylized facts that emerge from an informal inspection of the data. This will serve us in drawing conclusions for the econometric model we estimate in this paper, and in choosing the sample period for the analysis.

Figure 2.1 presents the home price index (in logs) deflated by the CPI excluding housing. Two facts stand out: (1) prices trend upward over time; and (2) price variation around the trend is characterized by long cycles. On average, prices increase at a pace of 2.9 percent per year in real terms (the slope of the trend line in Figure 2.1), and when deflated by the general CPI (not shown) the pace is a bit slower—2.4 percent a year. This rate is not exceptional in international standards. Figure 2.2 presents the distribution of the rate of home price increases, in real terms[4], in 19 OECD countries with available data since the early 1970s and the comparable figure for Israel.[5] Over the last 50 years, real home prices have increased in the OECD countries at an

[4] Prices are deflated by consumption prices from the National Accounts.
[5] For comparison with the OECD data, the figure for Israel is also deflated by consumption prices from the National Accounts.

Figure 2.3: Home prices relative to GDP per capita
Index, Average=100, 1964-2019

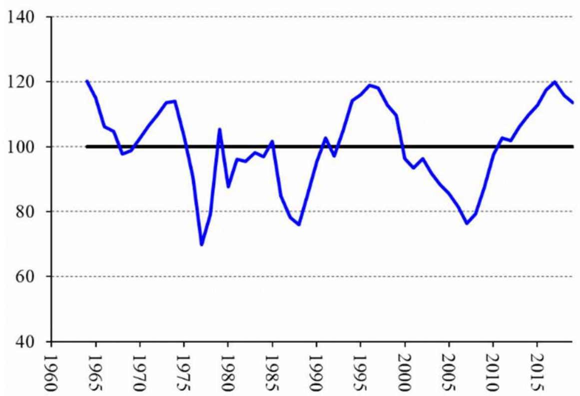


Figure 2.4: Rent-price ratio (right scale) and real medium- to long-term forward return
1961-2019

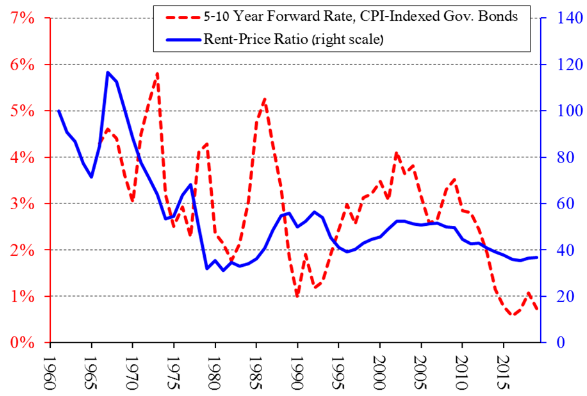
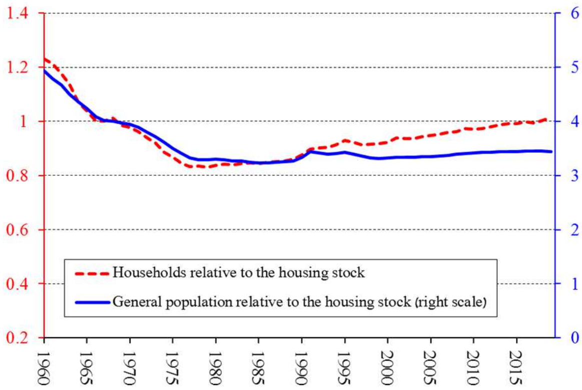


Figure 2.5: Demography relative to the housing stock
1960-2019



annual rate of 1.9 percent, on average. Over the same period, starting in 1970, real home prices in Israel rose a bit faster, at a pace of 2.7 percent annually, though compared with the rate in other OECD countries, this pace is not exceptional.

As mentioned, prices display long cycles (Figure 2.1), and in particular, the recent cycle started in 1997 and lasted for two decades (assuming the end of our sample actually represents the peak of the cycle). Long cycles suggest that, despite of their upward trend, prices may decline for fairly long periods. For instance, during the decade starting in 1997, the peak of the previous cycle, and ending in 2007, the trough of the current cycle, prices have declined by nearly 25 percent (in real terms).

Figure 2.3 presents the development of home prices relative to GDP per capita. The most striking result is that this ratio is trendless, that is, over a long period of time home prices and income tend to increase by similar rates. Also visible in the figure are the long cycles and the high level of prices relative to income at the end of the sample.

Figure 2.4 presents the rent-price ratio and compares it to an alternative financial return (medium- to long-term forward return on CPI-indexed government bonds). This comparison is implied by a standard asset-pricing equation that equates the return from homeownership to the return from alternative financial assets. In principle, one should add to the latter a risk premium and the expected capital gains of homeownership; however, to the extent that these factors are trendless over a long period, we expect the rent-price ratio to approximately follow the return from the financial markets.[6] The figure displays a positive correlation between the series throughout the sample, with the exception of the large immigration years in the early 1990s. We conclude that the common movement of rents, prices and the forward rate is approximately consistent with the long-run relation as implied by the asset-pricing equation.

Figure 2.5 presents the development of demography relative to the housing stock[7], where we measure demography by the number of households and by the general population. This comparison provides an indication of housing density. Both indicators display a persistent decline in density from the beginning of the sample until the late 1970s, apparently resulting from the long process of absorbing large-scale immigration during the early years of the State of Israel. Beginning in the 1980s, the number of persons per dwelling is stable, around 3.3 to 3.4; however, in terms of households per dwelling the data display a persistent rise, suggesting a decline in the number of persons per household. In 1980 there were 0.84 households per dwelling and at the end of the sample this ratio stands at 1.01.[8]

To conclude this section, we note that the long cycles, as observed in Figures 2.1 and 2.3, imply that deviations from the long-run equilibrium may persist for lengthy periods. To the extent that these deviations affect market dynamics in the short run, any empirical analysis of the housing market must rely on a sample long enough to cover numerous cycles. Earlier contributions analyzing the Israeli housing market used relatively short samples. Nagar and Segal (2011) cover the years 1999–2010, and Weiner and Fuerst (2017) used a slightly longer sample, 1998–2013. Neither case covers a full cycle (Figures 2.1 and 2.3). In an earlier paper, Bar-Nathan, et al. (1998) utilized a sample for the years 1974–90. Their sample covers more

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6 In estimating the long-run relation (see Section 5 below), we control for the risk premium that stems from the volatility of inflation, as suggested by Rubinstein (1998). This risk factor is non-stationary during the sample period, due to the high inflation years of the 1980s in Israel.

7 We measure the housing stock in a similar method as Nagar and Segal (2011) and Weiner and Fuerst (2017); nevertheless, we believe that this estimate understates the actual growth rate of the housing stock, at least starting 1995. See Section 4.1.1 for details.

8 For a discussion on the methods for measuring demography, see Section 4.1.1 and Appendix A.

than one cycle and they estimate structural equations, therefore their work is probably more successful in identifying the long-run relations.

In this paper we attempt to combine a structural model with a long sample to allow for proper estimation of the long-run relations. As noted, the comparison of demographic development to the stock of housing (Figure 2.5) suggests that until the late 1970s Israel was in an ongoing process of absorbing a large immigrant population, and it seems that these years do not represent fluctuations around a stable long-run equilibrium. For the purpose of the econometric estimation, we therefore choose to start our sample in 1980. It seems that starting from that year, approximately, the demographic development relative to the housing stock is relatively stable, regardless of whether demography is measured using the population size or using the number of households.

3. The DiPasquale–Wheaton model for the housing market

This section describes the theoretical framework of DiPasquale and Wheaton (1992) for analyzing the housing market.[9] The model, as also noted by DW, is more suitable for analyzing the long-run equilibrium than the short-run market dynamics. Later in this paper, the DW framework will guide the empirical specification of our long-run equations. After the estimation, we will examine the response of the endogenous variables in the model (prices and quantities) to shocks through the lens of the theoretical model.

The model is summarized in Panel A of Figure 3.1. There are four endogenous variables in the model: the stock of housing (the horizontal axis to the right), rents (the vertical axis pointing upward), home prices (the horizontal axis to the left), and construction activity (the vertical axis pointing downward). The exogenous variables are the demographic development and income, both of which shift the demand for housing services; the return from the financial markets, which affects the pricing of homes; and construction cost, which shifts construction supply. The model is made up of four components that are described in the four quadrants in the figure:

(1) The first quadrant describes the market for housing services. The housing stock is a state variable and therefore housing supply is perfectly inelastic (SRS curve); in the long-run, the supply is upward sloping (LRS curve). We present the method for deriving the LRS curve after

[9] For extensions of the model, see Colwell (2002).

presenting the rest of the components of the model. The demand for housing services declines with their price, i.e., rent, and demographic developments and income fluctuations shift the demand curve, where demographic expansion and a rise in income raise demand.

(2) The second quadrant represents the asset-pricing equation. Home prices are determined as the ratio of rents (determined in the first quadrant) to an alternative financial return (r). An increase in interest rates in the financial markets raises the slope of the ray from the origin in the diagram, and given the level of rents, home prices fall.

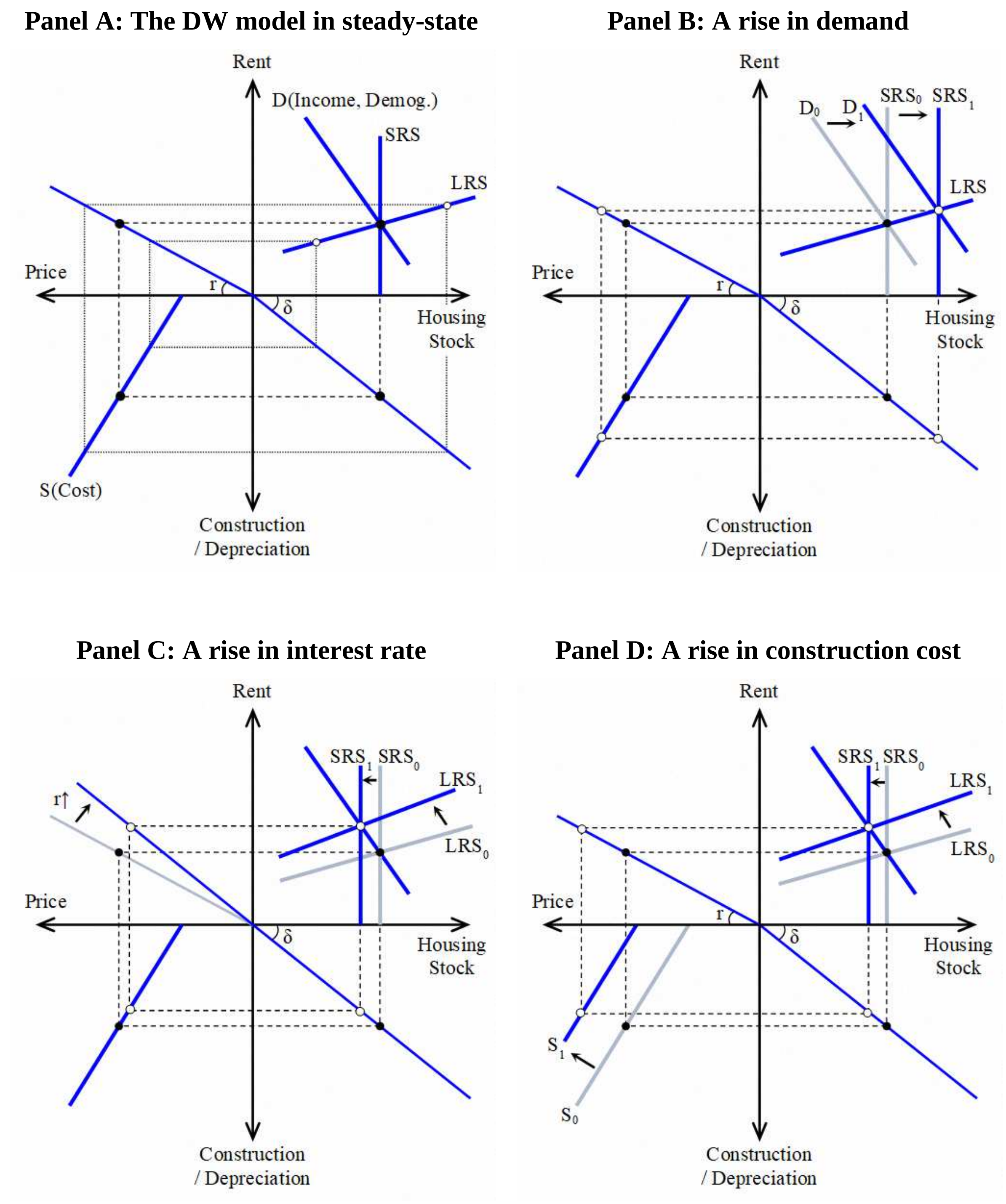
(3) The third quadrant presents the construction market. Homebuilders raise construction supply as home prices (determined in the second quadrant) rise, and changes in construction cost shift the supply curve. A rise in cost reduces supply, and given the price level, construction activity falls.

(4) The fourth quadrant presents a stock-flow identity that ties the scale of construction and depreciation to the stock of housing.[10] The scale of construction is determined in the third quadrant, while depreciation equals the depreciation rate (δ) times the housing stock, and is measured in the fourth quadrant using the ray from the origin (with slope δ). The net addition to the stock of dwellings equals the difference between construction and depreciation. The figure presents the system in steady-state, where construction equals depreciation and hence the housing stock remains unchanged.

Finally, the long-run supply curve (LRS in the first quadrant) describes the quantity of dwellings supplied in the long run at each level of rent. This extension of the model is due to Colwell (2002). To plot this curve, start from an arbitrary level of rent. Given rent and interest rate, the price level is determined in the second quadrant. Then, given price and construction supply, the scale of construction is determined in the third quadrant. Finally, given the scale of construction we find in the fourth quadrant the long-run level of the housing stock—that is, the stock level at which total depreciation equals newly constructed dwellings. This results in a rent-stock combination that lies on the LRS curve. Repeating this process for different levels of rent exposes an upward-sloping supply curve. The white points in Panel A represent two points along the LRS curve, and the long-run equilibrium is located at the intersection of the LRS and the demand curve (the black point in the figure). Changes in the construction cost, interest rate and depreciation rate shift the LRS curve.

[10] The model does not account for dwellings under construction and therefore a period in the theoretical model should be interpreted as the average building time of a dwelling.

Figure 3.1: Long-run effects in the DiPasquale–Wheaton model



This framework allows the analysis of the effects of changes in the exogenous variables on the housing market, but it is more appropriate for analyzing their long-run effects. Although the model does generate endogenous dynamics, they rely entirely on the long-run relations described above. Short-run effects resulting from inertia or other factors, such as monetary policy, are absent from the model. Furthermore, Colwell (2002) demonstrates that the short-run dynamics are sensitive to the choice of model's parameters, and in particular, the convergence to the steady-state may be either monotonic or may overshoot the long-run equilibrium. Therefore, in what follows we discuss briefly only the effect of permanent changes in the exogenous variables.

Panels B, C, and D in Figure 3.1 present an exogenous rise in demand, the interest rate and construction cost, respectively. The initial steady-state is marked by the black points, and the new steady-state is marked by the white ones.

Panel B presents a rise in demand following demographic expansion and/or a rise in income. The increase in demand is represented by a shift of the demand curve to the right, from D_0 to D_1. Higher demand raises rents (first quadrant), which in turn lift prices (second quadrant). The rise in prices stimulates construction activity (third quadrant) and therefore the stock of housing increases as well (fourth quadrant). Overall, the market reaches a new equilibrium with higher rents and housing stock, as represented by the intersection of the new demand curve, D_1, with the long-run supply curve, LRS, which remained unchanged. In addition, home prices and construction activity are higher in the new equilibrium.

Panel C presents a rise in the interest rate. This is represented by a higher slope of the ray from the origin in the second quadrant and a shift inward of long-run supply in the first quadrant. For a given level of rent, a higher interest rate reduces home prices (second quadrant), which in turn dampens construction activity (third quadrant) and hence reduces the housing stock (fourth quadrant). Lower supply, alongside a fixed demand curve, raises rents (first quadrant). Overall, a rise in the interest rate reduces prices, construction activity and the housing stock and raises rents.

Finally, Panel D displays a rise in construction cost. This change is represented by a shift to the left of construction supply, from S_0 to S_1, in the third quadrant, and a shift inward of long-run supply in the first quadrant. For a given level of house prices, higher construction cost reduces homebuilders' activity (third quadrant), which in turn reduces the stock of housing (fourth quadrant). Lower supply, alongside a fixed demand curve, raises rents (first quadrant), and as a result home prices rise (second quadrant). Overall, higher construction cost raises prices and rents, and reduces construction activity and the stock of housing.

4. The data and unit-root tests

This section presents the data series we use in the econometric estimation and the considerations for choosing them, and tests whether they contain unit-root. If the series are governed by unit-root dynamics, we would be able to estimate an error-correction model, provided that they are also cointegrated. We test for cointegration in the next section. The choice of series is motivated by the theoretical model of DW, presented above. The model is estimated in real terms, and we deflate all price, cost and income variables by the CPI excluding the housing component. All variables are measured as annual averages.[11] Table 4.1 describes briefly each variable and the method for its measurement. Figure 4.1 presents the series during the sample period, 1980–2019. The figure presents each variable in level (blue continuous line in the upper panel) and in first difference (red dashed line in the lower panel).

4.1 The choice of variables

4.1.1 The demand equation

In order to estimate the demand for housing services we have to choose variables to represent rents, income, the stock of housing and demography.

Rents. To measure rents, we use the rent component of the CPI for the period until 1998, and starting from 1999 we use the owner-occupied housing component, both deflated by the CPI excluding housing. The rent component measures the rent in existing leases; these mainly include leases that were signed in the past and therefore they do not necessarily represent the spot price in the market. Starting in 1999, the Central Bureau of Statistics (CBS) started measuring the spot price, i.e., the price in new and renewing leases, through the owner-occupied housing component. This is a better measurement of rents for our purpose because it reflects the market conditions at the time of the measurement, and we therefore use this variable starting from the period it became available. We note, however, that in annual frequency the difference between the series is expected to be insignificant.[12] The rent variable in the model is labeled "rent".

[11] With the exception of construction activity which measures activity during a given year (a flow variable).

[12] Measurement bias may generate inconsistency between the series. Raz-Dror (2019) demonstrates that, due to measurement methodology, the rent component had undervalued the rise in rents during the period 2008–15. It is therefore better to use the owner-occupied housing component that did not suffer from a similar bias. Since then the CBS has made efforts to improve its measurement, see ICBS (2019).

Income. The relevant income for housing demand is the income of the household occupying the dwelling. Fluctuations in income may result from changes in the wage level and from changes in the scope of employment. Accordingly, we measure income using the average wage per employee post (deflated by the CPI excluding housing) multiplied by the employment rate in the economy at the prime working age population, 25–64. We label the income variable in the model "rw_emp".

The stock of housing. Official estimates for the number of dwellings in the economy exist for 1995 and 2018. The figure for 1995 is reported in the 1995 Census of Population and Housing, and that of 2018 is reported in the Dwelling and Building Register, both published by the CBS.[13]

Nagar and Segal (2011) and Weiner and Fuerst (2017) measure the stock of housing by cumulating construction completions and adding them to the 1995 census figure. Similarly, Bar-Nathan, et al. (1998) calculate a stock series starting in 1975, though their estimates account for depreciation, which they subtract from the figure of cumulated construction. Further, they utilized a stock figure from the 1983 Census of Population and Housing.[14] For data until 1995 we use the series of Bar-Nathan, et al. (1998), afterwards we aggregate housing completions, similar to Nagar and Segal (2011) and Weiner and Fuerst (2017). We label the variable representing the stock of housing in the model "h_stock".

We note that we expected to derive an estimate for the scale of depreciation (demolition of old dwellings) by comparing our result for 2018 to the data from the Dwelling and Building Register for that year; however, our stock estimate is lower by about 2 percent than the official figure, suggesting a negative depreciation rate. We therefore settled for cumulating housing completions without accounting for depreciation, as in Nagar and Segal (2011) and Weiner and Fuerst (2017). This result raises doubts regarding the quality of the data and the possibility of comparing the 1995 official stock data to those of 2018, even though they supposedly cover the same population of dwellings.[15] The stock series is a weak link in this paper, and to the

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[13] The 1995 Census of Population and Housing covers all forms of settlements, excluding Kibbutz (cooperative settlement) and dwellings in institutions that do not belong to any municipality. The Dwelling and Building Register is based on data from property tax ("Arnona") collected by the municipalities. Similar data exist starting in 2012, but those do not cover regional councils (around 8.5 percent of the total number of dwellings in 2018). The register does not cover dwellings that are not reported to the authorities, and does not include dwellings in cooperative settlements and institutions that do not belong to any municipality.

[14] Unfortunately, we could not find the figure from the 1983 census.

[15] This may reflect under-reporting of additions of new dwellings. Even if housing completions data are accurate at the time of reporting, it may be possible that over time new dwellings are added, on the basis of existing ones, due to splitting apartments illegally and adding units to family homes. We stress, however, that we do not have empirical evidence to support or refute this hypothesis.

extent that the *pace* at which the stock of housing is cumulated in our data is indeed lower than the actual pace, we will underestimate the sensitivity of the stock to various shocks. Later, we will attempt to quantify the size of the potential bias in our estimates of the long-run elasticities (see Section 5.3.3). That said, to the extent that during the sample period there is a stable relationship between the actual stock of housing and our estimated series, then we expect a proper estimation of the contributions of the different factors to the development of the endogenous variables in the model, despite the measurement error.

Demography. Demographic development is a central factor of demand for housing services. Nagar and Segal (2011) and Weiner and Fuerst (2017) used the size of the general population to measure demography. However, since the housing stock is measured in units of dwellings (and not in area, for example) the relevant population to housing demand is the adult population. Accordingly, Bar-Nathan, et al. (1998) used the population aged 20 and above. We use the population age 25 and above—the prime working age population plus retirees, and label it "pop".

We note that the number of households in the economy probably provides a better indication for housing demand. However, its measurement method is not suitable for our purpose. The CBS defines a household as a person or a group of persons who live regularly in the same dwelling and share a budget for food. At the same time, housing density, i.e., the number of persons living under one roof, is endogenous to the developments in the market. In particular, we expect housing density to rise with the price of housing services, as a number of "potential" households would tend to share dwellings as housing becomes more expensive. In such a case, the measurement method as applied by the CBS would tend to understate the number of households indicative of housing demand. For example, if the rise in the price of housing leads young couples to stay living in their parents' home, it is likely that the CBS would count the couple and the parents as one household, although for the purpose of estimating demand we would like to count them as two households. Appendix A presents supportive evidence for this argument.

Appendix A also presents an estimate for the series of potential households, which is based on population data by marital status. In the example above, when a rise in the price of housing leads a young couple to live in their parents' home, utilizing the number of married couples allows better identification of the number of households that is relevant for housing demand. Our estimates extract the exogenous component of the households' series, at least to the extent

Table 4.1: The variables in the model and their measurement

Variable	Description	Units	Method of measurement
rent	Rent	Index, real terms	Rent component of the CPI until 1998, and starting 1999 measured by the owner-occupied housing component of the CPI, both deflated by the CPI excluding housing.
rw_emp	Income	Index, real terms	Average wage per employee post (deflated by the CPI excluding housing) multiplied by the employment rate.
h_stock	The stock of housing	Units of dwellings	Measured by cumulating housing completions and adding them to the 1995 stock figure (available from the Census of Population and housing). Until 1995, figures are from Bar-Nathan, et al. (1998).
pop	Population age 25+	Number of persons	Measured by multiplying the general population by the share of persons age 25 and above.
price	Home prices	Index, real terms	The home-price index of the CBS, deflated by the CPI excluding housing.
fwd_rate	Real financial return	Percent	5-10 years forward return on CPI-indexed government bonds.
inf_std	Standard deviation of inflation	Percent (log difference)	The standard deviation of monthly CPI-inflation (measured in log-difference) during a calendar year.
comp	Housing completions	Units of dwellings	The number of dwellings for which construction was completed during the year.
const_cost	Construction cost	Index, real terms	The price index of inputs in residential building deflated by the CPI excluding housing.

that the marital status is unaffected by the developments in the housing market, and in our opinion it better reflects the demand for housing services compared to the raw CBS data.

That said, in the end we chose to measure demography using the adult population series rather than our estimate for potential households. Three reasons led us to this choice: First, both series are almost identical; the correlation coefficient between the series in (log) first difference is 0.94, and hence choosing one series over the other will not affect our results much. Second, generating the series for potential households combines several data sources and requires statistical filtering, and these are likely to generate measurement errors. In contrast, the population series is provided directly from the CBS and requires minimal processing on our behalf. Finally, the population series is available on a timelier basis. The households series is available with a lag of two years; hence, using it presents a difficulty in making an analysis at the end of the sample period, which is always the actual and more interesting part. The population series by age is available with one-year lag, though estimates for the general population are available at a monthly frequency and it is possible to generate an estimate for the adult population at the end of the sample in greater reliability than for potential households.

4.1.2 The asset-pricing equation

To estimate the asset-pricing equation, we have to choose variables to represent home prices, the financial return and rents, where the latter we have already presented above.

In the theoretical model, we specified the asset-pricing equation with no risk premium. Under cointegration, omitting the risk premium from the estimation would not affect the results if it follows a stationary process. However, Rubinstein (1998) points to a non-stationary risk factor. Following the high inflation of the 1980s in Israel, Rubinstein (1998) finds a negative relation between inflation volatility and home prices. He explains that homeownership provides insurance against unexpected inflation, and argues that the uncertainty regarding the inflation rate is rising with its level. We therefore expect the risk premium to be lower during periods of high inflation. Since in our sample the inflation rate is non-stationary, we augment the estimation of the asset-pricing equation with its standard deviation.

Home prices. We measure home prices using the CBS hedonic home-price index, deflated by the CPI excluding housing. We label this variable "price".

Alternative return from the financial markets. In principle, the asset-pricing equation should employ the full yield curve, as the price of an asset should reflect the present discounted value of the stream of income it generates—the income a year from today should be discounted by the one-year return and the income expected in 10 years should be discounted by the 10-year return. In the model we use the long-run version of this equation, suggesting the appropriate return is the expected long-run forward rate. Furthermore, the relevant return is the real return in terms of housing; however, as no bonds are indexed to housing prices in the Israeli market, we use CPI-indexed government bonds.[16] We use the net return, i.e. after tax, as this is the effective return from the standpoint of the public. In sum, we measure the return on alternative financial assets using the 5-10 year forward rate of CPI-indexed government bonds. We would have liked to use a forward return for a longer horizon, but due to data limitations at the beginning of the sample period we settle for the 5-10 year return.[17] We label the alternative financial return "fwd_rate".

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[16] Adding the expected long-run rate of capital gain (in real terms) would resolve this issue, as it accounts for the expected change in the price of houses relative to the CPI. Nevertheless, this rate is quite stable (Figure 2.1) and therefor omitting it would not affect the results under cointegration estimation.

[17] Due to data limitation, for the years 1980–84 we derive the forward rate from 4-6 year and 9-10 year bonds.

Standard deviation of inflation. We measure the standard deviation of inflation using the standard deviation of monthly CPI-inflation (measured in log-difference) during a calendar year. We label this variable "inf_std".

4.1.3 Construction supply equation

In order to estimate construction supply, we have to choose variables to represent home prices, construction activity and its cost. We have already presented home prices under the asset-pricing equation in the previous sub-section.

Construction activity. We measure construction activity using the series of housing completions, which measures the number of dwellings for which construction was completed during the period. Another natural candidate for representing construction activity is housing starts, though the choice between the two is open for judgment. Housing starts may be more sensitive to changes in price and cost relative to completions, as a deterioration in profitability, for example, is likely to prevent some projects being executed while projects that have already begun are more likely to be completed. However, in contrast, changes in profitability may affect the pace of construction and as a result will affect housing completions, while housing starts may react with a lag due to bottlenecks in the planning process. For the sake of consistency with the series representing the housing stock, we use housing completions. We label this variable "comp".

Construction cost. We measure construction cost using the price index of inputs in residential building deflated by the CPI excluding housing. This variable is labeled "const_cost".[18]

4.2 Unit-root tests

Table 4.2 presents the results of unit-root tests. We use two standard tests, Augmented Dickey-Fuller (ADF) and Phillip-Perron (PP). In the tests, all variables are logged, with the exception of the real financial return and the standard deviation of inflation. The tests were conducted on the variables in levels and in first difference. The null hypothesis in all tests is that a unit-root process generates the series. As some variables display a time trend (Figure 4.1), the tests for

[18] Admittedly, construction supply should also include the cost of land. However, data on land prices are not available, and we are forced to estimate supply without them. This constraint is of course valid to all contributions that have analyzed the housing market in Israel. Note, however, that if home-prices reflect a constant mark-up over land cost, omitting the latter from the specification does not affect the results.

Table 4.2: Unit-root tests for the variables of the model, P-Values
Sample period 1980–2019, Null hypothesis: variables have a unit-root

	ADF Tests*			PP Tests		
	(1)	(2)	(3)	(4)	(5)	(6)
	Level	Level	First Diff.	Level	Level	First Diff.
Variable	Constant and time trend	Constant only	Constant only	Constant and time trend	Constant only	Constant only
log(rent)	0.7094	0.4398	0.0008	0.8588	0.5135	0.0009
log(rw_emp)	0.2795	0.9032	0.0000	0.2815	0.9488	0.0000
log(h_stock)	0.8643	0.7620	0.0293	0.9044	0.7616	0.1774
log(pop)	0.7778	0.8125	0.0627	0.9510	0.7420	0.0619
log(price)	0.7804	0.9461	0.0000	0.5609	0.9073	0.0000
fwd_rate	0.1789	0.0830	0.0002	0.3825	0.1901	0.0002
inf_std	0.0617	0.0672	0.0000	0.0772	0.0867	0.0000
log(comp)	0.5696	0.4701	0.0000	0.3887	0.2728	0.0000
log(const_cost)	0.7052	0.9488	0.0021	0.7052	0.9563	0.0000

* The number of lags for the ADF test was chosen using Schwarz Information Criterion, while restricting to a maximum of 3 lags.

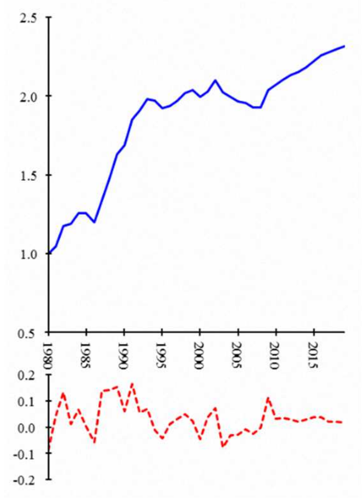
the variables in levels allow for a deterministic trend in the alternative hypothesis, i.e., a trend-stationary process – columns (1) and (4) in Table 4.2, as well as a trendless stationary process, columns (2) and (5). The series in first difference display no trend, and therefore the alternative hypothesis for them is a trendless stationary process, columns (3) and (6).

Overall, it is apparent from Table 4.2 that we cannot reject the hypothesis that the level of the variables contain a unit-root, and that their first difference is stationary. Hence, provided supportive results from cointegration tests, we will conduct the econometric analysis using an error-correction model. However, before performing the cointegration tests, we discuss briefly the results of the unit-root tests for some of the variables.

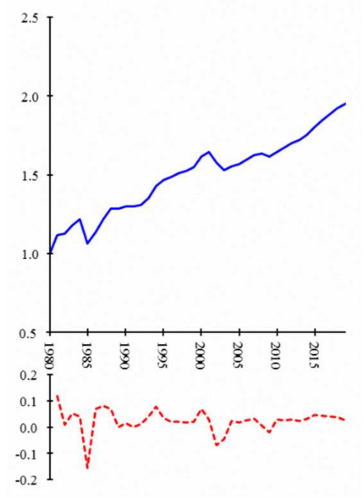
Real financial return. From an economic perspective, the real return (Figure 4.1.6) is not expected to follow a random walk, at least in long samples. This is (weakly) supported by the relatively low P-Value levels of the unit-root tests compared with the rest of the variables, and in particular the ADF test with only a constant rejects the unit-root hypothesis at 10 percent significance level (Table 4.2). Nevertheless, the companion PP test does not reject the hypothesis, as do the tests that allow for a deterministic trend. In addition, it is difficult to detect a stationary behavior by examining the real return in the figure, providing an informal support to the results of the formal tests. In sum, we treat the real return as a non-stationary variable, both because of the supportive evidence and because it is required in the estimation of the cointegration relations.

Figure 4.1: The variables of the model,
In levels (upper panel), in first-difference (lower panel), 1980–2019

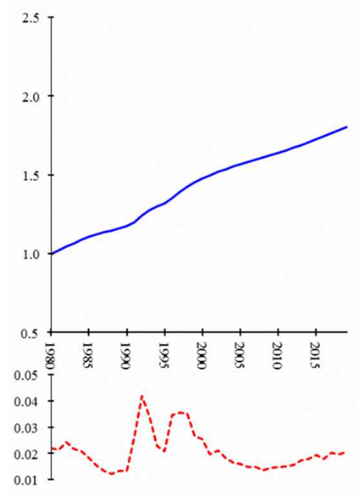
4.1.1 Rent
Index, real terms, log points
log(rent), Δlog(rent)



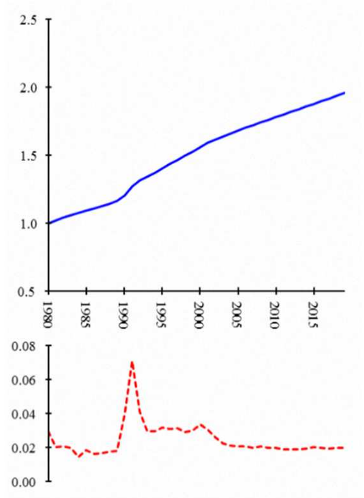
4.1.2 Income
Index, real terms, log points
log(rw_emp), Δlog(rw_emp)



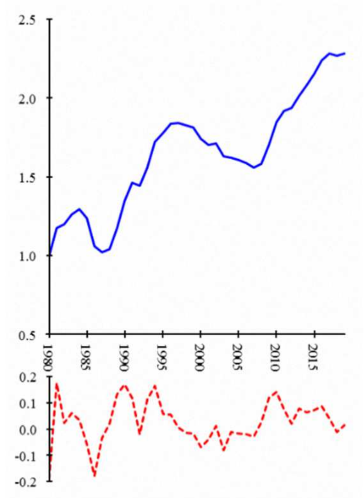
4.1.3 The stock of housing
Units of dwellings (indexed), log points
log(h_stock), Δlog(h_stock)



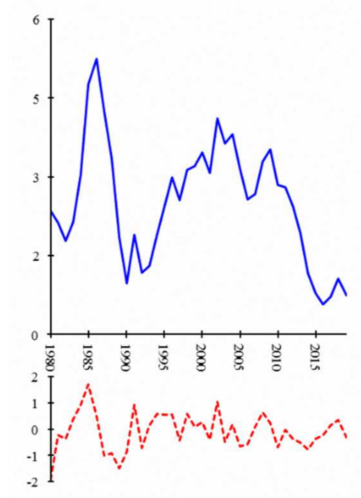
4.1.4 Adult population, age 25+
Index, log points
log(pop), Δlog(pop)



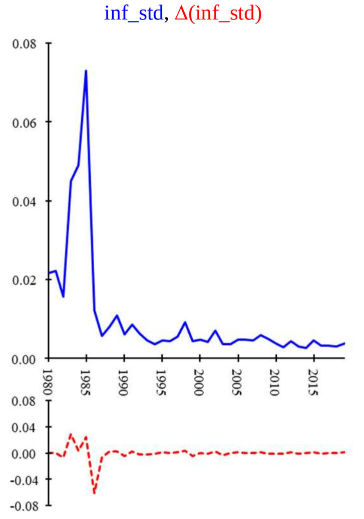
4.1.5 Home prices
Index, real term, log points
log(price), Δlog(price)



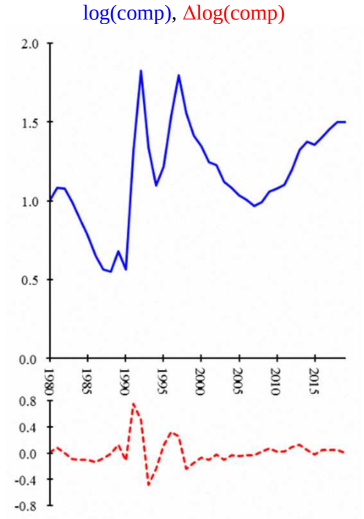
4.1.6 5-10 year forward rate of CPI-indexed gov. bonds, percent
fwd_rate, Δfwd_rate



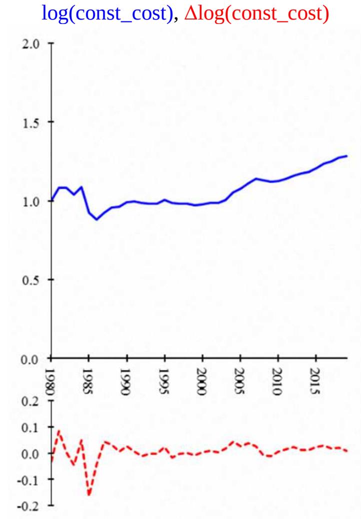
4.1.7 Standard deviation of inflation
log points
inf_std, Δ(inf_std)



4.1.8 Housing completions
Units of dwellings (indexed), log points
log(comp), Δlog(comp)



4.1.9 Construction cost
Index, real term, log points
log(const_cost), Δlog(const_cost)



Standard deviation of inflation. The results for the standard deviation of inflation are inconclusive, as the tests do not reject the unit-root hypothesis at a 5 percent significance level, but reject it at 10 percent level (Table 4.2). This result reflects the stabilization of the inflation rate in Israel over the last two decades, which is also apparent in the figure (Figure 4.1.7). This variable is required in the analysis in order to control for the risk premium of home prices at the beginning of the sample period, and as we demonstrate below, its presence in the regression brings the econometric results closer to those suggested by theory. For this reason, and as the stationarity tests are inconclusive, we treat the standard deviation of inflation as non-stationary.

Population and the stock of housing. Although we cannot reject the unit-root hypothesis for the population series (Table 4.2), an informal examination may raise concern that it is driven by a deterministic trend (Figure 4.1.4). The large immigration wave in the early 1990s may have created a break in the series, and in practice, population does not contain a unit-root but instead is driven by a deterministic trend that was shifted upwards. However, a unit-root test that allows for a break in the series, Perron (1989), also supports the unit-root hypothesis.[19] Similarly, the housing stock also seems to be driven by a deterministic trend (Figure 4.1.3), but in this case as well, the same test supports the unit-root hypothesis while accounting for the break.[20]

5. The econometric model: Long-run equations

In this section we utilize the theoretical model of DW to guide us in the empirical specification of the equations describing the long-run relations in the housing market. We specify the demand for housing services, the asset-pricing equation, and construction supply, and estimate them by OLS and by Fully-Modified OLS (FMOLS).[21] Under cointegration, FMOLS estimation is needed in order to derive consistent estimates for the standard errors. In this

19 The immigration wave from the former Soviet Union started in 1989, although the scale became significant only in 1990 and accelerated in 1991. From examining the population series (Figure 4.1.4), the break appears to occur in 1990. The test was performed with specification of "additive innovation", and it does not reject the unit-root hypothesis with Prob≥0.5. Furthermore, we performed additional unit-root tests for samples starting after the main immigration wave. The results are sensitive to the exact starting date of the sample, though samples starting in 2004 or later consistently do not reject the unit-root hypothesis.

20 After examining the series of the housing stock (Figure 4.1.3), we assume the break occurs in 1991, i.e., one year after the break in the population series. The test was performed with specification of "additive innovation", and it does not reject the unit-root hypothesis with Prob≥0.5. Furthermore, sensitivity tests for samples starting after the main immigration wave result in greater support for the unit-root hypothesis, relative to the population series. Samples starting in 1999 or later consistently do not reject the unit-root hypothesis.

21 For estimation by FMOLS, see Phillips and Hansen (1990).

section we also present cointegration tests for the estimated long-run equations. These include stationarity tests for the residuals via Augmented Dickey-Fuller (ADF) and Engle-Granger (EG) tests, and by using Johansen tests for the number of cointegration relations in each equation.[22,23] We note that generally, the ADF and EG tests provide support for cointegration, while the results of the Johansen tests are less conclusive and leave room for judgement.

At the end of this section, we close the model by tying the stock of housing to completions (the fourth quadrant in Figure 3.1), and present estimates for the long-run elasticities of the endogenous variables in the model with respect to the exogenous ones in general equilibrium, as implied by the theoretical model.

5.1 Specifying the long-run equations

5.1.1 The demand for housing services and the measurement of housing shortage

The demand for housing services declines with its price, i.e., rents, and rises with income and population. We estimate demand using the following equation:

$$log(h\_stock_t) = \beta_0^d + \beta_{rent}^d log(rent_t) + \beta_{pop}^d log(pop_t) + \beta_{rw\_emp}^d log(rw\_emp_t) + u_t^d \quad (1)$$

where we expect to get $\beta_{rent}^d < 0$ and $\beta_{pop}^d, \beta_{rw\_emp}^d > 0$. Panel A in Table 5.1 presents the results of the estimation. All estimated parameters are statistically significant and with the expected sign: a rise in rent reduces demand, and a rise in population and income raises it. The OLS and FMOLS estimates are similar in magnitude.

The population coefficient is significantly lower than unity. Previous papers analyzing the Israeli housing market do not estimate a similar demand equation; instead, they estimate equilibrium relations, and when using data for the stock of housing they do so relative to population, thereby imposing a unitary coefficient (Bar-Nathan, et al. (1998), Nagar and Segal (2011) and Weiner and Fuerst (2017)). A unitary coefficient is attractive in the sense that in the long run, the housing stock is determined solely by demographic needs, although it is not

[22] We note that ADF is not a formal test for cointegration, as it does not account for the fact that the residuals are the product estimation and not raw data. We present here the results of the test, as in Nagar-and Segal (2011), and view them merely as indicative.

[23] As a default, we perform the Johansen test with a constant in both the long- and short-run equations. We include one lag in the short-run equations, and examine the robustness of the results to that choice.

clear that theoretically this is a necessary condition, as other factors, such as the price of housing services relative to income or other goods, may also affect the stock of housing.

For our results to be consistent with the assumption that the population-stock ratio is stable over time, the population coefficient in equation (1) should be larger than 1. The reason is that in the long run, the stock of housing is determined by the intersection of demand and long-run supply (LRS curve in Figure 3.1), and to the extent that supply is upward sloping, the rise in the housing stock will be smaller than the shift in demand generated by a rise in population. A unitary population coefficient in equation (1) is consistent with a stable population-stock ratio only if the long-run supply curve is perfectly elastic. The fact that we get a coefficient smaller than 1 implies that the housing stock grows at a slower pace than adult population, and it may suggest a measurement problem of the housing stock series, as suggested in the previous section, though given the data in hand it would be improper to impose a unitary coefficient. Below we attempt to evaluate the possible bias in the estimated elasticities resulting from mismeasurement of the housing stock (see Section 5.3.3).

The residual of equation (1) provides an estimate for the surplus or shortage in housing units. In the public debate, it is common to refer to the gap between some demographic aggregate, typically the number of households, and the stock of housing as a measure for the shortage in housing units. Nagar and Segal (2011) and Weiner and Fuerst (2017) adopt this interpretation when examining the development of the housing stock relative to population. Equation (1), however, takes an economic approach in which the surplus or shortage are also affected other market conditions, and in particular, changes in the price of housing services assist in bringing the market to equilibrium. For example, even if the stock of housing conforms to demographic developments, a rise in households' income may generate excess demand and hence shortage in housing units. In that case, a rise in rents and/or a rise in supply will restore equilibrium, while the exact combination of the two is determined by the elasticities of demand and supply, as demonstrated in the DW model.

Finally, we note that the ADF and EG tests suggest that the residual of equation (1) is stationary, thereby implying cointegration among the variables in the equation. The Johansen tests, however, provide mixed results, as the Trace version of the test supports a single cointegration relation while the Eigenvalue version does not support cointegration (Table 5.1).[24]

5.1.2 The asset-pricing equation

The theoretical model evaluates home prices by the discounted present value of the stream of rents they are expected to generate in the long run. We specify the asset-pricing equation as follows:

$$log(price_t) = \beta_0^{ap} + \beta_{rent}^{ap} log(rent_t) + \beta_{fwd\_rate}^{ap} fwd\_rate_t + \beta_{inf\_std}^{ap} inf\_std_t + u_t^{ap} \quad (2)$$

This specification augments the equation with the standard deviation of inflation as a factor that controls for the risk premium, as suggested by Rubinstein (1998). We introduce the risk factor and the interest rate linearly, even though in the theoretical model prices are determined by the ratio of rent over the (risk-adjusted) interest rate, and therefore in a specification where the price and rent variables are logged, so should the discount rate. The specification above represents a linear approximation.[25]

Estimating equation (2) we expect to get $\beta_{rent}^{ap}, \beta_{inf\_std}^{ap} > 0$ and $\beta_{fwd\_rate}^{ap} < 0$. Panel B in Table 5.1 presents the estimation results. The OLS and FMOLS estimates are similar in magnitude, although the coefficients of the interest rate and the standard deviation of inflation are somewhat smaller (in absolute value) under the OLS estimation, but after accounting for their standard errors the difference does not seem substantial. All estimated parameters are statistically significant and with the expected sign: a rise in rent and in the standard deviation of inflation raise prices, while a rise in interest rate reduces them. Notably, the rent coefficient

[24] The Johansen tests in the table allow for one lag in the difference equations. When restricting the tests to include no lags, they provide clearer support for a single cointegration relation, and when allowing for two lags they suggest that two cointegration relations exist. One relation that immediately comes to mind is between population and the stock of housing, as effectively assumed by Bar-Nathan, et al. (1998) and Weiner and Fuerst (2017), and is also implied by Nagar and Segal (2011). The second relation is between rents and income. However, cointegration tests for these relations yield mixed results. Furthermore, we note that from a theoretical perspective, decomposing demand into these equations yields contradicting characterization of housing demand. The population-stock relation suggests that demand is perfectly inelastic, while the rent-income relation suggests it is perfectly elastic. In conclusion, we continue by assuming that equation (1) is characterized by a single cointegration relation.

[25] Also, the theoretical model assumes a fixed level of real rent in the long run, while the in the data rents are growing over time. In this case, the denominator of the asset-pricing equation equals the difference between the (risk-adjusted) interest rate and the growth rate of rents, both in real terms and evaluated at their long-run values. The specification of equation (2) reflects a first order approximation, holding constant the long-run growth rate of rents.

Table 5.1: Estimation results of long-run equations[1] and cointegration tests, 1980–2019

Panel A: Demand for housing services

Equation: Dep. Variable:	(1) log(h_stock)	
	OLS	FMOLS
log(rent)	-0.0430	-0.0488***
		(0.0173)
log(pop)	0.7806	0.7667***
		(0.0354)
log(rw_emp)	0.1011	0.1293**
		(0.0476)
Constant	0.5135	0.4127**
		(0.1634)
R^2	0.9983	0.9983
No. of Obs.	40	40
ADF[2]	0.0018	0.0098
EG z-stat.[3]	0.0000	
Johansen max no. of CIs[4]	Trace	Eigenvalue
0	0.0458	0.1525
1	0.1710	0.1180
2	0.6471	0.6556
3	0.3905	0.3905

Panel B: Asset-pricing equation

Equation: Dep. Variable:	(2) log(price)	
	OLS	FMOLS
log(rent)	0.9664	0.9996***
		(0.1257)
fwd_rate	-6.0397	-8.1085**
		(3.1878)
inf_std	5.9956	8.1280**
		(3.2186)
Constant	0.4090	0.3138
		(0.6132)
R^2	0.8654	0.8539
No. of Obs.	40	40
ADF[2]	0.0148	0.0035
EG z-stat.[3]	0.0000	
Johansen max no. of CIs[4]	Trace	Eigenvalue
0	0.0056	0.0234
1	0.1050	0.1157
2	0.4170	0.4797
3	0.2390	0.2390

Panel C: Construction supply

Equation: Dep. Variable:	(3) log(comp)	
	OLS	FMOLS
log(price)	0.7850	0.8274***
		(0.1710)
log(const_cost)	-0.9782	-1.1992*
		(0.6083)
Constant	4.3339	5.1331**
		(2.2578)
R^2	0.5383	0.5355
No. of Obs.	40	40
ADF[2]	0.0000	0.0000
EG z-stat.[3]	0.0000	
Johansen max no. of CIs[4]	Trace	Eigenvalue
0	0.1692	0.0451
1	0.9496	0.9517
2	0.5218	0.5218

[1] Standard errors in parenthesis; * 10 percent significance, ** 5 percent significance, *** 1 percent significance.
[2] Augmented Dickey-Fuller test with no constant; lag length determined by Schwarz information criterion; Prob. for rejecting the null hypothesis for the existence of a unit root. This is not a formal test for cointegration, as it does not account for the fact that the residuals are a function of estimated parameters.
[3] Engel-Granger test; lag length determined by Schwarz information criterion; Prob. for rejecting the null hypothesis of no cointegration.
[4] Johansen tests with one lag in the difference equations, and with a constant in both the long-run equations and the difference equations; Prob. for the rejection of the null hypothesis for the existence of no more than n cointegration relations, n=0 to the number of regressors (not including the constant).

is unitary, as suggested by theory. This result is obtained due to the inclusion of the standard deviation of inflation in the regression; in its absence, the estimated rent coefficient is smaller, around 0.8, though it is insignificantly different from unity (at a 10 percent significance level). Clearly, the main effect of the inflationary risk on home prices is at the beginning of the sample, during the years of high inflation, but the fact that its presence in the regression affects the rent coefficient and aligns it with theory, brings forward its importance.

Finally, we note that all cointegration tests support cointegration among the variables in the asset-pricing equation (Table 5.1).

5.1.3 Construction supply

Construction supply rises with home prices and decreases with construction cost. We estimate construction supply using the following specification:

$$log(comp_t) = \beta_0^s + \beta_{price}^s log(price_t) + \beta_{const\_cost}^s log(const\_cost_t) + u_t^s \qquad (3)$$

where we expect to get $\beta_{price}^s > 0$ and $\beta_{const\_cost}^s < 0$. Panel C in Table 5.1 presents the estimation results. The OLS and FMOLS estimates are similar in magnitude, and all estimated parameters are statistically significant and with the expected sign: a rise in home prices increases housing completions, and a rise in construction cost reduces them. Further, we cannot reject the hypothesis that the price and cost coefficients are equal in absolute value, suggesting that construction supply reacts to their difference, i.e., to profitability.

The price coefficient measures the price elasticity of long-run construction supply. Its estimated value is around 0.8, suggesting construction supply is somewhat inelastic, though it is insignificantly different from unity. Caldera and Johansson (2013) and Cavalleri, et al. (2019) estimate this elasticity for more than 20 OECD countries.[26] Our estimate is similar to the one Cavalleri, et al. (2019) obtain for Israel, 0.8, and is higher than that of Caldera and Johansson (2013), around 0.4; though their low elasticity may be a result of the relatively short sample they use for Israel. Both find that the elasticity of construction supply in Israel is moderately lower than the median elasticity in the OECD countries in their samples. Interestingly, these papers also find a connection between supply elasticities and regulation: countries with stricter regulation on land use tend to have less elastic supply.

[26] Note, however, that these papers measure construction activity using gross residential investment.

Finally, we note that the ADF and EG tests suggest that the residual of equation (3) is stationary, thereby implying cointegration among the variables in the equation. The Johansen tests, however, provide mixed results; the Eigenvalue version of the test supports a single cointegration relation while the Trace version does not support cointegration (Table 5.1).[27]

5.2 The residuals of the long-run equations

In estimating the error-correction model, we use the residuals of the long-run equations as explanatory variables for the short-run dynamics of the endogenous variables. The residual of the demand equation indicates excess demand or excess supply, relative to long-run conditions, in the market for housing services. Alongside this residual, we present, for comparison only, the residual from an equation estimating the stock of housing as a function of population alone. We use the residual of the asset-pricing equation to indicate over- or under-valuation of house prices, and the residual of construction supply to indicate excessive, or insufficient, construction relative to profitability. We use the residuals from the FMOLS estimations, and present them in Figure 5.1.[28]

The residual of the demand equation, equation (1), provides an estimate for the shortage, or surplus, in housing units relative to long-run demand conditions. In contrast, the approach of Nagar and Segal (2011) and Weiner and Fuerst (2017) provides a similar indication by examining the ratio of population relative to the stock of housing. Since we concluded that it is improper to impose a unitary coefficient between the variables, we generate an estimate for the shortage in housing, following their approach, by extracting the residual from the following equation:[29]

$$log(h\_stock_t) = \beta_0^{d,stock} + \beta_{pop}^{d,stock} log(pop_t) + u_t^{d,stock} \quad (4)$$

Figure 5.1.1 presents the estimates for housing shortage/surplus as suggested by the demand equation, equation (1), alongside the estimate from equation (4). It is not surprising to see that

27 When allowing for two lags in the difference equations, the Trace version supports a single cointegration relation while the Eigenvalue version does not support cointegration. With no lags, both tests do not support cointegration.

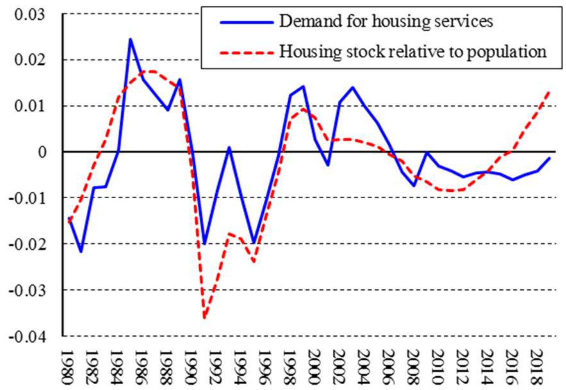
28 The difference between the OLS and FMOLS residuals is small. The correlation coefficients between them are 0.97 and higher.

29 Equation (4) is estimated by FMOLS for the sample period of 1980-2019 (40 observations). The population coefficient is 0.8119 and its standard deviation is 0.0106, suggesting the population coefficient is significantly lower than unity.

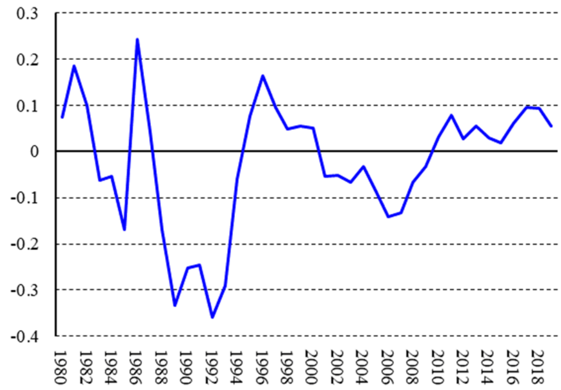
Figure 5.1: Long-run estimated residuals

log points, FMOLS estimation, 1980-2019

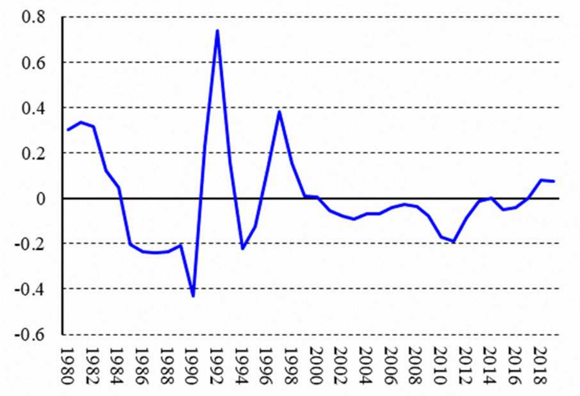
5.1.1 Demand residuals, equations (1) and (4)



5.1.2 Asset-pricing residual, equation (2)



5.1.3 Residual of construction supply, equation (3)



the two residual series are correlated, as the difference between them is driven only by the effect of rent and income.

The shortage in housing in the early 1990s, resulting from the immigration wave from the states of the former Soviet Union, is quite visible in the figure. Excess demand peaked in 1991, at around 2 percent of the housing stock, when measured by the demand equation, and about 3.6 percent when measured relative to population alone. As noted, the difference between the estimates is driven by the evolution of rent relative to income. Naturally, at that time rents increased sharply, also compared to income, thereby moderating demand and the implied shortage. The figure also suggests that excessive construction during the immigration period, as also suggested by Figure 5.1.3, generated some surplus in the market starting 1998; however, this surplus eroded and starting in 2007 the housing stock has become lower than the level required by both long-run demand and demography. This development is likely to have supported, among other factors, the rise in home prices over the last decade. The excess demand has persisted since then, and at the end of the sample, a small shortage remains. That said, the estimate based on the development of population suggests that the shortage was already closed in 2016. The difference between the estimates is due to a muted rise in rents relative to income, at least according to this measure, which kept demand elevated.

The residual from the asset-pricing equation (Figure 5.1.2) suggests that at the eve of the immigration wave homes were undervalued; this is a result of a sharp decline in financial returns that was not accompanied by sufficient rise in home prices. The undervaluation continued for several years, even after prices had risen sharply, as rising demand for housing services drove rents higher as well. During the second half of the 1990s, the rise in prices eventually generated overvaluation; however, the gradual decline in real prices that followed the immigration period, resulting from a surplus in housing units (Figure 5.1.1), eroded valuation, and by 2006–07, at the eve of the recent rise in prices, undervaluation reached 13.7 percent, on average. It is likely that this undervaluation, alongside the shortage in housing units that started to emerge in 2007 and the decline in returns, had also contributed to the rise in home prices that started in 2008. As prices started to rise, the market turned once again to overvaluation, and at the end of the sample, in 2019, we estimate it at 5.5 percent.

Finally, the residual of construction supply (Figure 5.1.3) reflects the sharp rise in construction resulting from the immigration wave in the early 1990s. However, a decade later it seems that construction activity stalled, relative to its expected level as suggested by our model, which explains the erosion in the stock of housing and the shortage that followed (Figure 5.1.1). Only by 2013 the pace of construction approximately matched its long-run level, and by 2018 it became even higher.

5.3 The long-run elasticities

5.3.1 Closing the model and methodology

In the DW model, a stock-flow identity ties the development of the housing stock to housing completions. The model suggests that in the long-run the ratio of completions to the housing stock should be constant, and therefore in estimating a long-run equation of the form:

$$log(h\_stock_t) = \beta_0^{stock,LR} + \beta_{comp}^{stock,LR} log(comp_t) + u_t^{stock,LR} \quad (5)$$

we expect the coefficient of housing completions, $\beta_{comp}^{stock,LR}$, to equal unity. Nevertheless, in practice the estimated coefficient is much smaller, around, 0.51.[30] Again, this might reflect mismeasurement of the housing stock, as discussed earlier.

The demand equation, equation (1), the asset-pricing equation, equation (2), construction supply, equation (3), and the stock-flow equation, equation (5), summarize the DW model empirically. We write this system of equations compactly as follows:

$$Ay = Bx \qquad \Rightarrow \qquad y = A^{-1}Bx \tag{6}$$

Where y is a vector of the endogenous variables, x is a vector of the exogenous variables, and A and B are coefficient matrices that summarize the estimation results presented above. The matrix $A^{-1}B$ expresses the long-run elasticities of y with respect to x. The elasticities estimated by each equation separately express the long-run elasticities of housing demand, of partial equilibrium relative to the financial markets, and of construction supply. In contrast, the elasticities we calculate using equation (6) are consistent with a simultaneous equilibrium in all segments of the model.

5.3.2 The long-run elasticities in the baseline estimation

Table 5.2 presents the estimates of the long-run elasticities in general equilibrium under the columns labeled "Baseline estimates". Note that the sign of the elasticities is consistent with the predictions of the DW model. This result comes as no surprise, because the estimates of the coefficients of the long-run equations have received the expected sign (Table 5.1).

An increase in demand, driven by a rise in income or population, raises all variables, rents, house prices, construction activity and the stock of housing. It appears that population is the dominant demand factor, as all variables are almost 6 times more responsive to population compared with their responsiveness to income.[31] This conclusion is reinforced by comparing the growth rates of these variables during the sample period, as on average both grew at similar rates; adult population grew at an average annual rate of 2.5 percent and real income by 2.4 percent. In this comparison, the immigration years in the early 1990s clearly bias upward the average population growth rate, and over the last decade, for example, real income has grown

[30] Equation (5) is estimated by FMOLS for the sample period of 1980-2019 (40 observations). The housing completions coefficient is 0.5150 and its standard deviation is 0.2144. The fit of this regression is poor, with its R^2 equals 0.1785.

[31] The ratio of elasticities is constant, and equals to the ratio between the population and income coefficients in the demand equation.

Table 5.2: Estimates of the long-run elasticities

Panel A: Long-run elasticities in general equilibrium

Elasticity of y: / w/r/t x:	log(h_stock)		log(rent)		log(price)		log(comp)	
	Baseline estimates	Unitary stock elasticity	Baseline estimates	Unitary stock elasticity	Baseline estimates	Unitary stock elasticity	Baseline estimates	Unitary stock elasticity
log(pop)	0.69	1.00	1.61	1.21	1.61	1.21	1.34	1.00
log(rw_emp)	0.12	0.17	0.27	0.20	0.27	0.20	0.23	0.17
fwd_rate	-0.36	-0.52	7.28	7.49	-0.83	-0.62	-0.69	-0.52
log(const_cost)	-0.06	-0.09	1.30	1.34	1.30	1.34	-0.12	-0.09

Panel B: Long-run supply elasticity (LRS curve)

	Baseline estimates	Unitary stock elasticity
w/r/t rent	0.43	0.83
w/r/t price	0.43	0.83

Note: The baseline estimates refer to the estimates based on equations (1), (2), (3) and (5). The estimates under "Unitary stock elasticity" are calculated under the restriction that the long-run elasticity of the stock of housing with respect to population is unitary, and a constant ratio of completions to the housing stock – see Section 5.3.3 for details.

faster than population (around 3.3 percent compared to 2.0 percent). However, the difference in growth rates is far from closing the difference in the sensitivity of the endogenous variables to population versus income.

An increase in the interest rate reduces home prices and quantities, i.e., the stock of housing and construction activity, and raises rents. In particular, the high sensitivity of rents stands out especially compared to the moderate reaction of home prices, which goes in the opposite direction. The mechanism in the model that generates this result goes through construction supply. As the interest rate rises, prices fall in order to equate the returns between the housing market and the financial market. The lower price level contracts construction activity and thereby the stock of housing contracts as well. Lower supply generates excess demand for housing services, and as a result rents rise. The high sensitivity of rents is a result of the very low elasticity of housing demand (see the rent coefficient in the demand equation – Panel A in Table 5.1). Furthermore, the rise in rents moderates the initial fall in prices, caused by the higher interest rate, and therefore reduces the long-run sensitivity of home prices to the interest rate. Nagar and Segal (2011) also report effects in opposite directions of the interest rate on home prices and rents. That said, they relate it to what they call "the substitution principle" between rental demand and owner-occupied demand. They explain that a rise in the interest rate reduces demand for homeownership because mortgages become more expensive, and as a result home prices fall; at the same time, demand for housing services is directed to the rental market, resulting in higher rents. The DW model provides an alternative explanation.

A rise in construction cost reduces quantities, i.e., the stock of housing and construction activity, and raises home prices and rents. Construction supply seems quite inelastic, as a rise of 1 percent in cost reduces construction by only 0.12 percent and the housing stock by 0.06 percent. The relative minor effect on quantities is reflected by much larger elasticities of home prices and rents.

Adams and Füss (2010) use data of 15 OECD countries to estimate the long-run elasticity of home prices (in real terms) with respect to economic activity, the long-term interest rate and construction cost (in real terms). Although their measurement of the variables differs from ours[32], it is interesting to compare the order of magnitude of their elasticities to those we estimate for Israel. The panel estimate of Adams and Füss (2010) of the price elasticities with respect to economic activity and construction cost are 0.34 and 1.30, respectively. These figures are very close to those we estimated for Israel, 0.27 and 1.30, respectively (Table 5.2). As for the semi-elasticity of prices with respect to the interest rate, the difference is more substantial. The panel estimate for the OECD countries is -0.4, while our estimate is -0.83. Nevertheless, the figure for Israel is within the range of estimates for the individual countries in their sample, where Canada and Spain display the greatest semi-elasticity (in absolute value) with a value of -1.16. It therefore seems that our estimates are reasonable in international comparison, at least those for the price elasticities.

We can also calculate the elasticity of the long-run supply curve (LRS curve in Figure 3.1) by dividing the stock elasticity with respect to income by the rent elasticity with respect to income (or alternatively by taking the ratio of the elasticities with respect to population). Our estimate for the long-run supply elasticity is 0.43, suggesting it is fairly inelastic. A similar calculation for the elasticity with respect to house prices yields an identical figure, because the rent coefficient in the asset-pricing equation is unitary (Table 5.1). These results reflect the need for substantial price adjustments in order to clear the housing market over time.

[32] Adams and Füss (2010) measure economic activity using the first principal component of real money balances, private consumption, industrial production, GDP and employment. For the interest rate, they use the return on 10-year nominal government bonds, and argue that it is sufficient to use the nominal return since inflation equally erodes the real returns of all assets, and therefore does not affect their relative attractiveness.

5.3.3 Sensitivity check

For the conclusion of this section, we try to assess the potential bias in the estimates of the elasticities in case our data undervalue the true pace of housing accumulation. In particular, we are interested in examining whether the long-run supply remains inelastic even after allowing for a higher growth rate of the housing stock.

To conduct this exercise we must put some structure on the problem. First, we model the measurement error in the data. We assume the following relation between the actual stock of housing and its measurement in the data:

$$\hat{Q}_t = aQ_t^b exp(\varepsilon_t) \qquad a > 0 \qquad 0 < b \leq 1 \qquad (7)$$

where Q is the actual housing stock, $\hat{Q}$ is our estimate for the stock in the data, and ε is a random, white noise, shock. The assumption that the parameter b is lower than unity reflects the concern that the growth rate of the housing stock in the data is lower than the actual rate. Recall that the housing stock is the dependent variable in the demand equation and that the estimated specification is logarithmic (see equation (1)). Therefore, in order to correct for the bias in the estimation, we must divide all estimated coefficients in that equation by the value of b. The constant term is also affected by the value of a, but it has no effect on the estimates of the elasticities presented in Table 5.2. Finally, the random shock in equation (7) joins that of equation (1), but has no effect on the estimates.

In order to identify the value of b, we assume a unitary long-run elasticity of the housing stock with respect to population, similarly to Bar-Nathan, et al. (1998), Nagar and Segal (2011) and Weiner and Fuerst (2017). In addition, we impose a unitary coefficient of housing completions in equation (5), that is, we impose a constant ratio in the long-run between housing completions and the housing stock.

Before presenting the results, we note that under these conditions the implied value for b is 0.71, which suggests a substantial bias in the data to an extent that seems unreasonable to us.[33] We interpret this as an indication that the assumption of a unitary elasticity is too strong, and we view the results of this exercise as bounding the values of the long-run elasticities, rather than correcting the baseline estimates. The results are presented in Table 5.2 under the columns labeled "Unitary stock elasticity".

[33] $b = 0.71$ implies that over time the completions data reflect only 71 percent of actual housing completions. This suggests undervaluation of almost 20,000 units of dwellings per year over the last decade, which in our view seems widely unreasonable.

In examining the results, note that, as expected, the elasticity of the housing stock has increased (in absolute value) with respect to all variables. In particular, the estimate of the elasticity of long-run supply has almost doubled—rising from 0.43 to 0.83. That said, and although this is a substantial difference, the conclusion that the long-run supply is inelastic remains, especially when keeping in mind that these figures should be taken as upper bounds for the actual elasticities.

As for the rest of the elasticities, they remain similar in magnitude to those of the baseline estimates. In particular, the elasticity of rents with respect to the interest rate remains high, while the sensitivity of prices to the interest rate is even somewhat lower.

6. The econometric model: The short-run equations

This section estimates the short-run dynamics of rents, home prices and construction activity. To that end, we estimate difference equations with error-correction factors, i.e., the residuals from the long-run equations. These residuals measure the misalignment of the endogenous variables relative to their long-run equilibrium level, and we expect them to affect the dynamics in the short-run as they act as a gravitational force that constantly pulls the system toward its long-run equilibrium. For example, we expect shortage in housing units to raise rents and home prices, which in turn will accelerate construction activity and thereby reduce the initial shortage.

We add to the model two exogenous variables that we did not use in the estimation of the long-run equations: the change in the shekel-dollar (NIS-USD) exchange rate (deflated by the CPI excluding housing), and the change in the short-term real interest rate. We add these variables to the estimation starting in 1997, after inflation in Israel dropped to single-digit level and monetary policy adopted an inflation targeting regime and the use of the overnight nominal interest rate as the main policy instrument.[34]

After years of high inflation, denominating rents and home prices in US dollars became common practice in Israel, to protect against their erosion by inflation. As a result, nominal rigidity in dollar terms emerged. With the decline in inflation during the late 1990s and early 2000s, exchange rate fluctuations became a dominant factor in the variation of prices (after conversion to shekels), and hence requiring to control for exchange rate movements in the

[34] The effect of these variables prior to 1997 is statistically insignificant.

regressions. As the shekel started to gain strength against the dollar, especially starting in 2007, the market moved to denominating prices in local currency. We therefore multiply the exchange rate in the regressions by the share of dollar-denominated rent contracts.[35] Note that since in our econometric specification we deflate nominal prices by the CPI excluding housing, we do the same for the exchange rate.

We measure the short-term real interest rate using the Bank of Israel policy rate net of expected inflation from the capital markets (breakeven inflation). This variable provides an indication of the effect of monetary policy on the housing market. That said, a better measurement of the effect of monetary policy may be achieved by deflating the interest rate by the inflation target rather than by expected inflation, as the latter is affected by other factors in addition to policy. However, for the agents acting in the housing market, it is the expected real rate that matters, and hence we choose to use it in the specification of the model, though we also evaluate the direct effect of monetary policy in sensitivity checks.

We estimate the short-run equations by OLS. Tables 6.1a and 6.1b present the estimation results, where the first rows in the tables summarize the effects of the error-correction terms, i.e., the deviations from the long-run equilibrium, on the dynamics in the short-run. Below we describe our choice for the specification of each equation (highlighted in red in the tables) and the considerations that have guided us.

At the end of this section, and in order to close the model, we estimate a stock-flow equation that links housing completion to the stock of dwellings. This equation represents the fourth quadrant in the DW model (see Figure 3.1), and we will use it for calculating the impulse response functions of the model (see Section 8).

6.1 Rent dynamics

Column (1) in Table 6.1a presents the equation for the short-run dynamics of rents. The coefficient of the error-correction term from the demand equation is negative and statistically significant, as expected. A 1 percent surplus of dwellings relative to demand is estimated to reduce rents in the next period by 5.8 percent.

[35] Data on the share of dollar-denominated rent contract were published by the CBS during the years 2005–13 in its Price Statistics Monthly. In 2005 about 89 percent of rent contracts were denominated in US dollars, and by 2013 this rate fell to merely 2 percent. We assume that before 2005 the share of dollar-denominated rent contracts was 90 percent, and zero after 2013.

As for short-run factors, rent displays high inertia as the coefficient of its lags are positive and sum up to 0.78. Changes in lagged home prices have a negative effect on rents, similar to the result of Bar-Nathan, et al. (1998). This may reflect short-term substitution between rental demand and homeownership, that is, a tendency towards homeownership provides a tailwind to home prices while demand for rentals declines, which pushes rents downward. The DW model provides an alternative explanation for the negative price coefficients: a rise in prices stimulates construction activity, and the rise in supply reduces rents. However, this argument goes through construction supply, and when we add housing completions to the regression (column (3) in Table 6.1a) its effect is insignificant. It therefore seems that this mechanism is more suitable for explaining long-run developments, rather than short-term dynamics.

We obtain a result along similar lines for the effect of the short-term real interest rate. The interest rate coefficient is positive, similar to the result of Nagar and Segal (2011). They argue that as a rise in the interest rate makes mortgages more expensive, it shifts demand from homeownership to rentals and therefore raises rents.

Changes in the stock of housing and population affect rent dynamics, beyond their effect through the error-correction factor. The estimated coefficients have the expected sign, negative for the stock of housing (supply effect) and positive for population (demand effect). In addition to population growth, we find that an acceleration in its growth rate also raises rents.

Finally, rents are sensitive to changes in income and in the NIS-USD exchange rate during the period it was customary to denominate them in dollars. The indexation to the dollar is reflected by its coefficient that is insignificantly different from 1.

Columns (2) through (4) in Table 6.1a examine the sensitivity of the results to the effects of additional factors. Column (2) adds the error-correction terms from the asset-pricing equation and from the supply equation, and column (3) examines the effect of the remaining variables of the model we did not include in the baseline specification. In both cases, the effects of the additional variables are insignificant, and compared with column (1), their inclusion in the regression does not change the results much. In particular, it is noteworthy to point out that rents do not react to asset pricing misalignment, at least not directly, and hence realignment is brought about through the adjustment of home prices (as discussed below). That said, rents contribute indirectly to closing deviations from the asset-pricing equation through their reaction to lagged home prices. A positive deviation, i.e., too-high home prices or too-low rents, reduces

Table 6.1a: Estimation results of short-run equations for rents and home prices, 1981-2019, annual frequency

Dependent variable:	(1) Δlog(rent)	(2) Δlog(rent)	(3) Δlog(rent)	(4) Δlog(rent)	(5) Δlog(price)	(6) Δlog(price)	(7) Δlog(price)	(8) Δlog(price)	(9) Δlog(price)
Resid_Demand(-1)	-5.7836***	-5.2081***	-5.4904***	-5.5322***	-4.0185***	-3.9922***	-4.6169***	-3.9544***	-4.2988***
	(0.9014)	(1.1933)	(1.1770)	(0.9376)	(0.7327)	(0.7719)	(1.1821)	(0.7705)	(0.8098)
Resid_Asset_Pricing(-1)		0.0222			-0.2116***	-0.2194***	-0.2029***	-0.1982***	-0.2152***
		(0.0603)			(0.0467)	(0.0490)	(0.0570)	(0.0573)	(0.0489)
Resid_Supply(-1)		0.0474					-0.0392		
		(0.0632)					(0.0411)		
Δlog(rent(-1))	0.3743***	0.3361**	0.2420	0.4157***			0.1297		
	(0.1187)	(0.1361)	(0.1634)	(0.1230)			(0.1579)		
Δlog(rent(-2))	0.4019***	0.4124***	0.4216***	0.3675***					
	(0.1180)	(0.1312)	(0.1255)	(0.1224)					
Δlog(h_stock(-1))	-4.0182***	-5.1475***	-3.9167***	-3.4870***				-0.0852	
	(0.9720)	(1.8010)	(1.2456)	(0.9670)				(1.0578)	
Δlog(pop(-1))	1.7787**	2.1745**	1.6668*	1.5619**				0.2215	
	(0.7335)	(0.9382)	(0.8202)	(0.7598)				(0.9146)	
ΔΔlog(pop)	3.9302***	4.0943***	4.1854***	3.9119***	3.2954***	3.3200***	3.1994**	3.3295***	2.8805***
	(0.8846)	(0.934)	(0.9742)	(0.9314)	(0.8903)	(0.9383)	(1.2975)	(0.9317)	(1.0084)
ΔΔlog(pop(+1))					2.7903***	2.6896***	2.7647***	2.8894***	2.7957***
					(0.8451)	(0.8893)	(0.9052)	(0.9728)	(0.8611)
Δlog(rw_emp)	0.3056**	0.2937**	0.3548	0.3300**	0.7411***	0.7251***	0.7081***	0.6942***	0.7301***
	(0.1298)	(0.1359)	(0.2249)	(0.1361)	(0.1539)	(0.1617)	(0.1958)	(0.1962)	(0.1817)
Δlog(price(-1))	-0.6059***	-0.5616***	-0.5677***	-0.5644***			-0.0781		
	(0.1126)	(0.1294)	(0.1257)	(0.1155)			(0.1472)		
Δlog(price(-2))	-0.4182***	-0.4131***	-0.4233***	-0.3816***					
	(0.0780)	(0.0804)	(0.0887)	(0.0789)					
Δfwd_rate(-1)					-2.2834*	-2.0399	-2.2606*	-2.3578*	-2.7218*
					(1.1460)	(1.2063)	(1.3130)	(1.2388)	(1.3708)
Δfwd_rate			-1.2463						
			(1.4205)						
(1-D1997)*Δinf_std			0.2237		1.8656**	1.9045**	1.7170**	1.8065**	1.6771**
			(0.6914)		(0.6784)	(0.7147)	(0.7646)	(0.7348)	(0.7258)
Δlog(comp(-1))			0.0356						-0.0386
			(0.0485)						(0.0414)
Δlog(const_cost)			-0.0021						-0.0679
			(0.0028)						(0.2623)
D1997×S×Δlog(dollar)	1.0845***	1.1073***	1.1592***	0.9903***					
	(0.2404)	(0.2652)	(0.2637)	(0.2486)					
D1997×Δ[BoI-π_exp]	1.2519*	1.2683*	1.2195						
	(0.6763)	(0.7195)	(0.7294)						
D1997×Δ[BoI-π_tar]				0.3168					
				(0.4352)					
D1997×Δ[BoI(-1)- π_exp(-1)]					-2.1244***		-1.9436**	-2.0499***	-2.1622***
					(0.6727)		(0.7326)	(0.7115)	(0.6997)
D1997×Δ[BoI(-1)- π_tar(-1)]						-1.1674**			
						(0.4739)			
Constant	0.0769***	0.0913***	0.0802***	0.0664***			0.0018		
	(0.0214)	(0.0312)	(0.0252)	(0.0215)			(0.0091)		
R^2	0.7762	0.7813	0.8015	0.7526	0.7960	0.7739	0.8084	0.7976	0.8023
No. of Observations	39	39	39	39	38	38	38	38	38

Table 6.1b: Estimation results of short-run equations for housing supply and the housing stock, 1981-2019, annual frequency

Dependent variable:	(1) Δlog(comp)	(2) Δlog(comp)	(3) Δlog(comp)	(4) Δlog(comp)	(5) Δlog(h_stock)	(6) Δlog(h_stock)
Resid_Demand(-1)	-8.2573***	-8.1901***	-10.9229***	-8.2756***		-0.1080**
	(1.7456)	(1.7661)	(2.8637)	(1.7647)		(0.0410)
Resid_Asset_Pricing(-1)	0.3210**	0.3182**	0.3070**	0.3176**		0.0099***
	(0.1184)	(0.1216)	(0.1425)	(0.1198)		(0.0029)
Resid_Supply(-1)	-0.4479***	-0.5045***	-0.5278***	-0.4443***		
	(0.1342)	(0.1476)	(0.1600)	(0.1358)		
Δlog(rent(-1))			0.4350			
			(0.3541)			
Δlog(h_stock(-1))	-10.5228***	-10.1973**	-8.4046*	-10.8329***	0.8711***	0.5104***
	(3.8363)	(4.3092)	(4.5434)	(3.9157)	(0.0530)	(0.0544)
Δlog(pop(-1))	15.4912***	14.7870***	14.5783***	15.4780***		0.4095***
	(2.2166)	(2.5540)	(2.4306)	(2.2406)		(0.0472)
ΔΔlog(pop)	7.0877***	7.2401***	8.2662***	6.9939***		0.2125***
	(2.1702)	(2.1772)	(2.5216)	(2.1997)		(0.0503)
Δlog(rw_emp)		0.4489				
		(0.4281)				
Δlog(price(-1))			-0.3394			
			(0.3102)			
Δfwd_rate			-0.4034			
			(2.5508)			
(1-D1997)*Δinf_std			-1.1060			
			(1.4509)			
Δlog(comp)					0.0174***	
					(0.0019)	
Δlog(comp(-1))		0.0955			0.0097***	0.0073***
		(0.0968)			(0.0018)	(0.0023)
Δlog(const_cost)		-0.7391				
		(0.5183)				
D1997×Δ[BoI(-1)- π_exp(-1)]				0.8479		
				(1.4910)		
Constant	-0.1487**	-0.1447**	-0.1764**	-0.1405**	0.0023*	
	(0.0646)	(0.0659)	(0.0724)	(0.0669)	(0.0012)	
R^2	0.8559	0.8696	0.8652	0.8574	0.9197	0.9148
No. of Observations	39	39	39	39	40	39

Legends			
Resid_Demand	Error-correction factor of the housing stock relative to demand	inf_std	Standard deviation of monthly CPI inflation during a calendar year
Resid_Asset_Pricing	Error-correction factor of the asset-pricing equation	comp	Number of dwellings for which construction was completed during the year
Resid_Supply	Error-correction factor of construction supply	const_cost	Cost index of inputs in residential building, deflated by CPI excl. housing
rent	Rent index, deflated by CPI excluding housing	dollar	NIS-USD exchange rate, deflated by CPI excluding housing
h_stock	The stock of housing	BoI	The Bank of Israel interest rate
pop	Adult population, age 25+	S	Share of rent contracts denominated in dollars
rw_emp	Average real wage per employee post multiplied by the employment rate	π_exp	Inflation expectations from the financial markets (breakeven inflation)
price	Home price index, deflated by CPI excluding housing	π_tar	Inflation target
fwd_rate	5-10 years forward return on CPI-indexed government bonds	D1997	A dummy variable, equals 1 starting 1997

prices in the next period (see below) and these pull rents upward after an additional period, due to the negative effect of prices on rents (column (1)). Furthermore, we note that the effect of the long-term interest rate on rents is insignificant, though its inclusion has affected the significance of the coefficients of income and the short-term interest rate (column (3)).[36] Finally, in column (4), we examine the effect of monetary policy more directly, as we discount the Bank of Israel interest rate by the inflation target instead of by inflation expectations. In this case, the effect of the short-term interest rate on rents becomes insignificant, suggesting that rents react to market rates and not necessarily directly to monetary policy.

6.2 Price dynamics

Column (5) in Table 6.1a presents the equation for short-run dynamics of home prices. The change in home prices is affected by the error-correction factors of the asset-pricing equation and that of the demand equation. An overvaluation of 1 percent reduces prices by only 0.2 percent after a year, reflecting that the convergence to the long-run equilibrium may take several years. A 1 percent surplus of dwellings relative to demand is estimated to reduce prices in the next period by 4.0 percent.

As for short-run factors, acceleration in current and expected population growth[37] lifts home prices, as do an increase in income and in inflation volatility.[38] A rise in financial returns reduces prices. Here we find a significant effect, and of similar magnitudes, of both the long- and short-term interest rates; a rise of 1 percentage point in either of them reduces home prices in the next period by slightly more than 2 percent. We note that although the coefficient of the long-term rate is somewhat larger, the effect of the short rate is more significant, and this result is robust to the different specifications we examined (columns (6) through (9)). In order to evaluate the direct effect of monetary policy, we discount the short rate by the inflation target instead of by inflation expectations (column (6)). In this case, the estimated coefficient is much smaller and the fit of the regression deteriorates somewhat. The coefficient of the short-term interest rate remains smaller even when the long-term rate is omitted (not shown). We conclude

[36] The regression in column (3) also includes variables from the supply equation; however, additional examinations point to the long-term interest rate as the factor that affects the coefficients of income and the short rate. This may reflect collinearity among the variables, and the coefficient of the long-term interest rate may become significant in a longer sample.

[37] We use next period's population growth rate as an indicator for its expected rate, as in Bar-Nathan, et al. (1998).

[38] The change in the standard deviation of inflation enters the regression only until 1996. After that period, inflation fell to a single-digit level, and changes in its volatility have become minor (Figure 4.1.7). This variable is important for the estimation of the high inflation period during the 1980s.

from the results that the effect of monetary policy is about 45 percent lower than the effect of the real short-term interest rate.

Columns (7) through (9) in Table 6.1a present robustness checks for the results. Column (7) adds the error-correction factor from the construction-supply equation, lagged changes in home prices and rents, and a constant term. The coefficients of these variables are insignificant, and the rest remain stable relative to their values under the baseline specification in column (5). Column (8) adds population growth and the growth of the housing stock, both lagged, and column (9) adds the variables from the supply equation, construction cost and housing completions; in both cases, the estimated coefficients of the additional variables are insignificant and the rest remain stable relative to their value under the baseline specification.

6.3 The change in housing completions

Column (1) in Table 6.1b presents the estimated short-run dynamics of construction supply (housing completions). All error-correction factors affect the change in housing completions. A 1 percent surplus of dwellings relative to demand reduces housing completions by 8.3 percent in the next period. Overvaluation of 1 percent relative to the asset-pricing equation raises housing completions by 0.3 percent. This effect may be driven by the slow convergence of prices to their equilibrium level, suggesting that current overvaluation may signal homebuilders that prices are expected to remain elevated in coming years. Finally, a 1 percent deviation of construction activity from its supply schedule reduces housing completions by 0.45 percent after a year. Among the short-run factors, we find that only changes in the housing stock and population have a significant effect on housing completions.

Columns (2) through (4) in Table 6.1b present robustness checks to the baseline specification. Column (2) adds supply factors, lagged housing completions and construction cost, and income from the demand equation. Column (3) adds factors from the asset-pricing equation, lagged home prices, rents, the forward rate and inflation volatility. In both cases, the coefficients of these variables are insignificant and they do not affect the results of the baseline estimation much. The result that lagged prices do not affect supply dynamics indicates that the actors in the construction market are forward looking, and the signals they receive from the asset-pricing equation and the dynamics of the housing stock relative to population are sufficient for them for learning about the future development of prices. Finally, column (4) examines the effect of the short-term interest rate, but its coefficient is insignificant and with a sign that is opposite of what is expected.

6.4 Closing the model: The dynamics of the housing stock

In the following sections we conduct two exercises that require the closing of the model: (1) a dynamic simulation that evaluates whether the model is able to track the endogenous variables based solely on the realization of the exogenous variables and initial conditions; and (2) analysis of impulse response functions that evaluates how shocks are transmitted through the system.

In the DW model, a stock-flow identity closes the model by linking the stock of housing and housing completions in a given period to the stock of housing in the next period. In principle, we can conduct a similar calculation in the econometric model as the series of the housing stock in the sample is constructed by accumulating housing completions; however, to that end we need knowledge of the level of the housing stock in the initial period. This approach is appropriate for the exercise of dynamic simulation because we have data on the level of the housing stock at the beginning of the sample, and all that is left to do is to accumulate the estimates of housing completions. However, we cannot apply this approach for the calculation of the impulse response functions, as they represent the behavior of the system for any arbitrary level of the housing stock. In order to close the model in that case, we must characterize generally how a percentage change in housing completions translates into a percentage change in the stock of housing. In addition, it would be convenient to maintain an auto-regressive structure, so we can calculate the dynamics of the model simply by rolling the system forward.

Along the lines of the DW model, we first estimate the housing stock as a function of housing completions and its own lag, all in log-difference. In this estimation, we are mainly interested in a good fit rather than an economic explanation, as the motivation for this estimation stems from an accounting identity. Column (5) in Table 6.1b presents the estimation results. The results reveal high inertia in the dynamics of the housing stock, and that both the contemporaneous and lagged change in completions are important for explaining its evolution. However, the contemporaneous housing completions is endogenous; hence, in order to achieve an auto-regressive representation, we substitute it with its baseline specification, as presented in column (1) of Table 6.1b. The results are summarized in column (6), where we omitted from the estimation the constant and the error-correction term of the supply equation, as both turned insignificant. The estimated coefficients maintain their sign from the equation describing the dynamics of housing completions (column (1)), with the exception of the coefficient of the lagged housing stock as it contains both the positive inertial effect (column (5)) and the contractionary effect on supply (column (1)). Overall, the estimation results in a high goodness of fit, 0.91. Below, we use this specification for the calculation of the impulse response functions.

7. Dynamic simulation and historical decomposition

7.1 Dynamic simulation

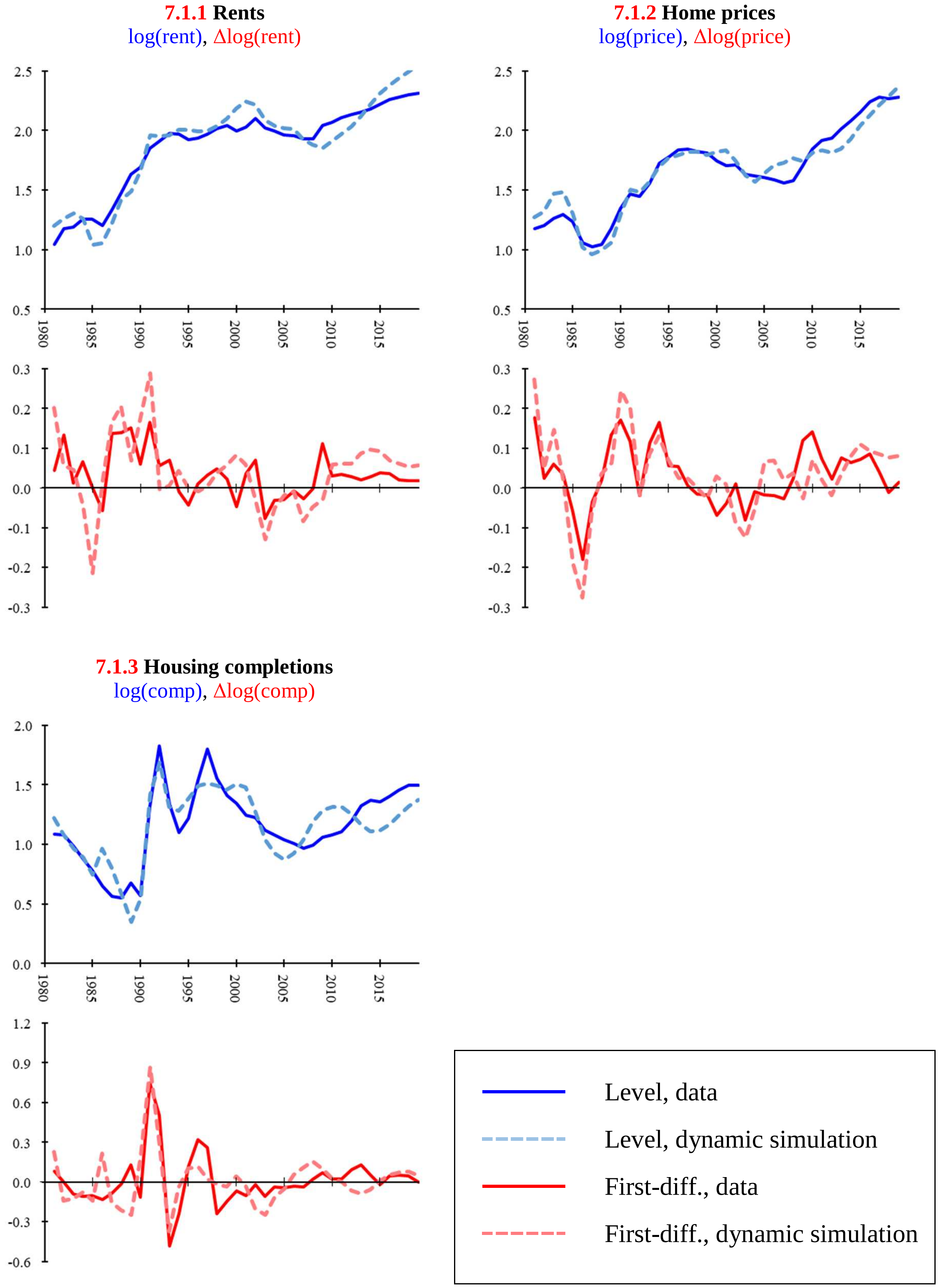
The sample period spans over four decades, and during that period the housing market may have gone through significant changes. Our concern is that relations among the variables that existed at the beginning of the sample may no longer hold at its end.

The econometric estimation yields decent goodness of fit, between 0.75 and 0.85, for the dynamics of rents, home prices and housing completions (Tables 6.1a and 6.1b). However, these equations rely on the realization of the endogenous variables (in lags), and in particular all error-correction terms are based these data. This section performs a dynamic simulation for the endogenous variables, that is, we estimate the value of the endogenous variables in every period based solely on the development of the exogenous variables and the initial conditions at the beginning of the sample, in 1980. If during the sample period, the housing market has gone through substantial structural changes that undermines the ability of the model to estimate the behavior of the endogenous variables, then we expect the results of the dynamic simulation to diverge from the actual data. Appendix B presents the methodology for calculating the dynamic simulation.

Figure 7.1 presents the results of the simulation for the evolution of rents, home prices and housing completions. Evidently, the model tracks well their development in the data. The results suggest that the stochastic trend in the data originates in the exogenous variables; market prices and quantities react to them, but do not contain shocks of their own that determine the stochastic trend. We conclude that despite the long sample period, the estimated relations are sufficiently fundamental so that structural changes, to the extent they occurred, did not affect them substantially, and that our specification does not omit any important exogenous factor that is detrimental to the long-run developments of the market.

Figure 7.1: Dynamic simulation of rents, home prices and housing completions

Levels (upper panels) and first-differences (lower panels), log points, 1981-2019



As for the factors behind the rise in home prices in the recent cycle, it is interesting to note that the simulation hints that pressures for a price increase already started in 2005, while in practice prices fell for two additional years (Figure 7.1.2). In 2007, at the eve of the rise in prices, the simulated price is about 17 percent higher than its actual level, suggesting that a low starting point explains at least part of the sharp rise in prices that followed. The historical decomposition in the next section provides a more detailed analysis of the developments in the housing market and of the factors driving them.

7.2 Historical decomposition

This section examines the contribution of the different variables to the development of rents, home prices and housing completions during the sample period. For ease of exposition, instead of presenting the estimated contributions year by year, we focus on four periods, according to the development of prices in the sample: We start from the years 1989–96 in which prices increased sharply due to the immigration wave from the states of the former Soviet Union; the second period covers the years 1997–2007, in which prices fell consistently; we then examine 2008–11 where prices started surging in the current cycle; and finally we examine the years 2012–19. Note however that, as discussed below, in order to understand the rise in prices during 2008–11, it is useful to examine their development at the eve of that period. Hence, we present the period of 2008–11 alongside the years 2005–07.

Figure 7.2 presents the historical decomposition of the contribution of the different variables to the development of rents, home prices and housing completions, as estimated by the short-run equations (Tables 6.1a and 6.1b). The decomposition presents the contribution of each of the exogenous variables, of the error-correction factors (presented in Figure 5.1), and the combined contribution of the lagged endogenous variables.[39]

Rents. We start with rents. Figure 7.2.1 presents its historical decomposition. Population development is the most dominant factor supporting the rise in rents throughout the sample. In particular, its contribution during the immigration wave stands out, especially when keeping in mind that this contribution is over and above the demographic effect captured by the shortage

[39] It is difficult to provide an economic interpretation for the contribution of the lagged endogenous variables, as they themselves are affected by the exogenous variables. We therefore combine the contributions of all endogenous variables under one factor, and avoid providing an economic interpretation for its contribution. Note that the error-correction terms are also functions of the endogenous variables; however, here the interpretation is clearer as they reflect deviations from long-run equilibrium conditions.

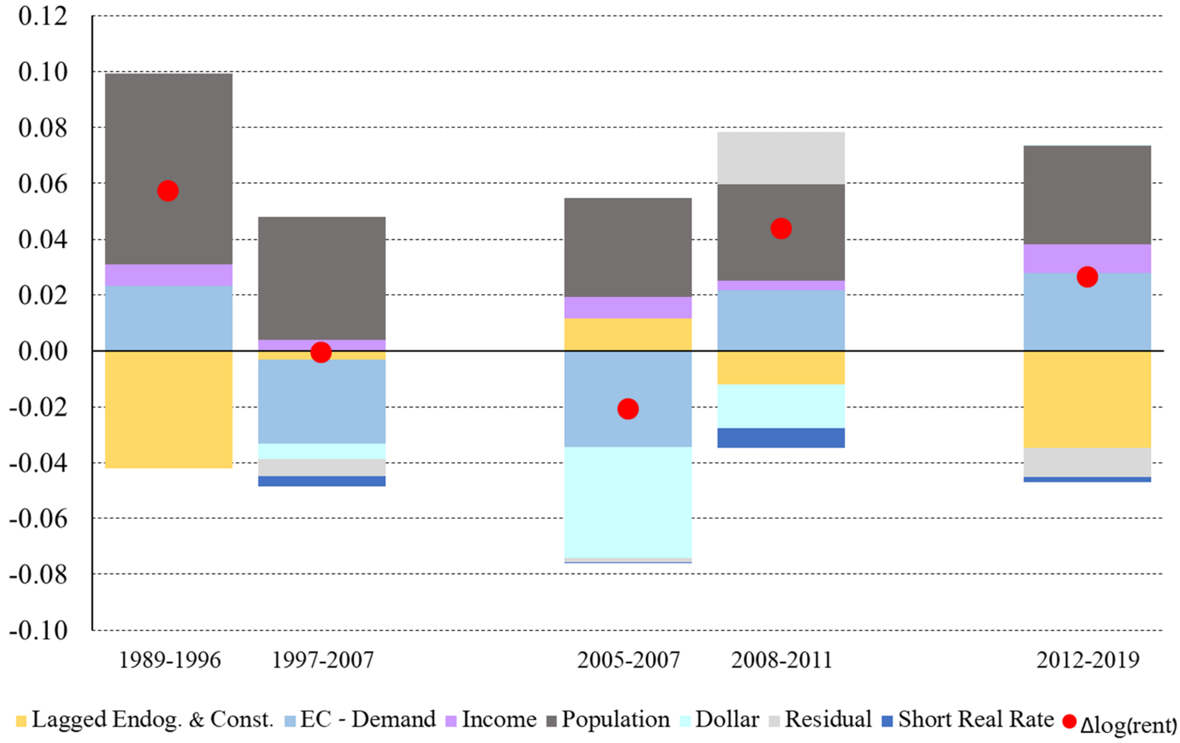
in dwellings (i.e., the error-correction term of demand). The housing shortage clearly contributed its share to the rise in rents, but its effect is smaller than the direct short-run effect of population growth. During the decade following the main immigration wave, population growth continued supporting rents. However, the shortage turned into a surplus and overall rents remained stable during the period. In 2008–11, rents rose sharply again. Compared with the preceding three years, it appears that the main factor that had changed is the transition from a surplus to a shortage in dwellings, due to several years of insufficient construction (see also Figures 5.1.1 and 5.1.3). In addition, the shekel-dollar exchange rate, which played a significant role in pushing rents downward during 2005–08, put lower pressure on rents, mainly due to abandoning the practice of denominating rent contracts in dollars. Finally, in recent years, 2012–19, rents have risen mainly due to population growth and a persistent shortage in dwellings. Overall, population growth has persistently supported rents throughout the sample, and in fact, this true for income as well, although quantitatively its contribution is much smaller. At the same time, it seems that the main factor generating cycles in rents is the development of shortage or surplus in dwellings, as measured by the error-correction term of the demand equation.

Home prices. Figure 7.2.2 presents the historical decomposition of home prices. During the immigration wave, the main factor that pushed prices higher was undervaluation of housing (see also Figure 5.1.2), which explains almost half of the total rise in prices during that period. Of course, the underlying factor is the immigration wave itself, but in terms of the model the direct effect comes from rents (which, as noted above, rose due to the rise in population), which in turn, drove prices higher. The rise in home prices was milder than suggested by the asset-pricing equation, resulting in undervaluation. Interestingly, this result is consistent with the theoretical prediction of Poterba (1984). In his model, price-setting is forward looking, and hence agents in the market understand that the rise in demand, which drives rents higher, will also increase future supply. As a result, the reaction of home prices is milder. Other factors also contributed to the rise in prices, including shortage in dwellings, population growth and a rise in income, though the contribution of each of them is much smaller than the contribution of the error-correction term of the asset-pricing equation.

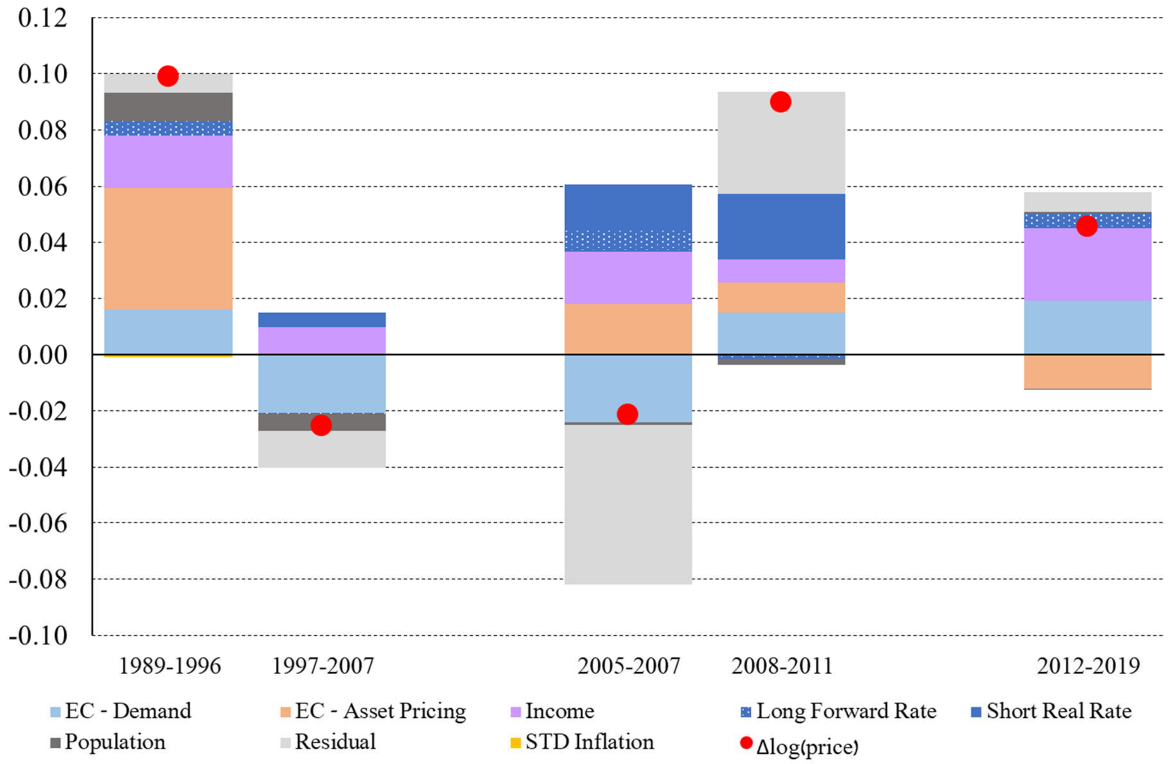
During the decade following the immigration wave, in 1997–2007, prices fell at an average annual rate of 2.5 percent. The effect of most factors is relatively minor during that period, with the exception of the transition from shortage into surplus in dwellings, which was the main factor driving prices lower.

Figure 7.2: Historical decomposition of rents, home prices and housing completions

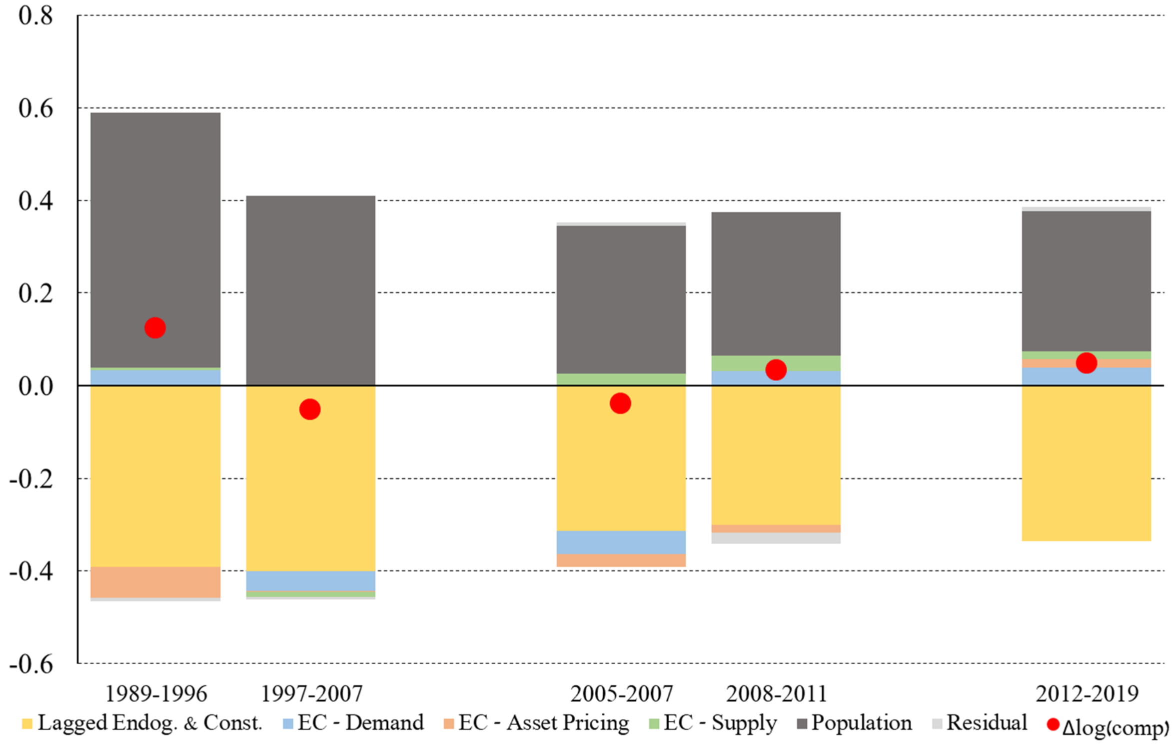
7.2.1 The change in rents, Δlog(rent)
Log points, annual averages



7.2.2 The change in home prices, Δlog(price)
Log points, annual averages



7.2.3 The change in housing completions, Δlog(comp)
Log points, annual averages



Notably, the model is unable to track well the rise in prices during 2008–11, as it generates a very large residual in that period. That said, examining the development of prices in the preceding three years sheds light on the reason for the large residual and the sharp rise in prices that followed. First, a large residual with the opposite sign stands out for the period preceding 2008. Both residuals, the positive in 2008–11 and the negative in 2005–07, are exceptional in size compared with the rest of the sample and this may indicate that pressures for higher prices have started to build as early as 2005.[40] During 2005–07, house prices actually fell by an average annual rate of 2.1 percent. Therefore, it seems that the rise in prices, starting in 2008, was largely driven by their low initial level, which did not conform to market's fundamentals at that time. This is also consistent with the error-correction term of the asset-pricing equation, which points to undervaluation of home prices during the period preceding 2008 (see also Figure 5.1.2). During 2006–07, at the eve of the rise in prices, the asset-pricing equation suggests an undervaluation of 13.7 percent on average. The large residuals here suggest that the undervaluation was also driven by short-run factors, and overall it may have been even larger, as suggested as well by the results of the dynamic simulation. In 2008–11 prices rose at

[40] In fact, the residual of 2008 is also negative even though prices have started rising in that year. That is, the model suggests that market conditions supported a higher rise in prices than actually realized in that year. Exceptional positive residuals are recorded mainly for 2009–10.

an annual pace of 9.0 percent, where 4.7 percentage points of which (about half) are associated with undervaluation (3.6 from the residual and 1.1 from the error-correction term). Other factors that supported the rise in home prices are the transition from a surplus in dwellings to a shortage, which on average contributed 1.5 percent per year (one-sixth of the total rise in prices), and the short real interest rate, which contributed on average 2.4 percent per year (about a quarter). In contrast to Nagar and Segal (2011), who emphasize the role of monetary policy as the main factor behind the surge in prices that at that time, our estimates suggest that although the short interest rate definitely provided tailwinds, it was not the main factor behind it. In fact, its contribution to prices during 2008–11 is not much larger than its contribution in the preceding three years. Furthermore, the contribution here is that of the short real rate, and as discussed above, we estimate the effect of monetary policy to be about 45 percent smaller.

Finally, in 2012–19, prices continued rising though at a lower, yet substantial, pace (4.6 percent per year, on average). During that period, the main factors supporting prices were a persistent shortage and the rise in income, while overvaluation has acted to moderate their rise.

Overall, since the beginning of the recent rise in home prices in 2008, the shortage in dwellings and the rise in households' income are the two factors that have consistently pushed prices higher. During that period, on average, the shortage in dwellings raised prices by 1.8 percent per year, while income growth contributed 2.0 percent annually.

Housing completions. Figure 7.2.3 presents the historical decomposition of housing completions. It is apparent that the two main factors driving housing completions are population growth and the housing stock[41], where population growth stimulates construction activity and a rise in the housing stock suppresses it. The magnitude of their effect overshadows the contributions of other factors in the regression, even though they are not negligible. In particular, during the period of the immigration wave, undervaluation slowed down the pace of construction, while the shortage in dwellings provided tailwinds. During 1997–2007, the effects of population growth and the housing stock approximately cancel each other, and the surplus in dwellings tilted activity toward a reduction in housing completions. From 2008 until the end of the sample, the shortage in dwellings alongside insufficient construction (the error-correction term of supply) have accelerated housing completions. Finally, we note that overvaluation, starting in 2012, has also supported the acceleration in housing completions.

[41] The stock of housing (lagged) is the only endogenous variable in the regression (column (1) in Table 6.1b).

8. Impulse response functions

The coefficients in the error-correction equations reflect the short-run reaction of each of the endogenous variables to market conditions, separately. This section analyzes the dynamic response of the system as a whole, that is, while taking into account the interaction between the various components of the model. To that end, we calculate the impulse response functions of the system to disturbances in the short-run equations.

The impulse response functions present the difference between the path of the endogenous variables under an arbitrary scenario and their path under an alternative one that differs only in the evolution of one of the shocks. The residuals in the short-run equations do not display serial correlation, hence in the following exercise we let the shocks decay within one period, that is, their value is zero in all periods except for the period in which we hit the system. For presentation purposes, in order to show all impulses in one graph, the size of the shocks to rents and prices is one percent, and the shock to housing completions is 10 percent.[42] Figure 8.1 presents the impulse response functions of the endogenous variables and those of the error-correction terms. Appendix B presents the methodology for calculating the impulse response functions.

8.1 A shock to rents

The continuous blue lines in Figure 8.1 present the response of the system to a 1 percent shock to rents. In the short-run, a rise in rents reduces construction activity due its contractionary effect on demand, though after three years the cycle is reversed as prices start to rise and support construction activity.

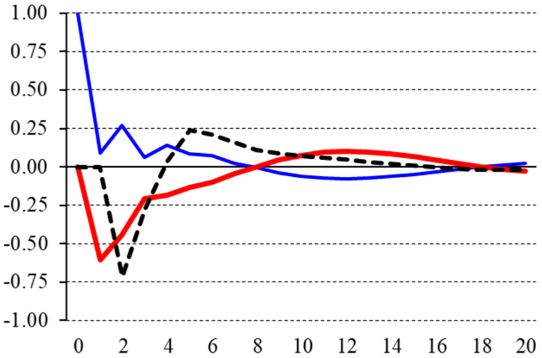
The rise in rents instantaneously affects two error-correction terms; it generates a surplus of dwellings (Figure 8.1.5) due to lower demand at the new rent level, and it makes home prices undervalued (Figure 8.1.6). These have opposing effects on prices, and at the estimated coefficients' value they approximately cancel each other, leaving prices stable one period after the shock (Figure 8.1.2). At the same time, both factors have a contractionary effect on construction supply, which reduces housing completions after one period (Figure 8.1.3). The decrease in supply reduces the stock of housing (Figure 8.1.4), and gradually erodes the initial

[42] The variance of housing completions is large compared to that of rents and prices. This implies that the system requires a relatively sizable shock in completions in order to obtain responses of similar magnitude to those obtained from the shocks to rents or home prices.

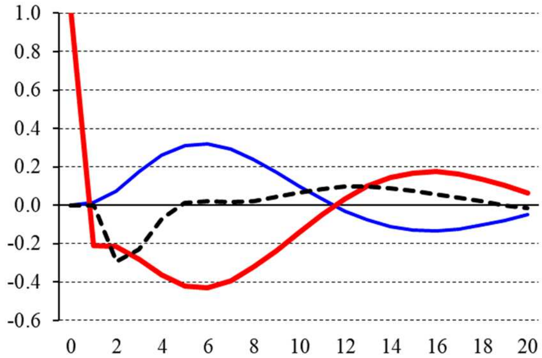
Figure 8.1: Impulse response functions to shocks in rents, prices and completions

100 × log points

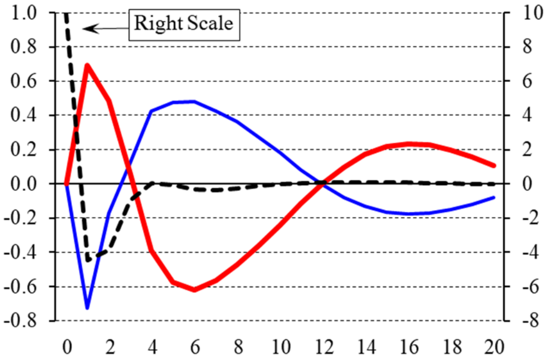
8.1.1 Response of rents, Δlog(rent)



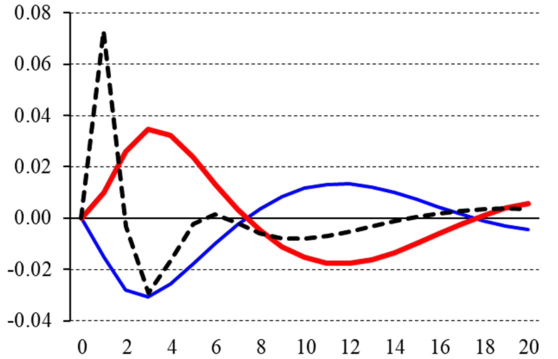
8.1.2 Response of home prices, Δlog(price)



8.1.3 Response of housing completions, Δlog(comp)

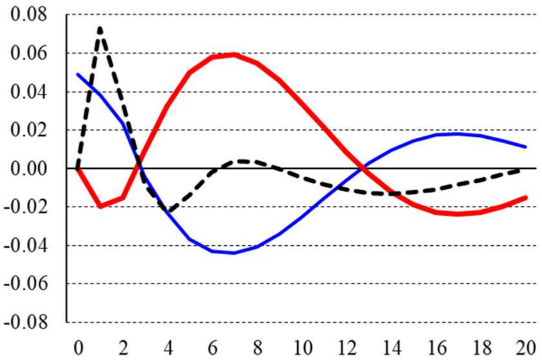


8.1.4 Response of the housing stock, Δlog(h_stock)



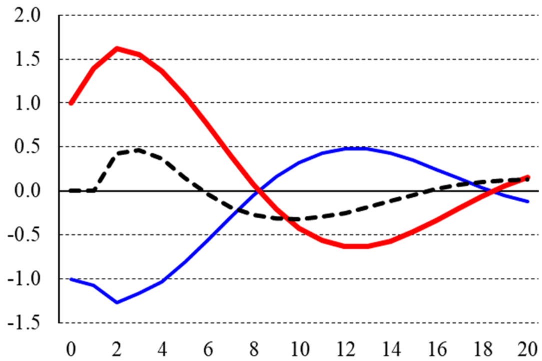
8.1.5 Error-correction: Demand equation

Shortage/Surplus, percent of the housing stock



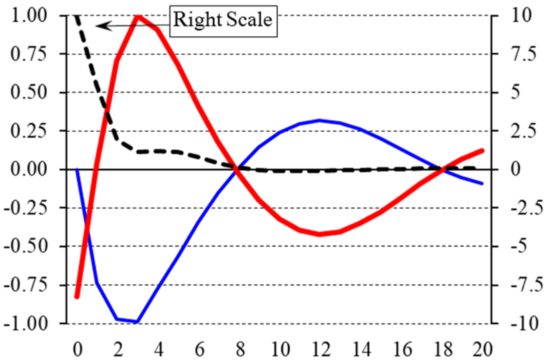
8.1.6 Error-correction: Asset-pricing equation

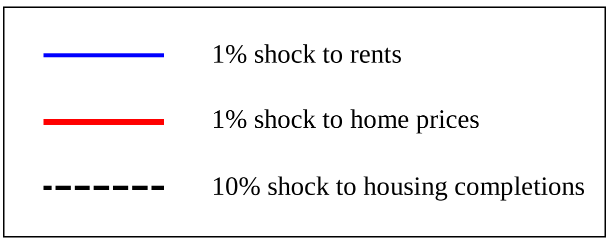
percent of house prices



8.1.6 Error-correction: Supply equation

percent of housing completions





surplus, though as long as prices are undervalued and the surplus persists, the pressures for lower construction activity continue.

Alongside these effects, the change in rents is highly inertial (Table 6.1a), and therefore, despite the surplus in dwellings during the initial periods, rent appreciation fades very slowly (Figure 8.1.1). The continued rise in rents prolongs the duration required for closing the price misalignment (undervaluation), which persistently supports a rise in prices. The rise in prices increases homebuilders' profitability, and alongside the initial fall in construction activity, housing completions become lower than the long-run equilibrium level (Figure 8.1.7). This effect supports reversing the cycle, and after three years from the shock, construction activity starts rising.

8.2 A shock to home prices

The continuous thick red lines in Figure 8.1 present the response of the system to a 1 percent shock to home prices. Generally, the reaction of the system to a rise in prices is approximately opposite to its reaction to a rise in rents. Initially, the higher prices expand supply, and after a few years the cycle is reversed and construction activity contracts.

The rise in prices instantaneously affects two error-correction terms; it generates overvaluation (Figure 8.1.6), and under-construction relative to the long-run supply (Figure 8.1.7). Both factors accelerate construction activity in the following year (Figure 8.1.3), while the overvaluation also puts downward pressure on prices (Figure 8.1.2) in order to realign prices with the asset-pricing equation. At the same time, the initial rise in prices reduces rents (Figure 8.1.1) due to its lagged effect (Table 6.1a), which generates a small shortage in housing (Figure 8.1.5), in spite of the rise in construction activity mentioned above. However, as prices start to fall, the initial rise in profitability erodes, and at the ongoing elevated level of construction activity, an excess supply emerges (Figure 8.1.7). After four years from the initial shock, construction activity is reversed, and housing completions start to contract.

8.3 A shock to housing completions

The dashed black lines in Figure 8.1 present the response of the system to a 10 percent shock to housing completions. The rise in supply generates excess construction and reduces rents and home prices in the short run.

The rise in completions is terminated after only one period (Figure 8.1.3) as it generates a surplus of dwellings (Figure 8.1.5). After an additional period, this surplus reduces rents and prices (Figures 8.1.1 and 8.1.2, respectively), but due to a stronger reaction by rents, home prices become overvalued (Figure 8.1.6). Although the increase in construction activity lasts for only one period, the excess supply persists for several years (Figure 8.1.7), reflecting that the fall in construction activity is relatively mild compared with its initial rise (Figure 8.1.3), and it is also a result of the overvaluation. After three years from the initial shock, the decline in rents stimulates demand sufficiently to turn the initial surplus into shortage (Figure 8.1.5) and the cycle is reversed, although with a relatively mild effect on the system.

9. Conclusion

The housing market is characterized by long cycles, reflecting persistent deviations from the long-run equilibrium. The estimation of an econometric model for the Israeli housing market reveals that these deviations have a crucial effect on its short-run dynamics. In order to identify the long-run equilibrium relations, the estimation relied on a sample that spans over four decades and the structural model of DW guided its specification.

The estimation provides several insights on the characteristics of the housing market, and on the factors contributing to its evolution during the sample period. We find that both long-run demand and long-run supply are quite inelastic. Notably, the supply elasticity is affected, among other factors, by the planning and construction policy—Cavalleri, et al. (2019) and Caldera and Johansson (2013), and the inelastic supply reflects the difficulty of the market to adjust its quantities to evolving demographic needs; as a result, the market-clearing mechanism works to a large extent through price adjustment. The model also sheds light on the interaction between home prices and rents: a rise in rents raises the return of homeownership, and hence increases home prices; in contrast, a rise in home prices reduces rents as it stimulates housing supply.

As for the factors behind the surge in prices in 2008–11, several indications suggest it was triggered by undervaluation in the preceding period: in 2006–07 home prices were 13.7 percent lower, on average, than their implied level by the asset pricing equation, and the dynamic simulation of the model points to an even larger figure. In addition, and although the model is unable to account well for the rise in prices during 2008–11, in the preceding three years prices had fallen excessively, in terms of the model, and the surge in prices that followed had largely corrected the misalignment in prices.

The shortage in dwellings had a moderate but persistent contribution to the recent rise in home prices, and starting in 2012 it is one of the main factors, alongside income growth, supporting them. That said, the acceleration in construction activity in recent years has closed much of the shortage towards the end of the sample. Finally, monetary policy also contributed to the rise in prices in 2008–11, though it played a minor role, and starting in 2012 its contribution is negligible.

The analysis in this paper paints the picture of the housing market in general contours. It uses macro data and does not dive into details such as changes in construction policies, subsidies to targeted populations, and taxation reforms. Nevertheless, the dynamic simulation of the model is able to track well the evolution of prices and quantities in the market over four decades, relying only on initial conditions from 1980 and the development of the exogenous variables. Therefore, it seems that the model is able to describe well the main developments in the market, despite its limitations.

Appendix A: Estimating "potential households"

In the body of the text, we noted that the endogenous reaction of housing density might affect the extent to which the series of the number of households, as measured by the CBS, is indicative of housing demand. Recall that the CBS defines a household as a person or a group of persons that live regularly in the same dwelling and share a budget for food. However, we expect this estimate to vary with housing affordability, as a number of "potential" households may tend to live in the same dwelling in face of rising housing costs. If this is the case, then the measurement method, as applied by the CBS, understates the number of households indicative of housing demand.

This appendix derives an estimate for potential households, compares it to the series of adult population we use in the body of the text for the estimation of the econometric model, and presents suggestive evidence for the endogeneity of the raw households' series.

To estimate the number of potential households we use population data by marital status and age. When a rise in the price of housing services pushes young couples to live in their parents' home, for example, information about the number of married couples may help identify the number of households relevant for housing demand. This approach assumes that marital status is unaffected by developments in the housing market; however, even if this assumption is not completely accurate, our estimate is likely to better reflect housing demand than the raw series of the number of households. Under this assumption, we attempt to extract the exogenous component of the raw series, i.e., the component that is unaffected by developments in the housing market. To that end, we use data on the number of married people age 20 and above and the number of unmarried people age 25 and above[43], and estimate the following equation:

$$log(hh_t) = \gamma_0 + \gamma_m log(married_t) + \gamma_{um} log(un\_married_t) \quad \text{(A1)}$$
$$+\gamma_{mt} trend_t \times log(married_t) + \gamma_{umt} trend_t \times log(un\_married_t) + u_t^{hh}$$

Where hh is the number of households as measured by the CBS, $married$ is the number of married persons age 20 and above, $un\_married$ is the number of unmarried persons age 25 and above, and $trend$ is a linear time trend. The interaction variables with the time trend are meant to capture the effect of changes in the distribution of marital status in the population over time. Our estimate for the series of potential households is the fitted value of the regression. We estimate equation (A1) by FMOLS, and note that the estimate we obtain from the logarithmic specification, as presented above, is almost identical to the one obtained from a specification that uses the original units.[44]

Figure A1 presents the estimated series and compares it to the series of adult population we used in the text. The two are almost identical, not only in their level but also in their rate of change, with the exception of minor differences at the beginning of the sample. The correlation coefficient between them, in first difference, is 0.94. This comparison suggests that the cost of using the series of adult population in the econometric analysis is probably low, even though the series of potential households is theoretically more appropriate for representing demography in the demand equation. The data processing required for generating potential households and their availability with a significant lag, also supports using the adult population in this study.

43 Until 1995 the CBS reported marital status by division between singles (i.e., never-married) and non-singles. In order to separate the non-singles to married and unmarried, we used the CBS labor-force surveys for calculating the share of married in the non-singles population.

44 Equation (A1) was estimated for the sample period of 1976-2018 (42 observations after adjustment), according to data availability. Estimation results:

Variable	constant	log(married)	log(un_married)	trend×log(married)	trend×log(un_married)
Coefficient	1.7837***	0.4275***	0.2934***	0.0018***	-0.0012***
(Standard error)	(0.4087)	(0.0738)	(0.0252)	(0.0004)	(0.0004)

*** 1 percent significance, R^2=0.9997

Figure A1: Potential households and the adult population (age 25+)

Level (upper panel) and first-difference (lower panel), in logs, 1980-2019

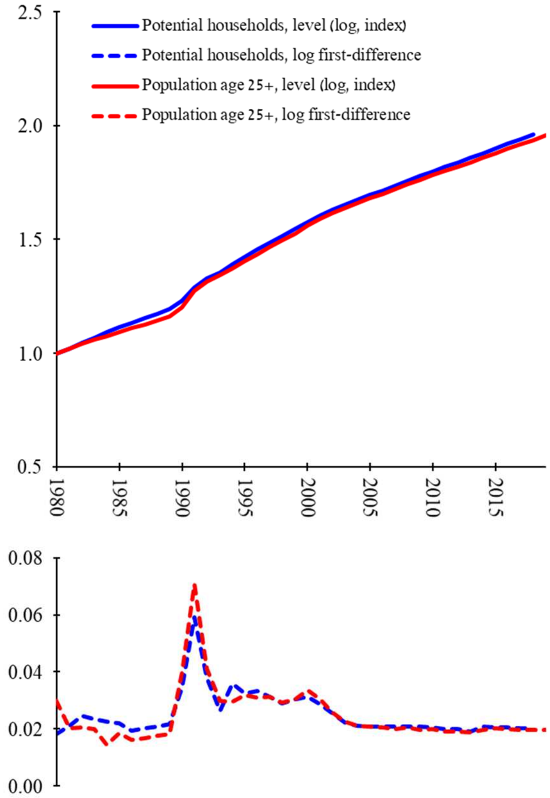
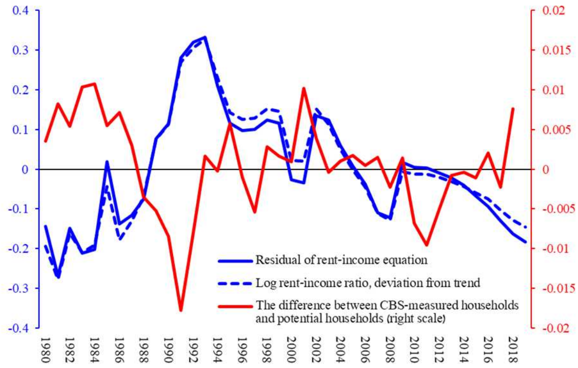


Figure A2: The difference between the measured number of households and "potential households", and the development of rents relative to income

Log points, 1980-2019



Finally, we look into the claim of endogeneity in the raw series of households. If there is truth to this hypothesis, then we expect that in periods of low housing affordability, i.e., in periods where the price of housing services is high relative to income, the number of potential households would be greater than the measured number of households in the raw data. This suggests that the residual of equation (A1) would be negative in periods of low housing affordability and positive in periods of high affordability. For an indication of this endogeneity, we examine the estimated residuals of equation (A1) relative to the rent-income ratio (detrended) and relative to the residual from regressing real rent on real income, as follows[45,46]:

$$log(rent_t) = \beta_0^{d,rent} + \beta_{rw\_emp}^{d,rent} log(rw\_emp_t) + u_t^{d,rent} \quad \text{(A2)}$$

Figure A2 presents the results. The correlation coefficient between the residuals is negative and significant and equals -0.54; so is the correlation with the rent-income ratio (detrended), which is -0.50. These results support the hypothesis that housing affordability affects housing

[45] We measure rent and income in the same way as in the main text. See Table 4.1 for details.

[46] Equation (A2) is estimated by FMOLS for the sample period of 1980–2019 (40 observations). The income coefficient is 1.4255 and its standard deviation is 0.1640. The R^2 is 0.8523.

density, and in particular it affects the measurement of the number of households in the official statistics. Notably we do not find similar evidence when measuring housing affordability using home prices. In that case, the correlation coefficients are practically zero.

Appendix B: The methodology for calculating the dynamic simulation and impulse response functions

This appendix presents the methodology for calculating the dynamic simulation and the impulse response functions. We write the model in general form as follows:

$$AY_t = BX_t^{LR} + u_t \quad \text{(B1)}$$

$$\Delta Y_t = \alpha u_{t-1} + \sum_{i=1}^{p} \beta_i \Delta Y_{t-i} + \gamma X_t^{SR} + \varepsilon_t \quad \text{(B2)}$$

Where (B1) summarizes the long-run equations and (B2) summarizes the short-run equations. The number of long-run equations equals the number of cointegration relations (which we label as r), and the number of short-run equations equals the number of endogenous variables (n). $Y_t \in \mathbb{R}^n$ is the vector of endogenous variables, $X_t^{LR} \in \mathbb{R}^{k_{LR}}$ is the vector of exogenous variables in the long-run equations, and $X_t^{SR} \in \mathbb{R}^{k_{SR}}$ is the vector of exogenous variables in the short-run equations. Let k denote the total number of exogenous variables in the system, that is $k = k_{LR} + k_{SR}$. Δ is the first-difference operator, and p is the number of lags in the short-run equations. u is a vector of the error-correction terms and ε is a vector of residuals of the difference equations. $A, B, \alpha, \beta_1 \ldots \beta_p, \gamma$ are coefficient matrices of conformable dimensions.

Using (B1), substitute for u_{t-1} into (B2), and rearrange to get an $AR(p+1)$ representation for Y_t:

$$Y_t = (I_n + \alpha A + \beta_1) Y_{t-1} + \sum_{i=2}^{p} (\beta_i - \beta_{i-1}) Y_{t-i} - \beta_p Y_{t-p-1} - \alpha B X_{t-1}^{LR} + \gamma X_t^{SR} + \varepsilon_t \quad \text{(B3)}$$

Below we use the auto-regressive representation of (B3) for calculating the dynamic simulation and the impulse response functions.

B.1 Dynamic simulation

The dynamic simulation calculates the development of the endogenous variables only as a function of the exogenous variables and initial conditions. Given the value of the endogenous variables at the beginning of the sample, estimates for the coefficient matrices, and the realized path of the exogenous variables, one can use equation (B3) recursively to derive estimates for the endogenous variables in every period (setting the residuals to zero).

The dynamic simulation in the text uses equation (B3) for rents, home prices and housing completions—that is, we use only three of the four equations defined by (B3). In order to close the model we must specify an equation for the stock of dwellings. Recall however, that in our data this series is calculated by accumulating housing completions, and hence there is no need to represent it as a stochastic process; instead, we simply conduct an analogous calculation in the simulation:

$$h\_stock_t = h\_stock_{t-1} + comp_t \tag{B4}$$

Finally, we note that the simulation in the text uses 1980 data as the initial conditions, the estimated value of the entries in A and B are presented in Table 5.1, and those of α, the β's and γ are presented in table 6.1a and 6.1b.

B.2 Impulse response functions

We now turn to calculating the dynamic response of the endogenous variables to disturbances in the residuals of the short-run equations. The impulse response functions describe the difference between the evolution of the endogenous variables under an arbitrary path of the exogenous variables and the random shocks, and their evolution under an identical path that only differs in a disturbance to one of the shocks.

Unlike the dynamic simulation, in this case we cannot accumulate housing completions to calculate the stock of dwellings, because the model is estimated in log-differences and we have to convert *percentage changes* in completions into *percentage changes* in the housing stock, at any arbitrary level of the housing stock. To calculate the impulse response functions we therefore use the estimation of the short-run dynamics of the housing stock, column (6) in Table 6.1b, which links empirically housing completions to the stock of dwellings in log-differences.

We can now write equation (B3) as an $AR(1)$ process:

$$\tilde{Y}_t = \Lambda \tilde{Y}_{t-1} + \Gamma \tilde{X}_t + \tilde{\varepsilon}_t \tag{B5}$$

Where:

$$\tilde{Y}_t \equiv [Y_t{}' \quad \cdots \quad Y_{t-p}{}']' \qquad \tilde{X}_t \equiv [X_{t-1}^{LR}{}' \quad X_t^{SR}{}']' \qquad \tilde{\varepsilon}_t \equiv [\varepsilon_t{}' \quad 0_{np\times 1}{}']'$$

$$\Lambda \equiv \begin{bmatrix} I_n + \alpha A + \beta_1 & \beta_2 - \beta_1 & \beta_3 - \beta_2 & \cdots & \beta_p - \beta_{p-1} & -\beta_p \\ & I_{np} & & & & 0_{np\times n} \end{bmatrix}_{n(p+1)\times n(p+1)}$$

$$\Gamma \equiv \begin{bmatrix} -\alpha B & \gamma \\ 0_{np\times k_{LR}} & 0_{np\times k_{SR}} \end{bmatrix}_{n(p+1)\times k}$$

Let IMP_{t+s}^{i} denote the difference in period $t + s$ between the value of the endogenous variables under some arbitrary baseline scenario, i.e., an arbitrary path of $\tilde{X}_t$ and $\tilde{\varepsilon}_t$, and their values under an identical scenario except that the i'th disturbance in this scenario is higher by δ in period t and then immediately returns to its value in the baseline.[47] In the text, δ is set to 0.01 for rents and home prices, and to 0.1 for housing completions.

Define e_i $(i = 1, \ldots, n)$ as a vector size $n(p + 1) \times 1$, where in our case $n = 4$ and $p = 2$, whose entries are all zero except for the entry at the i'th place which equals 1:

$$e_i(j) = \begin{cases} 1 & if\ j = i \\ 0 & otherwise \end{cases}$$

Now, using equation (B5), we can calculate IMP_{t+s}^{i} recursively:

$$IMP_t^i = \delta e_i \qquad i = 1, \ldots, n$$

$$IMP_{t+s}^i = \Lambda IMP_{t+s-1}^i \qquad s = 1,2,3, \ldots \qquad i = 1, \ldots, n$$

[47] In principle one can introduce persistence to the shocks, however in our estimation the residuals display no serial correlation.

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