Hot and Cold Seasons in the Housing Markets*

L. Rachel Ngai
London School of Economics, CEP, CEPR

Silvana Tenreyro
London School of Economics, CEP, CEPR

April 2008

PRELIMINARY AND INCOMPLETE

Abstract

In the U.K., every year during the second and third quarters (the “hot season”), regional housing markets experience sharp above-trend increases in (quality-adjusted) prices and in the number of transactions. During the fourth and first quarters (the “cold season”), house prices and the number of transactions fall below trend. A similar seasonal cycle for transactions is observed in other developed countries. Housing prices, however, do not necessarily follow a seasonal pattern in all countries. In particular, in the U.S., while transactions are highly seasonal, prices display no seasonality. We discuss why the traditional asset-pricing approach to the housing market fails at explaining seasonal booms and busts and present a search model that can quantitatively mimic the seasonal fluctuations in transactions and prices in both the U.K. and the U.S. The model features a “thick-market” externality that can generate substantial differences in the number of transactions across seasons. The existence and extent of seasonality in prices depend on the distribution of market power between buyers and sellers.

*For helpful comments, we would like to thank Robert Barro, Francesco Caselli, Christian Julliard, Francois Ortalo-Magne, Denise Osborn, Chris Pissarides and Richard Rogerson. E-mails: Ngai: <l.nagi@lse.ac.uk>, Tenreyro: <s.tenreyro@lse.ac.uk>.
1 Introduction

A rich empirical and theoretical literature has been motivated by dramatic boom-to-bust episodes in regional and national housing markets.\(^1\) Booms are typically defined as times when prices rise and there is intense trading activity, whereas busts are times when prices and trading activity fall below trend.

While the boom-to-bust episodes motivating the extant work are relatively infrequent and of unpredictable timing, this paper shows that in several housing markets, booms and busts are just as frequent and predictable as the seasons. In particular, in all regions of the U.K., as well as other continental European countries, every year a housing boom of considerable magnitude takes place in the second and third quarters of the calendar year (the “hot season”), followed by a bust in the fourth and first quarters (the “cold season”). In other countries, including the U.S., transactions display a strong seasonal pattern, while prices display no seasonality. The first contribution of this paper is to document the existence, quantitative importance, and cross-country variation of these seasonal booms and busts.

The surprising size and predictability of seasonal fluctuations in housing prices in some countries poses a challenge to standard models of durable-good markets. In those models, anticipated changes in prices cannot be large: If prices are expected to be much higher in May than in December, then buyers will shift their purchases to the end of the year, narrowing down the seasonal price differential. More formally, in the absence of risk, the asset-market equilibrium condition states that the one-period rental value of a house plus its appreciation should equal the one-period gross cost of housing services.\(^2\) Calling \(p_t\) and \(d_t\) the real price of housing and rental services, respectively, and assuming that the gross real service cost is a (potentially changing) proportion \(v_t\) of the property price, the equilibrium asset-market condition is:

\[
d_{t+1} + (p_{t+1} - p_t) = v_t \cdot p_t
\]

where \(v_t\) is the sum of the (potentially time-varying) depreciation rate, maintenance and repair expenditure rate, property tax rate, and the tax-adjusted interest rate.\(^3\) The arbitrage condition

\(^1\)See for example Stein (1995), Krainer (2001), Ortalo-Magne and Rady (2005) and the contributions cited therein.

\(^2\)For an early asset-market approach to the housing market, see Poterba (1984).

\(^3\)The effective interest rate is a weighted average between mortgage interest rate plus the opportunity cost of housing equity, where the weights are given by the loan-to-value ratio.
thus states that the seasonals in real prices must be accompanied by seasonals in the cost of housing services \( v_t \) or in the rental service flow \( d_t \). Rents, however, display no seasonality, implying a substantial and, as we shall argue, unrealistic degree of seasonality in service costs \( v_t \). For example, the price seasonality observed in the U.K. implies that service costs should be roughly 300 percent higher in the cold season than in the hot season. This seems unlikely, particularly because interest rates and tax rates, two major components of \( v_t \), display no seasonality. The implied seasonality of service costs is even higher, and hence even more implausible in other countries, such as France and Belgium.

We investigate a number of possible explanations for the seasonal booms and busts. The seasonal in housing markets does not seem to be driven by seasonal differences in liquidity related to overall income. Income is typically high in the last quarter, a period in which housing prices and the volume of transactions tend to fall below trend.\(^4\) At any rate, all these variables are predictable, and in an informationally efficient market, their effect should be incorporated in prices so that future price changes are unforecastable. Indeed, the predictable nature of housing prices fluctuations is confirmed by U.K. estate agents, who in conversations with the authors observed that during winter months there is less activity and owners tend to sell at a discount. And, perhaps more compelling, publishers of house price indexes go to great lengths to produce seasonally adjusted versions of their indexes, usually the index that is published in the media. As stated by the publishers:

"House prices are higher at certain times of the year irrespective of the overall trend. This tends to be in spring and summer, when more buyers are in the market and hence sellers do not need to discount prices so heavily, in order to achieve a sale." and "...we seasonally adjust our prices because the time of year has some influence. Winter months tend to see weaker price rises and spring/summer see higher increases all other things being equal." (From Nationwide House Price Index Methodology.)

"Houses prices are seasonal with prices varying during the course of the year irrespective of the underlying trend in price movements. For example, prices tend to be higher in the spring and summer months when more people are looking to buy." (From Halifax Price Index Methodology.)

\(^4\)Beaulieu and Miron (1992) and Beaulieu, Miron, and MacKie-Mason (1992) show that in most countries, including the U.K., income peaks in the fourth quarter of the calendar year. There is also a seasonal peak in output in the second quarter, and seasonal recessions in the first and third quarters. Housing price seasonality is not in line with income seasonality: prices are above trend in the second and third quarters.
The seasonal behavior of housing markets and the failure of *a priori* appealing explanations, thus poses a new puzzle to the standard asset-market approach. This paper tries to resolve the puzzle by resorting to a search-theoretic approach.

Specifically, we develop a search model in which housing prices and the volume of transactions in each season (or semester) are derived from the maximizing behavior of both buyers and sellers. At the beginning of each season a house can be in one of two states: “matched,” when it delivers a positive housing service flow to its owner, or “on sale,” when it does no longer yield housing services to its owner. Each match has a probability of breaking, in which case the house goes “on sale.” Agents who own houses where the match is broken seek to sell them (“sellers”) and agents who are *not* matched to a house seek to buy one (“buyers”). Buyers and sellers are randomly matched. Upon visiting a house, the buyer draws an idiosyncratic matching quality reflecting the utility services the house will yield while matched; this match quality is only observed by the buyer. The potential buyer searches until she finds a house whose utility services, net of price, are above the option value of keeping searching.

The model yields a quantitatively large amplification mechanism: A slightly higher probability that a housing match breaks in a given season (e.g., because of changes in schools, household size, jobs, etc.) can trigger a “thick-market” externality that makes it appealing for a large number of agents to buy during that season. This is because, in the model, buyers are more likely to find a better-quality match (and hence their willingness to pay increases) when there are more houses on sale. Hence, in a thick market (the hot season), the volume of transactions goes up. Whether or not prices also go up depends on the distribution of market power between buyers and sellers. Because the quality of matches and hence buyers’ willingness to pay increase in a thick market, when sellers “set prices” (that is, sellers have monopoly power in the transaction) they can extract all the surplus of the transaction (buyers’ higher willingness to pay) by charging higher prices in hot seasons. When instead buyers set prices, they get all the surplus of the transaction and prices are therefore insensitive to the season. The extent of price seasonality hence depends on the degree of market power of sellers and buyers.

We show that the calibrated model can account for a large fraction of the seasonal fluctuations in transactions in the U.K. and the U.S., and at the same time match the seasonality in prices in the U.K. together with the lack of seasonality in prices for the U.S.\(^5\) The only crucial distinction

---

\(^5\)Our focus on these two countries is largely driven by the reliability and quality of the data.
between the two economies in the calibrated model is that in the U.K. sellers have more power to set prices than in the U.S. As we later argue, this can be justified on the grounds that land is scarcer and building regulations more stringent in the U.K.

To summarize, the contribution of this paper is twofold. First, it documents seasonal booms and busts in housing markets and shows that the predictability and high extent of seasonality in prices observed in some of them cannot be quantitatively reconciled with the standard asset-pricing equilibrium condition embedded in most models of housing markets (or consumer durables, more generally).

Second, it develops a search model that can account for the empirical puzzle and shed new light on the mechanisms governing fluctuations in housing markets.

The paper is organized as follows. Section 2 presents the empirical evidence and discusses different potential (though ultimately unsuccessful) explanations. Section 3 argues why, given the evidence, we need to deviate from the standard asset-pricing approach to housing markets. Section 4 presents the new model. Section 5 presents a quantitative analysis of the model and confronts it with the empirical evidence. Section 6 presents concluding remarks.

2 Hot and Cold Seasons

This section documents the behavior of housing prices across what we refer to as the two main seasonal terms: the summer term (second and third quarters of the calendar year) and the winter term (first and fourth quarters) in different countries and regions within a country.

2.1 Data

In the analysis we shall pay particular attention to the housing-market records of the U.K. and the U.S., the countries for which the data are of highest quality. Below is a brief description of the data on prices and transactions in these two countries. A description of the data sets and sources for other countries studied in this Section is available in the Data Appendix.

U.K.

In the U.K. there are two main data sets providing quality-adjusted non-seasonally adjusted
prices: the Halifax House Price Index, derived from the data collected by Halifax, one of the country’s largest mortgage lenders, and the price index produced by the Office of the Deputy Prime Minister (ODPM).\footnote{Other price indices, like Nationwide, report quality adjusted data but they are already seasonally adjusted. The Land Registry data reports average prices, without adjusting for quality.}

Halifax reports regional indexes on a quarterly basis for the 12 standard planning regions of the U.K., as well as for the U.K. as a whole. The indexes calculated are ‘standardized’ and represent the price of a typically transacted house. The standardization is based on hedonic regressions that control for a number of characteristics, including location, type of property (house, sub-classified according to whether it is detached, semi-detached or terraced, bungalow, flat), age of the property, tenure (freehold, leasehold, feudal), number of rooms (habitable rooms, bedrooms, living-rooms, bathrooms), number of separate toilets, central heating (none, full, partial), number of garages and garage spaces, garden, land area, and road charge liability. Accounting for these characteristics allows to control for the possibility of seasonal changes in the composition of the set of properties (for example, shifts in the location or sizes of properties). The index reports transaction prices based on mortgages to finance house purchase at the time the mortgage is approved; re-mortgages and further advances are excluded.

The ODPM index is based on the same method as is the Halifax index, and differs only in two respects. First, it collects information from a large sample of all mortgage lenders in the country.\footnote{The Halifax index uses all the data from Halifax mortgages.} And second, it reports the price at the time of completion, rather than approval. Completion might take on average three to four weeks after the agreement, due generally to paper-work delays. The ODPM index goes back to 1963, though only after 1993 does it include all mortgage lenders (before that time prices are based on Building Societies reports).

To compute real price indexes, we later deflate the housing price indexes using the non-seasonally adjusted retail price index (RPI) including “All items except housing” provided by the U.K. Office for National Statistics.

As an indicator of the number of transactions, we use the number of mortgages advanced for home purchases; the data are collected by the ODPM through the Survey of Mortgage Lenders and are disaggregated by region.
The non-seasonally adjusted price index for the U.S. comes from the Office of Federal Housing Enterprise Oversight (OFHEO), which in turn builds its index from data provided by Fannie Mae and Freddie Mac, the biggest mortgage lenders; this is a repeated-sale index (and hence, barring depreciation, quality is kept constant). The index is calculated for the whole of the U.S. and also disaggregated by state (the 50 states and the District of Columbia) and by the 379 metropolitan statistical areas defined by OFHEO.

To compute real price indexes, we use the non-seasonally adjusted consumer price index (CPI) including “All items less shelter” provided by the U.S. Bureau of Labor Statistics.\footnote{As it turns out, there is little seasonality in the U.S. CPI index, a finding first documented by Barsky and Miron (1989), and hence the seasonal patterns (or lack thereof) in nominal and real housing prices coincide.}

Data on the number of transactions come from the National Association of Realtors, and correspond to the number of sales of existing single-family homes. The data are disaggregated into the four major Census regions.

### 2.2 The Cross-Country Evidence

This Section briefly summarizes the cross-country evidence on seasonal fluctuations in housing prices and transactions. The extent of seasonality is summarized by means of country-by-country OLS regressions of the type:

\[
g_{rt} = \alpha_r + \beta_r S_t + \varepsilon_t \quad \text{and} \quad g_{pt} = \alpha_p + \beta_p S_t + \varepsilon_t,
\]

where \(g_{rt}\) is the annualized growth rate of the quarterly number of transactions, \(g_{pt}\) is the annualized growth rate of the quarterly (quality-adjusted) house price index (expressed both in nominal and real terms), \(S_t\) is a dummy variable that takes the value 1 if \(t\) corresponds to the second or third quarter of the calendar year, and 0 otherwise. \(\alpha_r\) (\(\alpha_p\)) measures the average growth rate in the number of transactions (housing prices) during the period and \(\beta_r\) (\(\beta_p\)) measures the average difference in growth rates between summers and winters. A statistically significant value for the \(\beta\)'s rejects the null of no difference in growth rates across seasons. Table 1 and Table 2 report the slope coefficients and standard errors of the regressions for transactions (Table 1) and both nominal and real prices (Table 2).
Table 1 suggests a strong and positive “summer” effect in all countries for which non-seasonally adjusted data on housing transactions are available. Table 2 displays a uniform pattern of signs for housing prices, with countries in the northern hemisphere displaying a positive second-and-third quarter effect and countries in the southern hemisphere displaying a negative effect (note that the austral summer takes place in the fourth and first quarters and hence the negative signs in the southern hemisphere). However, the statistical and economic significance varies across countries. Belgium, France, and the U.K. display strongly significant summer effects; Ireland, Sweden, and South Africa exhibit a less marked, though still significant summer effect; and finally, Denmark, Norway, the U.S., Australia, and New Zealand show no statistically significant summer effect.

While the time span differs across countries, a sensitivity analysis performed by the author shows that the period covered does not significantly affect the extent of seasonality.

Table 1: Average Difference in the Annualized Growth Rate in the Number of Transactions between Second-Third Quarters and Fourth-First Quarters, by Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Coef.</th>
<th>Std. Error</th>
<th>Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Belgium</td>
<td>61.675**</td>
<td>(15.008)</td>
<td>51</td>
</tr>
<tr>
<td>Ireland</td>
<td>47.834**</td>
<td>(17.936)</td>
<td>120</td>
</tr>
<tr>
<td>Sweden</td>
<td>194.489**</td>
<td>(35.106)</td>
<td>75</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>121.184**</td>
<td>(17.398)</td>
<td>124</td>
</tr>
<tr>
<td>United States</td>
<td>162.354**</td>
<td>(19.369)</td>
<td>149</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard deviations) on the dummy variable $S_t$ (second-third quarters) in the regressions $g_t=a+b\times S_t+e_t$, where $g_t$ is the annualized nominal or real house price growth, as indicated; $a$ is a constant, omitted. The equations use quarterly data (see Appendix). Robust standard errors in parentheses. +Significant at the 10%; *significant at the 5%; **significant at 1%.
Table 2: Average Difference in Annualized Housing Price Growth (nominal and real) between Second-Third Quarters and Fourth-First Quarters, by Country

<table>
<thead>
<tr>
<th>Country</th>
<th>Northern Hemisphere</th>
<th></th>
<th></th>
<th>Southern Hemisphere</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nominal price inflation</td>
<td>Real price inflation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>14.447** (1.507)</td>
<td>13.695** (1.740)</td>
<td>95</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denmark</td>
<td>1.085 (2.074)</td>
<td>1.029 (2.072)</td>
<td>51</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>France</td>
<td>12.459** (1.200)</td>
<td>12.198** (1.220)</td>
<td>34</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ireland</td>
<td>6.076* (2.934)</td>
<td>4.456 (2.999)</td>
<td>35</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Netherlands</td>
<td>2.723 (1.537)</td>
<td>3.234 (1.701)</td>
<td>48</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Norway</td>
<td>3.072 (3.333)</td>
<td>4.628 (3.224)</td>
<td>52</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweden</td>
<td>4.504 (2.270)</td>
<td>5.484* (2.187)</td>
<td>76</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United Kingdom</td>
<td>8.233** (2.325)</td>
<td>6.105* (2.354)</td>
<td>91</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>United States</td>
<td>0.272 (0.772)</td>
<td>-0.692 (0.892)</td>
<td>120</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard deviations) on the dummy variable \( S_t \) (second-third quarters) in the regressions \( g_t = a + b \times S_t + e_t \), where \( g_t \) is the annualized nominal or real house price growth, as indicated; \( a \) is a constant, omitted. The equations use quarterly data (see Appendix). Robust standard errors in parentheses. +Significant at the 10%; *significant at the 5%; **significant at 1%.

2.3 The Within-Country Regional Evidence

The size of countries (and hence the number of potential regional housing markets) varies substantially in the sample studied before. In particular, for large countries, it is in principle inappropriate to talk about a single national housing market. The finding of no seasonal patterns in prices at the aggregate level, for example, might mask different seasonal behaviors at more disaggregated levels. Conversely, the existence of a seasonal pattern in the aggregate might reflect some aggregation anomalies. It is hence of importance to study the behavior of prices (and transactions) at a more disaggregated level. we do so in this Section, starting with the U.K. and the U.S., the countries with highest-quality data; we also document the behavior of rentals and interest rates for these two countries. Finally, we describe the seasonal patterns for prices in different regions of Belgium and France.

Housing Market Seasonality in the U.K.

Nominal Housing Price Changes

Figure 1 reports the average annualized price growth rates in the summer term (second and third
quarters) and the winter term (fourth and first quarters) over the period 1983 through 2005 using the Halifax index. As shown in the graph, the differences in price growth rates across seasons are generally very large and economically significant. During the period analyzed, the average price increases in the winter term were below 4 percent in all regions except for West Midlands (4.8 percent), Greater London (5.4 percent) and the North region (6.6 percent). In the summer term, the average growth rates were above 11 percent in all regions, except for the North (9 percent).

Figure 1: Average annualized housing price growth in summers and winters. Halifax Index 1983-2005.

Figure 2 shows the results from the ODPM index, starting in 1983 (for comparability with the Halifax Index). The patterns are similar to those reported using Halifax. The annualized average price growth during the summer term is above 12 percent in all cases, whereas the increase during the winter term is systematically below 6 percent, except for Greater London and Northern Ireland. The qualitative patterns are similar to those obtained from Halifax; as mentioned before, the relatively small quantitative differences between the two indexes might be explained by the lag between approval and completion.
As mentioned, the ODPM index goes back to 1968 for most regions. The price growth rates starting in 1968 are displayed in Figure 3.\(^9\) As the Figure shows, the average difference in growth rates between summers and winters during the longer period are of the same order of magnitude, roughly above 8 percent.

Figure 2: Average annualized housing price growth in summers and winters. ODPM Index 1983-2005.

Note: Annualized (quality-adjusted) price growth rates in summers (second and third quarters) and winters (fourth and first quarters) in the U.K. and its regions. ODPM index 1983-2005.

\(^9\)Regions for which the data start after 1980 are not displayed in the graph.
Real Housing Price Changes

The previous figures showed the seasonal pattern in nominal housing price inflation. The seasonal pattern of real housing prices (that is, housing prices relative to the overall non-seasonally-adjusted price index) depends of course on the seasonality of overall inflation. In the U.K. overall price inflation displays a slightly seasonal pattern. In particular, over the period 1983 through 2005, the average annualized non-seasonally-adjusted inflation rate in the summer term has been 4.7 percent, whereas the corresponding figure in the winter term has been 2.8 percent. The difference of 2 percent can hardly “undo” the differences of over 8 percent in nominal housing price inflation, implying a significant seasonal in real housing prices. This is illustrated in Figure 4. The graph is based on the Halifax index, but the results are similar for the ODPM index, not shown in the interest of space. Netting out the effect of overall inflation reduces the differences in growth rates between winters and summers to a country-wide average just above 6 percent.

we should note in addition that non-seasonally adjusted indexes of inflation are rarely used in practice (indeed it is even hard to find them), so they are unlikely to serve in contracts as financial means to “hedge” part of the seasonal nominal housing price fluctuations.
Figure 4: Average annualized real housing price growth in summers and winters. Halifax Index 1968-2005.

Number of Transactions

The seasonal differences in housing prices are mirrored by the patterns exhibited by the number of loans for housing purchases, which are a good proxy for the number of transactions. The data are collected by the National Survey of Mortgage Lenders and go back to 1974. As Figure 5 shows, the growth rate in the number of loans for mortgage completions in the U.K. increases sharply during the summer term, while declining in the winter term. Unlike for prices, there is no strong trend in the number of transactions (that is why the growth rate is negative in the winter). Similar results are obtained by detrending the data using a linear trend (not shown). The post-1983 pattern is qualitatively and quantitatively similar to the one depicted in the Figure.
Statistical Significance of the Differences between Summers and Winters

This Section reports on the statistical significance of the results displayed in the previous figures, as well as the characteristics of the houses and buyers involved in the transactions, by way of region-by-region OLS regressions similar to those used for the countries as a whole, as described in equations (2) and (3). The regressions are based on the Halifax data series, although similar results are obtained from the ODPM data (results available on request). Table 3 summarizes the results. The first two columns show the coefficients and standard errors for the regressions based on prices for all houses and buyers. They show that the differences in housing price inflation are statistically significant at standard levels in all regions, except the North.

The following four columns show the corresponding figures for the prices of existing houses and new houses. The figures indicate that seasonal differences are mainly driven by the prices of existing houses, though new houses also display a fair amount of seasonality in some regions. In particular, new houses’ inflation rates display a strong seasonal pattern in Greater London, Scotland, Northern Ireland and West Midlands; however, while economically sizeable, the seasonal differences are in many cases not statistically significant.

One consideration that might explain the lower precision in the seasonal effects in new houses is
that new houses represent a very small share of the market (due mostly to stringent construction restrictions), and hence the test on mean differences across seasons unavoidably displays lower significance levels. Another explanation for the difference might be differences in repair and maintenance costs across the two seasons. To the extent that repair costs are smaller in the summer (because good weather and the time of the owners are important inputs in construction), sellers will take this into account and post accordingly higher prices in the market. If differences in seasonal repair costs are behind the differences in prices, then, insofar as new houses need less repair and the potential buyers can ask the developers to tailor the final touches of the house to their needs, we should observe less seasonality in the prices of new houses than in those of existing houses. Though qualitatively possible, yet, the question remains as whether plausible differences in repair costs alone can quantitatively match the seasonal variation in the data, a point to which we come back later.

Table 3: Average Difference in Annualized Housing Price Inflation Between Summer and Winters, by Region and Type of House or Buyer

<table>
<thead>
<tr>
<th>Region</th>
<th>All Houses (All buyers)</th>
<th>Existing houses (All buyers)</th>
<th>New houses (All buyers)</th>
<th>Former owner occupiers (All houses)</th>
<th>First-time buyer (All houses)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coef.</td>
<td>Std. Error</td>
<td>Coef.</td>
<td>Std. Error</td>
<td>Coef.</td>
</tr>
<tr>
<td>N. West</td>
<td>8.629**</td>
<td>(2.813)</td>
<td>9.915**</td>
<td>(2.871)</td>
<td>-1.164</td>
</tr>
<tr>
<td>North</td>
<td>1.864</td>
<td>(3.224)</td>
<td>2.319</td>
<td>(3.333)</td>
<td>1.559</td>
</tr>
<tr>
<td>S. East</td>
<td>7.675**</td>
<td>(2.908)</td>
<td>8.061**</td>
<td>(2.889)</td>
<td>3.112</td>
</tr>
<tr>
<td>S. West</td>
<td>10.961**</td>
<td>(3.439)</td>
<td>11.202**</td>
<td>(3.556)</td>
<td>8.004</td>
</tr>
<tr>
<td>Scotland</td>
<td>11.028**</td>
<td>(2.604)</td>
<td>13.627**</td>
<td>(2.895)</td>
<td>15.305*</td>
</tr>
<tr>
<td>Wales</td>
<td>9.332*</td>
<td>(3.721)</td>
<td>9.255*</td>
<td>(3.726)</td>
<td>1.146</td>
</tr>
<tr>
<td>U.K.</td>
<td>8.233**</td>
<td>(2.325)</td>
<td>8.896**</td>
<td>(2.364)</td>
<td>5.674*</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable $S_t$ (second and third quarters) in the regression $g_t=a+b\times Summer$, where $g_t$ is the annualized rate of nominal housing price inflation; $a$ is a constant (omitted). The equations use quarterly data from 1983 to 2005. Robust standard errors in parentheses. +significant at the 10%; *significant at the 5%; **significant at 1%.
hand, first-time buyers might be less dependent on chains (that is, they do not need to sell a house before buying) and can thus better arbitrage across seasons. The regressions tend to point to slightly stronger seasonality in prices paid by former-owner occupiers, favouring the second hypothesis, though as before, the results can also be driven by the natural loss of precision caused by the relatively small number of first-time buyers in the market.

Table 4 shows the corresponding numbers for average differences in \textit{real} housing price growth. Since the average difference in overall inflation rates across summers and winters is around 2 percent, the average difference in real housing price growth is roughly equivalent to the difference in nominal housing price inflation minus 2 percent.

### Table 4: Average Difference in Annualized Real Housing Price Growth Between Summer and Winters, by Region and Type of House or Buyer

<table>
<thead>
<tr>
<th>Region</th>
<th>All Houses (All buyers)</th>
<th>Existing houses (All buyers)</th>
<th>New houses (All buyers)</th>
<th>Former owner occupiers (All houses)</th>
<th>First-time buyer (All houses)</th>
</tr>
</thead>
<tbody>
<tr>
<td>E.Midlands</td>
<td>10.148** (3.675)</td>
<td>10.854** (3.716)</td>
<td>-0.027 (5.989)</td>
<td>11.766** (3.951)</td>
<td>7.495+ (3.772)</td>
</tr>
<tr>
<td>N. West</td>
<td>6.224* (2.784)</td>
<td>7.620** (2.847)</td>
<td>-4.022 (7.140)</td>
<td>7.456* (3.012)</td>
<td>3.764 (2.905)</td>
</tr>
<tr>
<td>North</td>
<td>-0.224 (3.238)</td>
<td>0.284 (3.356)</td>
<td>-0.637 (5.747)</td>
<td>-1.315 (3.327)</td>
<td>1.446 (3.910)</td>
</tr>
<tr>
<td>S. East</td>
<td>5.677+ (3.015)</td>
<td>6.084* (2.990)</td>
<td>0.756 (4.211)</td>
<td>6.854* (3.001)</td>
<td>2.259 (3.109)</td>
</tr>
<tr>
<td>S. West</td>
<td>8.569* (3.579)</td>
<td>8.863* (3.701)</td>
<td>4.188 (4.997)</td>
<td>9.567* (3.687)</td>
<td>3.869 (4.012)</td>
</tr>
<tr>
<td>W. Midlands</td>
<td>5.291 (3.800)</td>
<td>4.983 (3.823)</td>
<td>14.448+ (8.201)</td>
<td>6.02 (4.004)</td>
<td>4.285 (3.656)</td>
</tr>
<tr>
<td>Yorkshire &amp; Humb</td>
<td>5.468+ (3.113)</td>
<td>6.195+ (3.169)</td>
<td>0.53 (6.536)</td>
<td>6.155+ (3.312)</td>
<td>5.521 (3.467)</td>
</tr>
<tr>
<td>Scotland</td>
<td>9.305** (2.462)</td>
<td>12.317** (2.695)</td>
<td>12.163+ (7.260)</td>
<td>11.010** (2.544)</td>
<td>4.476 (3.021)</td>
</tr>
<tr>
<td>Wales</td>
<td>6.895+ (3.723)</td>
<td>6.818+ (3.749)</td>
<td>-1.32 (8.084)</td>
<td>7.659* (3.743)</td>
<td>5.021 (3.957)</td>
</tr>
<tr>
<td>U.K.</td>
<td>6.105* (2.354)</td>
<td>6.788** (2.393)</td>
<td>3.444 (2.579)</td>
<td>7.016** (2.387)</td>
<td>3.760+ (2.255)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable \( S_t \) (second and third quarters) in the regression \( g_t = a + b \times \text{Summer}_t + e_t \), where \( g_t \) is the annualized rate of \textit{real} housing price inflation; \( a \) is a constant (omitted). The equations use quarterly data from 1983 to 2005. Robust standard errors in parentheses. +Significant at the 10%; *significant at the 5%; **significant at 1%.

The behavior of prices is mimicked by that of the number of transactions. Table 5 shows the average differences in growth rates in the number of transactions between summers and winters. The Table reports the slope coefficients and standard errors of the summer-dummy regression (2) corresponding to each region. The annualized difference in growth rates is roughly 120 percent. Northern Ireland and the North region show the smallest average difference, which is roughly 100 percent. As the Table shows, the difference is stronger for former-owner occupiers than for first-time buyers, consistent with the price patterns observed before. (Unfortunately, the data are not disaggregated by type of house).
Put together, the data point to a strong seasonal cycle, with a large increase in transactions and prices during the summer relative to the winter term. Also, the seasonal patterns are similar across regions, except for the North region, which tends to display less seasonality in prices.

**Rents**

Data on rents are not documented in as much detail as the data on prices. The series available corresponds to the aggregate of the U.K. and comes from the ODPM; the data are not disaggregated by region. We run regressions using as dependent variables both the rent levels and the log of rents on the summer-term dummy. We also include, where indicated, a trend term. The results are summarized in Table 6, which shows that there is virtually no seasonality in rents for the U.K. as a whole. This is in line with anecdotal evidence suggesting that rents are fairly sticky.
Table 6: Summer Differentials in Rents in the U.K.

<table>
<thead>
<tr>
<th></th>
<th>Rents</th>
<th>log(Rent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer-dummy S_t</td>
<td>-47.90833</td>
<td>-0.01406</td>
</tr>
<tr>
<td></td>
<td>(255.798)</td>
<td>(0.091)</td>
</tr>
<tr>
<td>Trend</td>
<td>61.67964**</td>
<td>0.02194**</td>
</tr>
<tr>
<td></td>
<td>(1.276)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard deviations) on the dummy variable S_t (second-third quarters) in the regressions x_t=a+b×S_t+e_t, where x_t is either the rent level or the log of the rent; a is a constant (omitted); a trend term is included where indicated. Data are quarterly, from 1989-2005. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%.

Mortgage Rates

Interest rates in the U.K. do not seem to exhibit a seasonal pattern. The evidence is summarized in Table 7, which shows the summer dummy coefficients for different interest rate series provided by the Bank of England. The first column shows the results for the quarterly average of the repo (base) rate; the second column shows the corresponding results for the average interest rate charged by 4 U.K. major banks (Barclays Bank, Lloyds Bank, HSBC, and National Westminster Bank); and the third column shows the results for the weighted average standard variable mortgage rate from Banks and Building Societies. The first two series cover the period 1978 through 2005, whereas the third goes from 1994 through 2005.

As the Table shows, none of the interest rate measures appears to be different, on average, during the summer term.

Table 7: Summer Differentials in Interest Rates in the U.K.

<table>
<thead>
<tr>
<th></th>
<th>Repo rate</th>
<th>Bank-4 Rate</th>
<th>Mortgage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer-dummy S_t</td>
<td>-0.163</td>
<td>-0.144</td>
<td>0.018</td>
</tr>
<tr>
<td></td>
<td>(0.701)</td>
<td>(0.696)</td>
<td>(0.310)</td>
</tr>
</tbody>
</table>

Note: The Table shows the slope coefficients (and standard deviations) on the dummy variable S_t (second-third quarters) in the regressions x_t=a+b×S_t+e_t, where x_t is the Repo rate, the average of the 4 largest banks, or the mortgage interest rate, correspondingly; a is a constant (omitted). The equations use quarterly data from 1978 to 2005, except for the mortgage rate series, which starts in 1994. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%.

Housing Market Seasonality in the U.S.

Housing Price Changes

As noted before, the U.S. aggregate price index displays no seasonal patterns. The question is
whether this result masks different seasonal patterns at a more disaggregated level. As it turns out, this not the case. In the interest of space, and given the lack of seasonality in the data, we omit the graphs and summarize the results in Table 8, displaying the summer-effects coefficients and standard deviations using state-level data.\footnote{The data correspond to the 50 states and the district of Columbia.} As shown in the Table, only in one state (Kentucky) there is a statistically significant summer effect on prices. (Similar results are found when using the metropolitan-statistical-area-level data from the same source.\footnote{This is based on the 379 metropolitan areas defined by OFHEO.}) The summer effect is also insignificant from an economic point of view; the only states with sizeable (though not statistically significant) effects are Hawaii (exhibiting a negative summer effect), and Massachusetts, South Dakota, Delaware, and West Virginia (exhibiting a positive summer effect).

Real prices display a similar pattern, as there is no significant differences in overall inflation rates across seasons in the US (results not shown).\footnote{On the lack of seasonality of overall inflation in the U.S., see Barsky and Miron (1989).}
Table 8: Average Difference in Annualized Housing Price Growth between Second-Third Quarters and Fourth-First Quarters, by US State.

<table>
<thead>
<tr>
<th>State</th>
<th>Coef.</th>
<th>Std. Error</th>
<th>State</th>
<th>Coef.</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>0.008</td>
<td>(3.591)</td>
<td>Montana</td>
<td>4.453</td>
<td>(3.426)</td>
</tr>
<tr>
<td>Alaska</td>
<td>-0.692</td>
<td>(1.655)</td>
<td>North Carolina</td>
<td>0.406</td>
<td>(0.904)</td>
</tr>
<tr>
<td>Arizona</td>
<td>0.789</td>
<td>(2.473)</td>
<td>North Dakota</td>
<td>-6.223</td>
<td>(5.320)</td>
</tr>
<tr>
<td>Arkansas</td>
<td>0.588</td>
<td>(1.930)</td>
<td>Nebraska</td>
<td>-2.829</td>
<td>(1.819)</td>
</tr>
<tr>
<td>California</td>
<td>2.094</td>
<td>(1.757)</td>
<td>New Hampshire</td>
<td>3.030</td>
<td>(3.231)</td>
</tr>
<tr>
<td>Colorado</td>
<td>1.606</td>
<td>(1.387)</td>
<td>New Jersey</td>
<td>-0.237</td>
<td>(1.685)</td>
</tr>
<tr>
<td>Connecticut</td>
<td>2.890</td>
<td>(2.004)</td>
<td>New Mexico</td>
<td>0.207</td>
<td>(1.719)</td>
</tr>
<tr>
<td>District of Columbia</td>
<td>1.967</td>
<td>(6.001)</td>
<td>Nevada</td>
<td>-0.688</td>
<td>(2.128)</td>
</tr>
<tr>
<td>Delaware</td>
<td>10.757</td>
<td>(6.212)</td>
<td>New York</td>
<td>-0.903</td>
<td>(2.262)</td>
</tr>
<tr>
<td>Delaware</td>
<td>0.133</td>
<td>(2.524)</td>
<td>Ohio</td>
<td>0.853</td>
<td>(0.797)</td>
</tr>
<tr>
<td>Georgia</td>
<td>-0.119</td>
<td>(1.202)</td>
<td>Oklahoma</td>
<td>-0.538</td>
<td>(1.595)</td>
</tr>
<tr>
<td>Hawaii</td>
<td>-31.388</td>
<td>(30.242)</td>
<td>Oregon</td>
<td>0.406</td>
<td>(1.798)</td>
</tr>
<tr>
<td>Idaho</td>
<td>-0.131</td>
<td>(2.086)</td>
<td>Pennsylvania</td>
<td>1.008</td>
<td>(1.495)</td>
</tr>
<tr>
<td>Illinois</td>
<td>0.292</td>
<td>(3.326)</td>
<td>Rhode Island</td>
<td>2.345</td>
<td>(2.276)</td>
</tr>
<tr>
<td>Indiana</td>
<td>0.066</td>
<td>(1.287)</td>
<td>South Carolina</td>
<td>-0.671</td>
<td>(1.723)</td>
</tr>
<tr>
<td>Iowa</td>
<td>-0.776</td>
<td>(1.238)</td>
<td>South Dakota</td>
<td>16.066</td>
<td>(10.273)</td>
</tr>
<tr>
<td>Kansas</td>
<td>1.031</td>
<td>(0.935)</td>
<td>Tennessee</td>
<td>-1.878</td>
<td>(1.705)</td>
</tr>
<tr>
<td>Kentucky</td>
<td>-1.883*</td>
<td>(0.941)</td>
<td>Texas</td>
<td>0.104</td>
<td>(1.449)</td>
</tr>
<tr>
<td>Louisiana</td>
<td>-2.335</td>
<td>(1.615)</td>
<td>Utah</td>
<td>-1.363</td>
<td>(1.590)</td>
</tr>
<tr>
<td>Maine</td>
<td>2.000</td>
<td>(1.878)</td>
<td>Virginia</td>
<td>-0.427</td>
<td>(1.278)</td>
</tr>
<tr>
<td>Maryland</td>
<td>0.570</td>
<td>(1.258)</td>
<td>Vermont</td>
<td>-3.082</td>
<td>(7.957)</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>16.131</td>
<td>(10.186)</td>
<td>Washington</td>
<td>1.084</td>
<td>(1.623)</td>
</tr>
<tr>
<td>Michigan</td>
<td>1.616</td>
<td>(1.468)</td>
<td>Wisconsin</td>
<td>2.594</td>
<td>(1.886)</td>
</tr>
<tr>
<td>Minnesota</td>
<td>-0.025</td>
<td>(1.373)</td>
<td>West Virginia</td>
<td>9.703</td>
<td>(10.014)</td>
</tr>
<tr>
<td>Missouri</td>
<td>2.726</td>
<td>(2.351)</td>
<td>Wyoming</td>
<td>-0.572</td>
<td>(2.663)</td>
</tr>
<tr>
<td>Mississippi</td>
<td>-0.004</td>
<td>(3.132)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable $S_i$ (second and third quarters) in the regression $g_t=a+b\times Summer+c_t$, where $g_t$ is the annualized rate of nominal housing price inflation; $a$ is a constant (omitted). The equations use quarterly data from 1975 to 2005. Robust standard errors in parentheses.
+Significant at the 10%; *significant at the 5%; **significant at 1%.

**Number of Transactions**

As already observed, the U.S. as a whole displays a strong seasonality in the number of transactions. This remains true across all four major regions of the U.S. (state-level data are not available). The growth rates in the number of transactions in summers and winters are plotted in Figure 6. The average difference across seasons, together with the standard errors are summarized in Table 9.

In sum, the data for the U.S. point to a strong seasonal pattern in the number of transactions, with no discernible seasonal pattern in housing prices.
Figure 6: Annualized growth rate of the number of loans in summers and winters in the U.S. and its regions

Table 9: Average Difference in Annualized Growth Rates in the Number of Transactions Between Summer and Winters, by Regions in the U.S.

<table>
<thead>
<tr>
<th>Region</th>
<th>Coef.</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>220.718**</td>
<td>(19.762)</td>
</tr>
<tr>
<td>Midwest</td>
<td>210.968**</td>
<td>(27.558)</td>
</tr>
<tr>
<td>South</td>
<td>179.038**</td>
<td>(21.219)</td>
</tr>
<tr>
<td>West</td>
<td>162.818**</td>
<td>(25.816)</td>
</tr>
<tr>
<td>United States</td>
<td>162.354**</td>
<td>(19.369)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable $S_t$ (Summer) in the regression $\hat{x}_t = a + b \times S_t + e_t$, where $x_t$ is the annualized growth rate of the number of transactions; $a$ is a constant (omitted). The equations use quarterly data from 1975 to 2005 for the regions and 1968-2005 for the U.S. as a whole. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%.

Rents

Data on rents for the U.S. come from the Bureau of Labor Statistics (BLS); as a measure of rents we use the non-seasonally adjusted series of owner’s equivalent rent and the non-seasonally adjusted rent of primary residence; both series are produced for the construction of the CPI and
correspond to averages over all cities. For each series, we run regressions using as dependent variables both the rent levels and the log of rents on the summer-term dummy. We also include, where indicated, a trend term. The results are summarized in Tables 10 (owner’s equivalent rent) and 11 (rent of primary residence). Both Tables show that there is no evidence of seasonality in rents for the U.S. as a whole.

### Table 10: Summer Differential in Rents in the U.S.: Owner’s Equivalent Rent

<table>
<thead>
<tr>
<th>Summer-dummy S_t</th>
<th>Rents</th>
<th>log(Rent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.19638</td>
<td>-0.00102</td>
</tr>
<tr>
<td></td>
<td>(8.133)</td>
<td>(0.051)</td>
</tr>
<tr>
<td>Trend</td>
<td>1.45183**</td>
<td>0.00905**</td>
</tr>
<tr>
<td></td>
<td>(0.005)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard deviations) on the dummy variable S_t (second-third quarters) in the regressions x_t=a+b×S_t+e_t, where x_t is either the rent level or the log of the rent; a is a constant (omitted); a trend term is included where indicated. Data are quarterly, from 1983-2005. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%. (BLS, owner’s equivalent rent.)

### Table 11: Summer Differential in Rents in the U.S.: Rent of Primary Residence

<table>
<thead>
<tr>
<th>Summer-dummy S_t</th>
<th>Rents</th>
<th>log(Rent)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>-0.16594</td>
<td>-0.00098</td>
</tr>
<tr>
<td></td>
<td>(7.120)</td>
<td>(0.047)</td>
</tr>
<tr>
<td>Trend</td>
<td>1.26671**</td>
<td>0.00827**</td>
</tr>
<tr>
<td></td>
<td>(0.012)</td>
<td>(0.000)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard deviations) on the dummy variable S_t (second-third quarters) in the regressions x_t=a+b×S_t+e_t, where x_t is either the rent level or the log of the rent; a is a constant (omitted); a trend term is included where indicated. Data are quarterly, from 1983-2005. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%. (BLS, rent of primary residence.)

**Mortgage Rates**

Interest rates in the U.S. do not exhibit a seasonal pattern (Barsky and Miron, 1989). Since housing service costs are of particular interest here, we summarize in Table 12 the summer effect (or lack thereof) in mortgage rates. The data come from the Board of Governors of the Federal Reserve and correspond to contract interest rates on commitments for fixed-rate first mortgages; the data are quarterly averages beginning in 1972; the original data are collected by Freddie Mac. As the Table shows, mortgage rates do not appear to be higher on average during the summer term, consistent with the findings in Barsky and Miron (1989).
Table 12: Summer Differential in Mortgage Rates in the U.S.

<table>
<thead>
<tr>
<th>Summer-dummy $S_t$</th>
<th>Mortgage Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.104</td>
</tr>
<tr>
<td></td>
<td>(0.477)</td>
</tr>
</tbody>
</table>

Note: The Table shows the slope coefficient (and standard deviation) on the dummy variable $S_t$ (second-third quarters) in the regressions $x_t = a + b \times S_t + e$, where $x_t$ is the average mortgage interest rate; $a$ is a constant (omitted). The equations use quarterly data from 1972 through 2005. Robust standard errors in parentheses. + Significant at 10%; * Significant at the 5%; ** significant at 1%.

Housing Market Seasonality in Belgium and France

Tables 13 and 14 show the housing-price regressions for Belgium and France, disaggregated by regions with available data. As the Tables show, in both countries all regions display a strong seasonal pattern, comparable to that reported for the country as a whole. Data on transactions at the regional level are not available; however, as seen before, there exist a substantial degree of seasonality in the number of transactions at the aggregate level for both countries. As noted in the Data Appendix, the housing price indexes for these countries are not quality adjusted and hence seasonal variation in prices might mask variation in the quality of the houses on the market; this is why we emphasize throughout the paper the results from the U.K. and the U.S.

Table 13: Average Difference in Annualized Housing Price Growth between Second-Third Quarters and Fourth-First Quarters in Belgium, by Region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Coef.</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Great Brussels</td>
<td>13.242**</td>
<td>(3.039)</td>
</tr>
<tr>
<td>Flanders</td>
<td>10.753**</td>
<td>(1.746)</td>
</tr>
<tr>
<td>Wallonia</td>
<td>19.329**</td>
<td>(1.903)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable $S_t$ (second and third quarters) in the regression $g_t = a + b \times S_t + e$, where $g_t$ is the annualized rate of nominal housing price inflation; $a$ is a constant (omitted). The equations use quarterly data from 1981 to 2005. Robust standard errors in parentheses. + Significant at the 10%; * significant at the 5%; ** significant at 1%.
Table 14: Average Difference in Annualized Housing Price Growth between Second-Third Quarters and Fourth-First Quarters in France, by Region.

<table>
<thead>
<tr>
<th>Region</th>
<th>Coef.</th>
<th>Std. Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ile-de-France</td>
<td>9.275**</td>
<td>(2.294)</td>
</tr>
<tr>
<td>Province (All regions except Ile-de-France)</td>
<td>17.347**</td>
<td>(1.906)</td>
</tr>
<tr>
<td>Provence-Alpes-Côte d'Azur</td>
<td>10.915**</td>
<td>(2.624)</td>
</tr>
<tr>
<td>Rhône-Alpes</td>
<td>11.977**</td>
<td>(2.648)</td>
</tr>
</tbody>
</table>

Note: The Table shows the coefficients (and standard errors) on the dummy variable $S_t$ (second and third quarters) in the regression $g_t = a + b \times S_{t} + e_t$, where $g_t$ is the annualized rate of nominal housing price inflation; $a$ is a constant (omitted). The equations use quarterly data from 1994 to 2005. Robust standard errors in parentheses.

+Significant at the 10%; *significant at the 5%; **significant at 1%.

3 Quantifying the Price Puzzle

We carry out a quantitative analysis using the findings for the U.K., given that the data are of better quality than those in other continental-European countries that also feature seasonality in prices. The U.S., as seen, displays no seasonality in prices.

We argued before that the predictability and size of the seasonal variation in housing prices in some countries pose a puzzle to models of the housing market relying on standard asset-market equilibrium conditions. In particular, the equilibrium condition embedded in most dynamic general-equilibrium models states that the marginal benefit of housing services should equal the marginal cost. Following Poterba (1984) and calling $t$ the semester-time period corresponding to season $x = w$ (winter) (with $t + 1$ corresponding to the summer season $x = s$) the asset-market equilibrium conditions for the summer and winter semesters are:$^{13,14}$

$$d_{t+1,s} + (p_{t+1,s} - p_{t,w}) = v_{t,w} \cdot p_{t,w}$$

$$d_{t,w} + (p_{t,w} - p_{t-1,s}) = v_{t-1,s} \cdot p_{t-1,s}$$

where $p_{t,x}$ and $d_{t,x}$ are the real asset price and rental price of housing services, respectively; $v_{t,x} \cdot p_{t,x}$ is the real gross (gross of capital gains) $t$–period cost of housing services of a house with real price $p_{t,x}$; and $v_{t,x}$ is the sum of after-tax depreciation, repair costs, property taxes, mortgage interest payments, and the opportunity cost of housing equity. As in Poterba (1984), we make the

$^{13}$This implies $t + 1$, $t + 3$, $t + 2j + 1$, $j > 1$ correspond to the summer season and $t + 2j$, $j > 1$ correspond to the winter season.

$^{14}$See also Mankiw and Weil (1989) and Muellbauer and Murphy (1997), among others.
following simplifying assumptions so that service-cost rates are a fixed proportion of the property price, though still potentially different across seasons \((v_{t,u} = v_{t+2,u} = v_w\) and \(v_{t,s} = v_{t+2,s} = v_s\): \(i\))

Depreciation takes place at rate \(\delta_x\), \(x = s, w\), constant for a given season, and the house requires maintenance and repair expenditures equal to a fraction \(\kappa_x\), \(x = s, w\), also constant for a given season. \(ii\) The income-tax-adjusted real interest rate and the marginal property tax rates (for given real property prices) are constant over time, though potentially different across seasons; they are denoted, respectively as \(r_x\) and \(\tau_x\), \(x = s, w\) (in the data, as seen, they are actually constant across seasons; we come back to this point below).\(^{15}\)

This yields:

\[ v_x = \delta_x + \kappa_x + r_x + \tau_x, \ x = s, w \]

Subtracting (5) from (4) and using the condition that there is no seasonality in rents \((d_w \approx d_s\),

\[ \frac{(p_{t+1,s} - p_{t,w}) - (p_{t,w} - p_{t-1,s})}{p_{t,w}} = \frac{v_{t,w} \cdot (p_{t,w} - p_{t-1,s})}{1} \]

\[ \frac{p_{t+1,s} - p_{t,w}}{p_{t,w}} = \frac{p_{t,w} - p_{t-1,s}}{p_{t-1,s}} \]

Considering the real differences in house price growth rates documented for the whole of the U.K., \(\frac{p_s - p_w}{p_w} = 7.04\%, \ \frac{p_w - p_s}{p_s} = 0.75\%\), the left-hand side of (7) equals \(6.3\% \approx 7.04\% - 0.75\% \cdot \frac{1}{1.0075}\).

Therefore,

\[ \frac{v_w}{v_s} = \frac{0.063}{v_s} + \frac{1}{1.0075} \]

The value of \(v_s\) can be pinned-down from equation (5), depending on the actual rent-to-price ratios in the economy. In Table 15, we summarize the extent of seasonality in service costs \(\frac{v_w}{v_s}\) implied by the asset-market equilibrium conditions, for different values of \(d/p\) (and hence different values of \(v_s = \frac{d_w}{p_s} + \frac{p_w - p_s}{p_s} = \frac{d_w}{p_s} + 0.75\%\)).

\(^{15}\)I implicitly assume the property-price brackets for given marginal rates are adjusted by inflation rate, though strictly this is not the case (Poterba, 1984): inflation can effectively reduce the cost of homeownership. This, however, should not alter the conclusions concerning seasonal patterns emphasized here. As in Poterba (1984) I also assume that the opportunity cost of funds equals the cost of borrowing.
Table 15: Ratio of Winter-To-Summer Cost Rates

<table>
<thead>
<tr>
<th>(annualized) $d/p$ Ratio</th>
<th>Relative winter cost rates $\frac{v_w}{v_s}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.0%</td>
<td>459%</td>
</tr>
<tr>
<td>2.0%</td>
<td>328%</td>
</tr>
<tr>
<td>3.0%</td>
<td>267%</td>
</tr>
<tr>
<td>4.0%</td>
<td>232%</td>
</tr>
<tr>
<td>5.0%</td>
<td>209%</td>
</tr>
<tr>
<td>6.0%</td>
<td>193%</td>
</tr>
<tr>
<td>7.0%</td>
<td>181%</td>
</tr>
<tr>
<td>8.0%</td>
<td>171%</td>
</tr>
<tr>
<td>9.0%</td>
<td>164%</td>
</tr>
<tr>
<td>10.0%</td>
<td>158%</td>
</tr>
</tbody>
</table>

As the Table illustrates, a remarkable amount of seasonality in service costs is needed to explain the differences in housing price inflation across seasons. Specifically, assuming annualized rent-to-price ratios in the range of 2 through 5 percent, total costs in the winter should be between 328 and 209 percent of those in the summer. Depreciation and repair costs ($\delta_x + \kappa_x$) might be seasonal, being potentially lower during the summer. But income-tax-adjusted interest rates and property taxes ($r_x + \tau_x$), two major components of service costs are not seasonal. Since depreciation and repair costs are only part of the total costs, given the seasonality in other components, the implied seasonality in depreciation and repair costs across seasons in the U.K. is even larger. Assuming, quite conservatively, that the a-seasonal component ($r_x + \tau_x = r + \tau$) accounts for only 50 percent of the service costs in the summer ($r + \tau = 0.5v_s$), then, the formula for relative costs $\frac{v_w}{v_s} = \frac{\delta_w + \kappa_w + 0.5v_s}{\delta_s + \kappa_s + 0.5v_s}$ implies that the ratio of depreciation and repair costs between summers and winters is $\frac{\delta_w + \kappa_w}{\delta_s + \kappa_s} = 2\frac{v_w}{v_s} - 1$. For rent-to-price ratios in the range of 2 through 5 percent, depreciation and maintenance costs in the winter should be between 557 and 318 percent of those in the summer. (If the a-seasonal component ($r + \tau$) accounts for 80 percent of the service costs ($r + \tau = 0.8v_s$), the corresponding values are 1542 and 944 percent). By any metric, these figures seem extremely large.

Let us now for the sake of the argument concede that these figures are indeed as large as implied by the asset-pricing equilibrium condition, the question is then: why is it the case that depreciation

---

16 Good weather can help with external repairs and owners’ vacation might reduce the opportunity cost of time—though it is key here that leisure is not too valuable for the owners.

17 Call $\lambda$ the aseasonal component as a fraction of the summer service cost rate: $r + \tau = \lambda v_s$, $\lambda \in (0, 1)$ (and hence $\delta_s + \kappa_s = (1 - \lambda)v_s$). Then: $\frac{v_w}{v_s} = \frac{\delta_w + \kappa_w + \lambda v_s}{\delta_s + \kappa_s + \lambda v_s} = \frac{\delta_w + \kappa_w + \lambda v_s}{\delta_s + \kappa_s + \lambda v_s}$. Or $v_w = \delta_w + \kappa_w + \lambda v_s$. Hence: $\frac{v_w - \lambda v_s}{v_s} = \frac{\delta_w + \kappa_w - (1 - \lambda)v_s}{v_s} = \frac{\delta_w + \kappa_w}{v_s} - \frac{\lambda}{1 - \lambda}$, which is increasing in $\lambda$ for $\frac{v_w}{v_s} > 1$. 

26
and repair costs are so seasonal in the U.K. (and potentially higher in other continental European
countries that exhibit larger seasonality in prices) while in other countries, such as the U.S., they
are a-seasonal? Deviations from the standard asset-pricing equilibrium condition are needed to
match both the U.K. and the U.S. data.

The need to deviate from the asset-market approach has been acknowledged, in a different con-
text, among others, by Stein (1995). While static in nature, Stein’s model is capable of generating
unexpected booms and busts in prices (and transactions) in a rational-expectation setting. In a
dynamic setting with forward-looking agents, however, predictably large changes in prices could
not be sustained: Expected price increases in the next season will actually be priced in the current
season (or, in other words, sellers will refuse to sell at lower prices today given the perspective of
higher prices in the next season); similarly, prospective buyers will benefit from waiting (at most a
few months) and paying a significantly lower price. Even when agents are both sellers and buyers,
if they are aware of the differences in prices, in a dynamic setting they will seek to sell in the
summer and to buy in the winter; the excess supply in the summer will then push prices down,
while the excess demand in the winter will push them up.

In the next Section, we develop a new search model for the housing market that can generate
significant differences in the number of transactions across seasons. The model can also deliver
seasonality in prices, comparable to that observed in U.K. data, as well as no seasonality, as in
U.S. data.

4 A Search Model for the Housing Markets

The basic setup of the model builds on previous contributions by Krainer (2001), Wheaton (1990),
and Williams (1995), which in turn borrow from the labor search literature (see, for example,
Pissarides (1990)).

The model economy is populated by a unit measure of infinitely lived agents who have linear
preferences over a non-durable consumption good and a housing good. Each period agents receive
a fixed endowment of the consumption good which they can use to buy houses with. The housing
good is indivisible and agents can only live in one house at a time (though they could potentially
own more than one). The housing stock is constant and there are as many houses as agents. Each
house starts a period in one of two “states:” It can be either “matched,” when it delivers positive
housing services flow to its owner, or “on sale,” when it does no longer yield any service to its owner. As long as a house is “matched,” it yields idiosyncratic housing services $\varepsilon$ to its owner, which we assume to be constant over time. The “quality of the match” $\varepsilon$ is only observed by the potential buyer, but not by the seller.

There are two seasons, $j = s, w$ (for summer and winter); each model period is a season, and seasons alternate. At the beginning of a period, each match has a probability $(1 - \phi^j)$ of breaking, and the house goes “on sale.” The parameter $\phi^j$ is the only (ex ante) difference between any two seasons.

Agents who are not matched to a house seek to buy one (“buyers”) and agents who own houses where the match is broken seek to sell them (“sellers”). Note that an agent may be only “buyer,” only “seller,” and both “buyer” and “seller.” Also, sellers may have multiple houses to sell. Buyers and sellers are randomly matched. Each period a buyer visits only one house, and each house is visited by only one buyer.

We call $v^j$ the stock of vacant houses and $b^j$ be the number of agents without a house in season $j = s, w$, all of which are determined in equilibrium. Since when a match is destroyed a homeowner becomes both a buyer and a seller simultaneously, it is always the case that $v^j = b^j$, that is, the number of vacant houses equals the number of potential buyers.

The sequence of events is as follows. At the beginning of period $t$, an existing match between a homeowner and his house breaks with probability $1 - \phi^j$, adding to the stock of vacant houses and potential buyers. Every seller meets with a buyer randomly. The potential buyer observes the utility services $\varepsilon$ (not observable to the seller) generated by the match and decides whether or not to buy. If the transaction goes through, the buyer pays $p^j$ to the seller, and starts enjoying the utility flow from that period. If the transaction does not go through, the house lies empty and the buyer does not receive any flow utility from housing. We discuss two price setting scenarios. In the first, and benchmark, which we call “the seller’s market,” the seller posts a price and the buyer decides whether the match quality is high enough to pay the price. In the second, the buyer sets a price and makes a take-it-or-leave-it offer to the seller.
4.1 Sellers’ Market

4.1.1 Utility services

The model embeds the intuitively appealing notion that in a market with many houses on sale a buyer can find a house closer to her ideal and hence her willingness to pay increases. We model this idea by assuming that the (idiosyncratic) quality of a match, $\varepsilon$, in season $j$ follows a distribution $F^j (\varepsilon)$ with positive support such that:

$$F^j (\varepsilon) \leq F^{j'} (\varepsilon); \forall \varepsilon \iff v^j \geq v^{j'} \text{ for } j, j' = s, w$$  \hspace{1cm} (8)

That is, $F^j (\cdot)$ stochastically dominates $F^{j'} (\cdot)$ if and only if $v^j > v^{j'}$, where $v^j (v^{j'})$, the stock of houses in a given season, is endogenously determined. In other words, when the stock of houses $v^j$ is bigger, the draw $\varepsilon$ is likely to be higher. We also assume that $F^j (\cdot)$ has a finite mean, $\int \varepsilon dF^j (\varepsilon) < \infty$.

Note that $\varepsilon$ captures the quality of a match between a house and the potential buyer. In other words, for any vacant house, the potential utility services are idiosyncratic to the match between the house and the buyer. Hence, $\varepsilon$ is not the type of the house (or of the seller who owns a particular house); indeed, there is only one representative house in our model, with the utility derived from living in the house being idiosyncratic. This is consistent with the data we look at, which are adjusted for observable characteristic of houses such as size and location, but not for the (unobserved) quality of the match.

4.1.2 The Homeowner

The value function for a homeowner who lives in a house with quality $\varepsilon$ in season $s$ is given by:

$$H^s (\varepsilon) = \varepsilon + \beta \phi^w H^w (\varepsilon) + \beta (1 - \phi^w) [V^w + B^w]$$

With probability $(1 - \phi^w)$ he receives a moving shock and becomes both a seller and a buyer, with continuation value $(V^w + B^w)$, and with probability $\phi^w$ he keeps receiving utility services $\varepsilon$ and stays in the house. (Notice that the formula for $H^w (\varepsilon)$ is perfectly isomorphic to $H^s (\varepsilon)$; in the interest of space we omit here and throughout the paper the corresponding expressions for season $w$.)

$$H^s (\varepsilon) = \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon + \frac{\beta [(1 - \phi^w) (V^w + B^w) + \beta \phi^w (1 - \phi^s) (V^s + B^s)]}{1 - \beta^2 \phi^w \phi^s}.$$  \hspace{1cm} (9)
4.1.3 The Buyer

Upon visiting a house the buyer draws a match quality \( \varepsilon \) from the distribution \( F_s(\varepsilon) \equiv F(\varepsilon | \nu^s) \) in season \( s \). (And, correspondingly, from \( F_w(\varepsilon) \equiv F(\varepsilon | \nu^w) \) in season \( w \)). Since the match quality is idiosyncratic to a house and buyer, it is natural to assume that the seller does not observe \( \varepsilon \). Thus, in a seller’s market, the seller posts a price \( p^s \) independent of the level of \( \varepsilon \). The buyer’s value function in season \( s \) is:

\[
B^s = E^s\{H^s(\varepsilon) - p^s, \beta B^w}\,, \tag{10}
\]

where \( E^s[.] \) indicates the expectation taken with respect to the distribution \( F_s(.) \).

As said, buyers consume no housing services until they find a successful match. This can be the case, for example, if buyers searching for a house pay a rent equal to the utility they derive from the rented property; what is key is that the rental property is not owned by the same potential seller with whom the buyer meets.\(^{18}\)

Since \( H^s(\varepsilon) \) is increasing in \( \varepsilon \), a “reservation policy,” whereby the buyer accepts the posted price if \( \varepsilon \) exceeds a cutoff level, is optimal. The transaction is hence carried out if \( \varepsilon > \varepsilon^s \), where the cutoff \( \varepsilon^s \) is given by:

\[
H^s(\varepsilon^s) - p^s = \beta B^w, \tag{11}
\]

\( 1 - F^s(\varepsilon^s) \) is thus the probability that a transaction is carried out. From (9), the response of the reservation quality \( \varepsilon^s \) to a change in price is given by:

\[
\frac{\partial \varepsilon^s}{\partial p^s} = \frac{1 - \beta^2 \phi^w \phi^s}{1 + \beta \phi^w}. \tag{12}
\]

4.1.4 The Seller

Taking the optimal decision rules of the buyer as given, the seller chooses a price to maximize the expected surplus value of a sale. The seller’s value function is

\[
V^s = \beta V^w + u + \max_p \{[1 - F^s(\varepsilon^s(p))] (p - \beta V^w)\}, \tag{13}
\]

where \( u \) is the utility flow from being a seller; this could be interpreted, for example, as a net rental income received by the seller while the house in on the market; to be consistent with the

---

\(^{18}\)Glaeser and Gyourko (2007) argue that the rental market and the buying/selling market appear to be independent in practice.
data, we assume that the rental income $u$ does not vary across seasons. Again, what is key is that the tenant is not the same potential buyer visiting the house.\footnote{The current setting assumes that if the transaction does not go through, both parties have to wait until next season. It is a matter of computation to expand the model into two (or more) subperiods within a season to incorporate the fact that both parties can still hold the summer values if they disagree in, say, April. We choose not to do it, but adjust our interpretation of the quantitative results. If in the data the seasonal difference between “July-September” and “January-March” is much smaller than the difference between “April-June” and “October-December,” then the seasonality generated by the model should be smaller than the data, which spans from April through September and October through March.}

The optimal price $p^s$ solves

$$[1 - F^s(\varepsilon^s)] - [p - \beta V^w] f^s(\varepsilon^s) \frac{\partial \varepsilon^s}{\partial p^s} = 0. \quad (14)$$

Rearranging terms we obtain:

$$\frac{p^s - \beta V^w}{p^s}_{\text{mark-up}} = \left[ \frac{p^s f^s(\varepsilon^s) \frac{\partial \varepsilon^s}{\partial p^s}}{1 - F^s(\varepsilon^s)} \right]^{-1},$$

which makes clear that the price-setting problem of the seller is similar to that of a monopolist who sets a markup equal to the inverse of the elasticity of demand (where demand in this case is given by the probability of a sale, $1 - F^s(\varepsilon^s)$).

4.1.5 Market equilibrium

**Prices** Let $S^s_v \equiv p^s - \beta V^w$ be the surplus to a seller from a housing transaction. The optimal decisions of the buyer (12) and the seller (14) together imply:

$$S^s_v = \frac{1 - F^s(\varepsilon^s)}{f^s(\varepsilon^s)} \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s}. \quad (15)$$

Equation (15) says that the net surplus to a seller generated by the transaction is higher when the distribution has a thicker tail, $\frac{1 - F^s(\varepsilon^s)}{f^s(\varepsilon^s)}$. Together with the value function of the seller, the optimal price satisfies (see derivation in Appendix 8.1):

$$p^s = \frac{\beta u}{1 - \beta} + \left( 1 + \frac{\beta^2 [1 - F^s(\varepsilon^s)]}{1 - \beta^2} \right) S^s_v + \frac{\beta [1 - F^w(\varepsilon^w)]}{(1 - \beta^2)} S^w_v. \quad (16)$$
Reservation quality Let \( S_b^s (\varepsilon) \equiv H^s (\varepsilon) - p^s - \beta B^w \) be the surplus to a buyer from buying a house with flow value \( \varepsilon \). The reservation quality \( \varepsilon^s \) satisfies \( S_b^s (\varepsilon^s) = 0 \). Using (9), the surplus to a buyer is

\[
S_b^s (\varepsilon) = H^s (\varepsilon) - H^s (\varepsilon^s) = \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} (\varepsilon - \varepsilon^s). \tag{17}
\]

The total surplus from a transaction with flow value \( \varepsilon \) is

\[
S^s (\varepsilon) \equiv H^s (\varepsilon) - B^s - V^s = S_b^s (\varepsilon) + S_v^s. \tag{18}
\]

An equilibrium with positive number of transactions exists if the total surplus is positive. By definition, \( \varepsilon^s \) also satisfies \( S^s (\varepsilon^s) = S_v^s \); using (9), \( \varepsilon^s \) solves (see Appendix 8.1):

\[
\frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon^s = S_v^s + \frac{\beta \phi^w (1 - \beta^2 \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w) - \frac{\beta^2 \phi^w (1 - \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^s + B^s). \tag{19}
\]

The reservation quality \( \varepsilon^s \) depends on the sum of the outside options for buyers and sellers in both seasons. The outside option in the summer is \( B^w + V^w \), that is, the sum of the seller’s and the buyer’s values in winter. The value of being buyer depends on the expected surplus value of homeownership, conditional on drawing a match quality \( \varepsilon > \varepsilon^s \), that is, \( E^s [S_b^s (\varepsilon) \mid \varepsilon > \varepsilon^s] \). The value of a seller depends on the present value of the rental income \( u \) and the expected surplus from meeting other buyers. We can hence write (see Appendix 8.1)

\[
B^s + V^s = \frac{u}{1 - \beta} + \frac{\beta [1 - F^w (\varepsilon^w)]}{1 - \beta^2} [E^w (S^w (\varepsilon) \mid \varepsilon > \varepsilon^w)] + \frac{1 - F^s (\varepsilon^s)}{1 - \beta^2} E^s (S^s (\varepsilon) \mid \varepsilon > \varepsilon^s). \tag{20}
\]

Using (19) and (20), the thick-and-thin market equilibrium (through the distribution \( F^s \) (and \( F^w \))) affects the equilibrium match quality \( \varepsilon^s \) (and \( \varepsilon^w \)) through the tail \( \frac{1-F}{f} \) and the conditional mean \( E^s [\varepsilon \mid \varepsilon > \varepsilon^s] \) (and \( E^w [\varepsilon \mid \varepsilon > \varepsilon^w] \).

Stock of vacant houses The law of motion for the stock of vacant houses (and hence for the stock of buyers) is

\[
v^s = (1 - \phi^s) (v_w [1 - F^w (\varepsilon^w)] + 1 - v^w) + v^w (1 - [1 - F^w (\varepsilon^w)] \tag{21}
\]

where the first term includes houses that received a moving shock this season and the second term comprises vacant houses from last period that did not find a buyer. The expression simplifies to

\[
v^s = v^w \phi^s F^w (\varepsilon^w) + 1 - \phi^s, \tag{21}
\]
that is, in equilibrium $v^s$ depends on the equilibrium matching values of $\varepsilon$ and on the distribution $F(.)$.

An equilibrium is a vector $(p^s, p^w, B^s + V^s, B^w + V^w, \varepsilon^s, \varepsilon^w, v^s, v^w)$ that jointly satisfies equations (16), (19), (36) and (21), with the surpluses $S^j, S^j_\delta (\varepsilon)$, and $S^j (\varepsilon)$, for $j = s, w$, derived as in (15), (17) and (18).

4.2 Buyers’ Market

The setup of the model is the same as before, except that now we assume that it is the buyer, rather than the seller, who makes a take-it-or-leave-it offer after visiting a house. The buyer extracts all the surplus from the seller by setting a price such that $S^j_v = 0$, $j = s, w$. Together with the value function of the seller, the equilibrium prices in seasons $s$ and $w$ become

$$p^s = p^w = \frac{\beta u}{1 - \beta},$$

which is the same as (16) after setting $S^s_v = S^w_v = 0$. The optimal strategy of the buyer still follows the reservation rule defined in (11). The equilibrium values of $\varepsilon^s$ and $B^s + V^s$ are the same as in (19) and (20) with $S^s_v = 0$. (The values for $\varepsilon^w$ and $B^w + V^w$ are, as before, isomorphic to $\varepsilon^s$ and $B^s + V^s$.) The equilibrium values of the stock of vacancies $v^s$ and $v^w$ follow the same law of motion as in (21).

5 Model-generated Seasonality of Prices and Transactions

5.1 Qualitative Results

We now derive the extent of seasonality in prices and transactions generated by the model, and show how they depend on whether sellers or buyers have the power to set prices, as well as on the level of rental income $u$. The driver for seasonality in the model is the probability of a moving shock, which we assume to be higher in the summer: $1 - \phi^s > 1 - \phi^w$. Using (21), the stock of vacant houses in season $s$ is given by:

$$v^s = \frac{(1 - \phi^w) \phi^s F^w (\varepsilon^w) + 1 - \phi^s}{1 - \phi^w \phi^s F^s (\varepsilon^s) F^w (\varepsilon^w)},$$

(The expression for $v^w$ is correspondingly isomorphic). The \textit{ex ante} higher probability of a shock in the summer $1 - \phi^s > 1 - \phi^w$ clearly has a direct positive effect on $v^s$. Because $F^s (\varepsilon)$ first-order
stochastically dominates $F^w(\varepsilon)$ when $v^s > v^w$ (that is, $F^s(\varepsilon) \leq F^w(\varepsilon); \forall \varepsilon$), this can amplify the
seasonal shock to generate a higher seasonality in vacancies (as long as the indirect effect through $\varepsilon^s$ is small). This amplification effect is what we call a thick-market externality. As shown in (16), since the rental income $u$ is a-seasonal, housing prices are seasonal only if the surplus to the seller is seasonal. Two observations follow:

**Remark 1** *In a buyer’s market, there is no seasonality in prices.*

**Remark 2** *In a seller’s market, prices are seasonal. The extent of the seasonality in prices is decreasing in the rental flow $u$.*

To see this, note that when the buyer sets a price, the surplus of the seller is zero; the equilibrium price is equal to the outside option of the seller, that is, his rental income $u$, which is a-seasonal. Hence prices are a-seasonal in a buyer’s market. When the seller sets a price his surplus is positive in both seasons; the equilibrium price is hence the sum of his outside option ($u$) plus a positive surplus from the sale. The surplus $S^s_v$, as shown in (15), is seasonal. Given $v^s > v^w$, the thick market effects implies a thicker tail in quality in the hot season. In words, the quality of matches goes up in the summer and hence buyers’ willingness to pay increases; sellers can then extract a higher surplus in the summer: thus, $S^s_v > S^w_v$. The extent of seasonality in prices decreases as the a-seasonal component—the outside option $u$—increases.

We next turn to the degree of seasonality in transactions. The number of transactions in equilibrium in season $s$ is given by:

$$Q^s = v^s [1 - F^s(\varepsilon^s)].$$

(An isomorphic expression holds for $Q^w$). A bigger stock of vacancies in the summer, $v^s > v^w$, tends to increase transactions in the summer. Whether buyers or sellers set prices also affects the degree of seasonality in transactions through the equilibrium value of $\varepsilon^s$. More specifically, a higher reservation quality in the hot season, $\varepsilon^s > \varepsilon^w$, tends to decrease the degree of seasonality in transactions. As shown in (19), the equilibrium cutoff $\varepsilon^s$ depends on the surplus to the seller ($S^s_v$) and on the sum of the seller’s and buyer’s outside options. We have already shown that $S^s_v > S^w_v$ in a seller’s market because of the thick-market effect. Using (17), the thick market effect also implies that the expected surplus to the buyer is higher in the hot season, so the expected total surplus is also higher in the hot season: $E^s(S^s(\varepsilon) \mid \varepsilon > \varepsilon^s) > E^w(S^w(\varepsilon) \mid \varepsilon > \varepsilon^w)$. It follows from (20)
that \((B^s + V^s) > (B^w + V^w)\). The seasonality of \(S^s_v\) implies a higher reservation value \(\varepsilon^s\) in the hot season \(s\) (the marginal house has to be of higher quality in order to generate a bigger surplus to the seller). The seasonality in sellers’ and buyers’ outside options on the other hand, tends to reduce the cutoff \(\varepsilon^s\) in the hot season \(s\). This is because the outside option in the hot season \(s\) is the sum of values in the winter season: \((B^w + V^w)\). To see this negative effect more explicitly, rewrite (19) as

\[
\frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon^s = S^s_v + \frac{\beta \phi^w (1 - \beta) (1 + \beta \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w) + \frac{\beta^2 \phi^w (1 - \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w - V^s - B^s),
\]

so \((B^s + V^s) > (B^w + V^w)\) has a negative effect on \(\varepsilon^s/\varepsilon^w\). This gives rise to the following observations:

**Remark 3** In both a seller’s and a buyer’s market, transactions are seasonal. The seasonality of transactions is higher in a buyer’s market.

To see this, note that the outside option for both the buyer and the seller in the hot season is to wait and transact in the cold season. This makes both buyers and sellers less demanding in the hot season, yielding a larger number of transactions. In other words, the “counter-seasonality” in outside options increases the seasonality in transactions. On the other hand, when the seller sets prices, the surplus of the seller is higher in the hot season and hence sellers are more demanding and less willing to transact, which reduces the seasonality of transactions. Hence, in a seller’s market, the seasonality of outside options and of the surplus to the seller have opposite effects on the seasonality of reservation quality, causing a relatively lower degree of seasonality in transactions. In as buyer’s market instead only the seasonality of the outside options affects (positively) the degree of seasonality. Therefore, the seasonality of transactions is higher when the buyer sets prices. Finally, the effect of rental income on the seasonality of transactions is as follows:

**Remark 4** In both the seller’s and buyer’s market, the extent of the seasonality of transactions is decreasing in the rental flow \(u\).

The observation follows from the fact that the extent of the seasonality of outside options for buyers and sellers is decreasing in \(u\) (similar to the reasoning in Remark 2). Hence, as \(u\) increases, transactions become less seasonal.
5.2 Calibration of the model

We now calibrate the model to study its quantitative implications. We calibrate the discount factor $\beta$ so that the implied annual real interest rate is 5 percent.

We set the average moving shock $\phi = (\phi^s + \phi^w) / 2$ to match the average duration of stay in a given house. The median duration in the U.S. from 1993 through 2005, according to the American Housing Survey, was 18 semesters. The median duration in the U.K. during this period, according to the Survey of English Housing was 26 semesters. These two surveys also report the main reasons for moving. Around 30-40 percent of the people report that living closer to work or to their children’s school and getting married as the main reasons. Using the monthly data on marriages from 1980 through 2003 for the U.K. and the U.S., we find that marriages are highly seasonal in both countries, with most marriages taking place between April and September. (The difference in annualized growth rates of marriages between the broadly defined “summer” and “winter” semesters are 200 percent in the U.S. and 400 percent in the U.K.). These factors are of course not entirely exogenous (marriages are often planned with considerable anticipation), but some carry a considerably exogenous component; in particular, the school calendar is exogenous to housing market developments. (See Tucker, Long, and Marx (1995)’s study of seasonality in children’s residential mobility.) In all, the survey evidence supports our working hypothesis that the \textit{ex ante} probability to move is higher in the summer. Though it is not possible to measure the size of the difference in seasonal probabilities $\phi^w - \phi^s$ directly from the data, we choose as a benchmark a very small seasonal difference of 5 percent, that is, $\phi^w - \phi^s = 0.05$. As will become clear from the quantitative results, this small difference will be enough to generate a degree of seasonality in transactions comparable to that in the data.

To illustrate the thick market effect, We assume $F^j(\cdot)$ follows a uniform distribution on the support $[0,v_j]$ (where $v_j$ is endogenously determined) Intuitively, a hot season with higher $v_j$ is characterized by a housing market where the matching quality is better on average.

The final parameter we need to calibrate is the net rental flow received by the seller, $u$. We use a range of values for $u$ so that the implied average (de-seasonalized) rent-to-price ratio (\textit{received by the seller}), $r = u/p$, ranges between 1 percent and 2.5 percent per semester (that is, between 2 and 5 percent per year) in a seller’s market.\footnote{Note that $u/p$ here is the \textit{net} rental flow received by the seller after paying taxes, and other relevant costs. Hence, it should be lower than the actual rent-to-price ratios typically advertised by estate agents in the U.K.} \footnote{We have not found reliable data on rent-to-price ratios for the U.K. Different sources, typically commercial,} To do so, we use the equilibrium equations in
the model without seasonality, that is, the model in which \( \phi^s = \phi^w = \phi = \frac{\phi^s + \phi^w}{2} \). From (16), the equilibrium price in a seller’s market is

\[
p = \frac{\beta u}{1 - \beta} + \left( \frac{1}{1 - \beta} \right) \frac{1 - F(\varepsilon^d)}{f(\varepsilon^d)(1 - \beta \phi)},
\]

where equilibrium reservation quality \( \varepsilon^d \) can be derived from (19) (see Appendix 8.2):

\[
\frac{\varepsilon^d}{1 - \beta \phi} = S_v + \frac{\beta \phi u + \frac{\beta \phi}{1 - \beta \phi} \int_{\varepsilon^d}^{\varepsilon} F(\varepsilon) d\varepsilon}{1 - \beta \phi F(\varepsilon^d)}.
\]

where \( S_v = \frac{1 - F(\varepsilon^d)}{f(\varepsilon^d)(1 - \beta \phi)} \). From the price equation (26), \( r \) is bounded above by \((1 - \beta) / \beta = 0.025\) per semester (or 5 percent per year), for our calibrated value for \( \beta \). We substitute \( u = r \cdot p \) and find the equilibrium value of \( p \) for each value of the semester-rent-to-price ratio \( r \) in the range \([0.01, 0.05]\), given the calibrated values for \( \beta \) and \( F(.) \). This yields a range of a-seasonal values for \( u = r \cdot p \) corresponding to the different values of \( r \). Using this range of values for \( u \), we then solve the model with seasonal shocks \( \phi^s < \phi^w \) under the two settings (seller’s market and buyer’s market). Note that in a buyer’s market, even though \( u \) varies, the rent-to-price ratio is always constant, given by: \( \frac{u}{p} = \frac{w}{p} = \frac{1 - \beta}{\beta} = 0.025 \) per semester.

5.3 Quantitative Results

To be completed.

Report the baseline results

6 Discussion and Extensions

6.1 Efficiency

This Section discusses the efficiency of equilibrium in the decentralized economy under both a seller’s and a buyer’s market scenarios.

Abstracting from seasonality for the moment, there are two sources of inefficiency in the decentralized economy. First, the match quality \( \varepsilon \) is private information: only buyers observe it. This report different values. We hence follow the conservative strategy of studying the implications of different values in a reasonable range. For the U.S., various sources of anecdotal evidence tend to place the average rent-to-price ratios in the range of 2 to 3 percent per semester (4 to 6 percent per year). This will be consistent with our choice of \( \beta \), which implies a rent-to-price ratio of 2.5 percent per semester in a buyer’s market—see text.
implies that the number of transactions in a seller’s market is inefficiently low. Second, the optimal decision rules of buyers and sellers take the stock of houses in each period as given, thereby ignoring the effects of their decision rules on the stock of houses in the following periods. The thick market effect generates a negative externality that makes the number of transactions in the decentralized economy (both in a seller’s and a buyer’s market) inefficiently high. We now derive the planner’s optimal level of transactions to illustrate these points.

The planner observes the match quality \( \varepsilon \) and is subject to the same exogenous moving shocks that hit the decentralized economy. The interesting comparison is the level of the reservation quality achieved by the planner with the corresponding levels in a seller’s and a buyer’s market. We first show the key result in an environment without seasonality, and then extend it to the model with seasonality.

To spell out the planner’s problem, we follow Pissarides (2000) and assume that the planner takes as given the expected housing utility service per person at the beginning of the period, which we denote by \( h \), as well as the beginning of period’s stock of vacant houses, \( v \). The Bellman equation for the planner is hence given by (see Appendix 8.3 for derivation):

\[
W(h, v) = \max_{\varepsilon^p} \{ h + \beta [uv' + W(h', v')] \}
\]

\[
h' = \phi h + v \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF(\varepsilon)
\]

\[
v' = v \phi F(\varepsilon^p) + 1 - \phi,
\]

where a “\( x \)” indicates the value of \( x \) in the following period. The planner’s solution is thus (see Appendix 8.3)

\[
(\text{Planner}) : \frac{\varepsilon^p}{1 - \beta \phi} = \frac{\beta \phi u + \frac{\beta \phi}{1 - \beta \phi} \left( \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF(\varepsilon) + \nu T_2 \right)}{1 - \beta \phi F(\varepsilon^p) + \beta \phi v T_1}, \tag{28}
\]

where the thick-market effect enters through two terms, \( T_1 \equiv \frac{\beta}{\nu} [1 - F(\varepsilon^p)] > 0 \) and \( T_2 \equiv \frac{\beta}{\nu} \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF(\varepsilon) > 0 \). The first term \( T_1 \) indicates that the thick-market effect shifts up the acceptance schedule \([1 - F(\varepsilon)]\). The second term \( T_2 \) indicates the thick-market effect increases the conditional quality of transactions.

The two sources of inefficiency can now be seen explicitly by comparing (28) to (27). The positive term \( S_v \) affecting \( \varepsilon^d \) in the decentralized seller’s market increases the reservation quality and hence lowers the number of transactions with respect to the efficient (planner’s) outcome. This source of inefficiency disappears in a buyer’s market, since \( S_v = 0 \). The second source of inefficiency,
through the thick-market externality, is present in both the seller’s and the buyer’s market. The thick market effect, captured by $T_1$ and $T_2$, generates two opposite forces. The term $T_1$ decreases $\varepsilon^p$, while the term $T_2$ increases $\varepsilon^p$ in the planner’s solution. Thus, the positive thick-market effect on the acceptance rate $T_1$ implies that the number of transactions is too low in the decentralized economy, while the positive effect on quality $T_2$ implies that the number of transactions is too high. Since $1 - \beta \phi$ is close to zero, however, the effect through $T_2$ dominates. Therefore, the overall effect of the thick market externality is to increase the number of transactions in the decentralized economy compared to the efficient outcome.\footnote{This result is similar to that in the stochastic job matching model of Pissarides (2000, chapter 8), where the reservation productivity is too low compared to the efficient outcome in the presence of search externalities.}

Hence, the number of transactions in a buyer’s market is too high compared to the planner’s solution while in a seller’s market it can be too low or too high, depending ultimately on the shape of the distribution $F(\cdot)$.

We now return to our baseline model with seasonality. Taking the stock of vacant houses at the beginning of season $s$ as given, the planner’s Bellman equation in season $s$ is given by (see Appendix 8.3):

$$W^s(h^s, v^s) = \max_{\varepsilon^s} \{h^s + \beta [uv^w + W^w(h^w, v^w)]\}$$

$$h^w = \phi^s h^s + v^s \int_{\varepsilon^s}^{s^s} \varepsilon dF^s(\varepsilon)$$

$$v^w = v^s \phi^s F^s(\varepsilon^s) + 1 - \phi^s$$

An isomorphic equation is obtained for $W^w(h^w, v^w)$. The optimal reservation quality, $\varepsilon^s$, is

$$(\text{Planner}): \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^s \phi^w} \varepsilon^s = \frac{\beta \phi^w u (1 + \beta \phi^w A^w) + \beta \phi^s B^w + \beta^2 \phi^s \phi^w A^w B^s}{1 - \beta^2 \phi^s \phi^w A^s A^w}, \quad (29)$$

where

$$A^s \equiv F^s(\varepsilon^s) - v^s T_1^s; \quad B^s \equiv \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^s \phi^w} \left( \int_{\varepsilon^s}^{\varepsilon^s} \varepsilon dF^s(\varepsilon) + v^s T_2^s \right),$$

$$T_1^s \equiv \frac{\partial}{\partial v^s} [1 - F^s(\varepsilon^s)] > 0, \text{ and } T_2^s \equiv \frac{\partial}{\partial v^s} \int_{\varepsilon^s}^{\varepsilon^s} \varepsilon dF^s(\varepsilon) > 0.$$
We have shown previously that for a given level of vacant houses, the overall effect of the thick-market externality is to increase the number of transactions in the decentralized economy relative to the efficient outcome because the term $T_2$ dominates $T_1$. The question is whether this excessive number of transactions is more severe when the level of vacant houses is higher or lower. Note that if $T_1^s > T_1^w$ and $T_2^w > T_2^s$, then the Planner’s solution implies a higher $\varepsilon^s/\varepsilon^w$ than the decentralized solution in a buyer’s market. As a result, this leads to lower seasonality in transactions in the Planner’s solution. This would be the case if the distribution $F_s(\cdot)$ were uniform on the support $[0,v^s]$, as we assume in our calibration. To see this, note that $F_j^i(\cdot) = (v^j + \varepsilon^i) / 2$, which implies that $T_j^i = 1/2$ is constant.

To compare the Planner’s solution with the decentralized solution in a seller’s market, the additional source of inefficiency stems from the surplus terms $S_s^v$ and $S_w^v$ in (19). As we will shown in Remark 3 below, the presence of the surplus term implies the seasonality in the number of transactions in a seller’s market is lower than is a buyer’s market. Therefore, the seasonality in the number of transactions in the seller’s market can be too high or too low compared to the seasonality implied by the Planner’s solution, depending on the shape of the distribution $F(\cdot)$.

### 6.2 Transaction Costs

We now extend our model to allow for transaction costs of buying a house for both the buyers and the sellers in seasons $j = s, w$:

\[
    T_j^b(p^j) = \bar{\tau}_b^j + \tau_b p^j;
\]
\[
    T_j^v(p^j) = \bar{\tau}_v^j + \tau_v p^j.
\]

We allow for fixed-cost components, $\bar{\tau}_b^j$ and $\bar{\tau}_v^j$, such as moving costs and repairing costs, to be seasonal. The proportional components $\tau_b$ and $\tau_v$, such as estate agent’s fees or taxes, are assumed to be a-seasonal. We show in the Appendix 8.4 that the equilibrium price equation (16) stills holds by simply replacing $p^s$ with $p^s - T_v(p^s)$, the net price received by the seller:

\[
    p^s - T_v^s(p^s) = \frac{\beta u}{1 - \beta} + \left(1 + \frac{\beta^2 [1 - F_s^s(\varepsilon^s)]}{1 - \beta^2}\right) S_v^s + \frac{\beta [1 - F_w^w(\varepsilon^w)]}{1 - \beta^2} S_w^w,
\]

where the surplus $S_v^s$ in the seller’s market (15) is now multiplied by $\frac{1 - \tau_v}{1 + \tau_b}$, which is analog to the “tax wedge” applied to a match between a firm and a worker in the labor literature:

\[
    S_v^s = \frac{1 - \tau_v}{1 + \tau_b} \left(1 - \frac{F_s^s(\varepsilon^s)}{f_s(\varepsilon^s)} \right) \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w}.
\]
The reservation quality equation (19) also holds by including the total transaction costs \( T_s^b (p^s) + T_s^v (p^s) \) on the right hand side:

\[
\frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon^s = S_v^s + T_s^b (p^s) + \frac{\beta \phi^w (1 - \beta^2 \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w) - \frac{\beta^2 \phi^w (1 - \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^s + B^s) .
\] (32)

Finally, \( S_b^b (\varepsilon) \) and \( (B^s + V^s) \) remain exactly as in (17) and (20) in the baseline model.

There are two interesting observations. First, for small enough proportional costs, \((1 - \tau_v) / (1 + \tau_b) \simeq 1 - (\tau_v + \tau_b)\), which implies that the modified surplus to the seller, \( S_v^s \), depends on the sum \((\tau_v + \tau_b)\) and \( \varepsilon^s \). From the modified (17) and (19), \( \varepsilon^s \) depends on total costs only. Hence, from (21), in equilibrium, the number of vacant houses, \( v^s \), depends only on total costs. It follows that the extent of seasonality in the number of transactions depends only on total costs. Second, the modified price equation (30) indicates that the seasonality in prices depends also on the how these costs are distributed between buyers and sellers.

7 Concluding Remarks

To be completed.

8 Appendix

8.1 Derivation for the model with seasonality

Deriving the optimal price (16):

Rewrite the value function of the seller (13) as

\[
V^s = \beta V^w + u + [p^s - \beta V^w] [1 - F^s (\varepsilon^s)]
\]

Using (12) and (14), we obtain

\[
V^s = \beta V^w + u + [1 - F^s (\varepsilon^s)] S_v^s,
\]

where

\[
S_v^s = \left( \frac{1 - F^s (\varepsilon^s)}{f^s (\varepsilon^s)} \right) \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s}.
\]

Solving out \( V^s \) explicitly:

\[
V^s = \frac{1 - F^s (\varepsilon^s)}{1 - \beta^2} S_v^s + \frac{\beta [1 - F^w (\varepsilon^w)]}{1 - \beta^2} S_v^w + \frac{u}{1 - \beta}.
\] (33)
It then follows from (14) that

\[ p^s = \left[ 1 + \frac{\beta^2 [1 - F^s (\varepsilon^s)]}{1 - \beta^2} \right] S^s_v + \frac{\beta [1 - F^w (\varepsilon^w)]}{1 - \beta^2} S^w_v + \frac{\beta u}{1 - \beta}. \] (34)

**Deriving reservation quality in (19):**

Rewrite

\[ p^s + \beta B^w = \beta (V^w + B^w) + p^s - \beta V^w \]

substitute \( S^s_v \),

\[ p^s + \beta B^w = \beta (V^w + B^w) + S^s_v \]

so the reservation quality (11) becomes

\[ \beta (V^w + B^w) + S^s_v = \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon^s + \frac{\beta \phi^w (1 - \beta^2 \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w) - \frac{\beta \phi^w (1 - \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^s + B^s). \]

**Deriving \( B + V \) in (20):**

By definition of optimal price \( p^s \) and reservation quality \( \varepsilon^s \), the value function (10) becomes:

\[ B^s = \int_{\varepsilon^s}^{\varepsilon^w} (H^s (\varepsilon) - p^s - T_b (p^s)) d\varepsilon + F^s (\varepsilon^s) \beta B^w \]

which can be rewritten as

\[ B^s = \beta B^w + (1 - F^s (\varepsilon^s)) E^s [S^s_b (\varepsilon) \mid \varepsilon > \varepsilon^s], \]

where

\[ S^s_b (\varepsilon) = H^s (\varepsilon) - p^s - \beta B^w \]

Together with the reservation equation (11), this implies

\[ S^s_b (\varepsilon) = H^s (\varepsilon) - H^s (\varepsilon^s) = \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} (\varepsilon - \varepsilon^s), \]

where the equality follows from (9). So the value of the buyer becomes

\[ B^s = \frac{1 - F^s (\varepsilon^s)}{1 - \beta^2} E^s [S^s_b (\varepsilon) \mid \varepsilon > \varepsilon^s] + \frac{\beta [1 - F^w (\varepsilon^w)]}{1 - \beta^2} E^w [S^w_b (\varepsilon) \mid \varepsilon > \varepsilon^w] \] (35)

Combining (35) with (33), we derive

\[ B^s + V^s = \frac{1 - F^s (\varepsilon^s)}{1 - \beta^2} E^s (S^s (\varepsilon) \mid \varepsilon > \varepsilon^s) + \frac{\beta [1 - F^w (\varepsilon^w)]}{1 - \beta} E^w (S^w (\varepsilon) \mid \varepsilon > \varepsilon^w) + \frac{u}{1 - \beta}. \] (36)
8.2 The model without seasonality

The value functions for the model without seasonality are identical to those in the model with seasonality without the superscripts $s$ and $w$. It can be shown that the equilibrium equations are also identical by simply setting $\phi^s = \phi^w$. Using (19),

$$\frac{\varepsilon^d}{1 - \beta \phi} = S_v + \frac{\beta \phi}{1 - \beta \phi} (1 - \beta) (V + B)$$

where $S_v$ follows from (15),

$$S_v = \frac{1 - F (\varepsilon^d)}{f(\varepsilon^d) (1 - \beta \phi)}.$$  

and $B + V$ from (20),

$$B + V = \frac{u}{1 - \beta} + \frac{1 - F (\varepsilon^d)}{1 - \beta} \left\{ \frac{E (\varepsilon - \varepsilon^d | \varepsilon > \varepsilon^d)}{1 - \beta \phi} + S_v \right\}$$

$$= \frac{1}{1 - \beta} \left[ u + [1 - F (\varepsilon^d)] S_v + \int_{\varepsilon^d}^{\varepsilon} \left( \frac{\varepsilon - \varepsilon^d}{1 - \beta \phi} \right) dF (\varepsilon) \right].$$

substitute into the reservation equation,

$$\frac{\varepsilon^d}{1 - \beta \phi} = S_v + \frac{\beta \phi}{1 - \beta \phi} \left[ u + [1 - F (\varepsilon^d)] S_v + \int_{\varepsilon^d}^{\varepsilon} \left( \frac{\varepsilon - \varepsilon^d}{1 - \beta \phi} \right) dF (\varepsilon) \right]$$

which can be rewritten as

$$\frac{\varepsilon^d}{1 - \beta \phi} = S_v + \frac{\beta \phi u + \frac{\beta \phi}{1 - \beta \phi} \int_{\varepsilon^d}^{\varepsilon} \varepsilon dF (\varepsilon)}{1 - \beta \phi F (\varepsilon^d)}.$$

8.3 The planner’s solution

For the model without seasonality,

$$W (h, v) = \max_{\varepsilon^p} \left\{ h + \beta [uv' + W (h', v')] \right\}$$

$$h' = \phi h + v \int_{\varepsilon}^{\varepsilon^p} \varepsilon dF (\varepsilon)$$

$$v' = v \phi F (\varepsilon^p) + 1 - \phi$$

The first-order condition implies

$$\beta W_{h'} v (-v f (\varepsilon^p)) + \beta W_{v'} \phi f (\varepsilon^p) = 0 \Rightarrow \varepsilon^p W_{h'} = \phi W_{v'}$$
where $W_x \equiv \frac{\partial W}{\partial x}$. Using the envelope-theorem conditions, we obtain:

\begin{align*}
W_h &= 1 + \beta W_h^\prime \phi \\
W_v &= \beta (u + W_v^\prime) (\phi F (\varepsilon^p) - v \phi T_1) + \beta W_h^\prime \left( \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF (\varepsilon) + v T_2 \right)
\end{align*}

where $T_1 \equiv \frac{\partial}{\partial v} [1 - F (\varepsilon^p)] > 0$ and $T_2 \equiv \frac{\partial}{\partial v} \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF (\varepsilon) > 0$. In steady state,

\begin{align*}
W_h &= \frac{1}{1 - \beta \phi} \\
W_v &= \frac{\beta u + \frac{\beta}{1 - \beta \phi} \left( \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF (\varepsilon) + v T_2 \right)}{1 - \beta \phi F (\varepsilon^p) + \beta \phi v T_1}
\end{align*}

Substituting this into the first-order condition, we get:

\begin{align*}
\varepsilon^p &= \frac{\beta \phi u + \frac{\beta}{1 - \beta \phi} \left( \int_{\varepsilon^p}^{\varepsilon} \varepsilon dF (\varepsilon) + v T_2 \right)}{1 - \beta \phi F (\varepsilon^p) + \beta \phi v T_1}.
\end{align*}

For the model with seasonality,

\begin{align*}
W^s (h^s, v^s) &= \max_{\varepsilon^s} \{ h^s + \beta [u v^w + W^w (h^w, v^w)] \} \\
h^w &= \phi^s h^s + v^s \int_{\varepsilon^s}^{\varepsilon} \varepsilon dF^s (\varepsilon) \\
v^w &= v^s \phi^s F^s (\varepsilon^s) + 1 - \phi^s
\end{align*}

The first-order condition implies

\begin{align*}
\varepsilon^s W^w_{h^w} &= \phi^s W^w_{v^w}
\end{align*}

and the envelope-theorem conditions are:

\begin{align*}
W^s_{h^s} &= 1 + \beta W^w_{h^w} \phi^s \\
W^s_{v^s} &= \beta (u + W^w_{v^w}) (\phi^s F^s (\varepsilon^s) - v^s \phi^s T^w_1) + \beta W^w_{h^w} \left( \int_{\varepsilon^s}^{\varepsilon} \varepsilon dF^s (\varepsilon) + v^s T^w_2 \right)
\end{align*}

In steady state,

\begin{align*}
W^s_{h^s} &= \frac{1 + \beta \phi^s}{1 - \beta^2 \phi^s \phi^w} \\
W^s_{v^s} &= \beta u + \beta \phi^s A^s W^w_{v^w} + \beta B^s,
\end{align*}

so

\begin{align*}
W^s_{v^s} &= \beta u + \beta \phi^s A^s W^w_{v^w} + \beta B^s.
\end{align*}
where:
\[
A^s \equiv F^s (\varepsilon^s) - v^s T^s_1 \\
B^s \equiv \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^w} \left( \int_{\varepsilon^s}^{\varepsilon^w} \varepsilon dF^s (\varepsilon) + v^s T^s_2 \right).
\]

Solving for \(W^s_v\),
\[
W^s_v = \beta u + \beta \phi^s A^s (\beta u + \beta \phi^w A^w W^s_v + \beta B^w) + \beta B^s
\]
Hence,
\[
W^s_v = \frac{\beta u (1 + \beta \phi^s A^s) + \beta B^s + \beta^2 \phi^s A^s B^w}{1 - \beta^2 \phi^w A^s A^w}
\]

Substituting this into the first order condition, the equilibrium reservation value \(\varepsilon^s\) solves
\[
\frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w A^w} \varepsilon^s = \frac{\beta \phi^s u (1 + \beta \phi^w A^w) + \beta \phi^w B^w + \beta^2 \phi^w \phi^w A^w B^s}{1 - \beta^2 \phi^w A^w A^w}
\]

### 8.4 The model with Transaction costs

We now introducing transaction costs of buying a house into the baseline model. The value function of the homeowner is the same as (9) in the baseline. The buyer’s value function is modified to:
\[
B^s = E_{\varepsilon^s} \max \{ H^s (\varepsilon) - p^s - T^s_b (p^s), \beta B^w \},
\]
so the cutoff \(\varepsilon^s\) is given by:
\[
H^s (\varepsilon^s) - p^s - T^s_b (p^s) = \beta B^w,
\]
and
\[
\frac{\partial \varepsilon^s}{\partial p^s} = \frac{1 - \beta^2 \phi^w \phi^s}{1 + \beta \phi^w (1 + \tau_b)}.
\]
The sell’s value function is modified to:
\[
V^s = \beta V^w + u + \max_p [1 - F^s (\varepsilon^s (p))] (p - T^s_v (p) - \beta V^w),
\]
where the optimal price \(p^s\) solves
\[
\frac{p^s - T^s_v (p^s) - \beta V^w}{(1 - \tau_v) p^s} = \left( \frac{p^s f^s (\varepsilon^s) \frac{\partial \varepsilon^s}{\partial p^s}}{1 - F^s (\varepsilon^s)} \right)^{-1}.
\]
Following similar simplification as in Appendix 8.1, we obtain
\[
S^s_v = \left( \frac{1 - \tau_v}{1 + \tau_b} \right) \left( \frac{1 - F^s (\varepsilon^s)}{f^s (\varepsilon^s)} \right) \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s}
\]
\[ p^s - T^s(p^s) = \frac{\beta u}{1 - \beta} + \left( 1 + \frac{\beta^2 [1 - F^s(\varepsilon^s)]}{1 - \beta^2} \right) S_v^s + \frac{\beta [1 - F^w(\varepsilon^w)]}{1 - \beta^2} S_w^s, \]
\[ \frac{1 + \beta \phi^w}{1 - \beta^2 \phi^w \phi^s} \varepsilon^s = S_v^s + T^s(p^s) + \frac{\beta \phi^w (1 - \beta^2 \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^w + B^w) - \frac{\beta^2 \phi^w (1 - \phi^s)}{1 - \beta^2 \phi^w \phi^s} (V^s + B^s), \]
and \( B^s + V^s \) as in (20).
References


9 Data Sources

For U.K. and U.S. data, see text.

**Australia**  The housing price index comes from the Australia Bureau of Statistics (ABS); it is a weighted average for eight capital cities, available from 1986; the series is based on prices at settlement and are based on data provided to the land titles office; it is not quality adjusted. The CPI (non seasonally adjusted, NSA) also comes from the ABS and is a national index, not available at a disaggregated level; in what follows, for all countries, the price index considered in the analysis corresponds to the national index.

**Belgium**  The housing price index comes from STADIM (*Studies & advies Immobiliën*) and covers Belgium and its three main regions from 1981; the series is based on the average selling prices of small and average single-family houses; apartments are not included; the data come from registered sales, and are not quality adjusted. The CPI (NSA) comes from the National Institute for Statistics.

**Denmark**  The housing price index comes from the Association of Danish Mortgage Banks and corresponds to existing single-family homes (including flats and weekend cottages). The data come from the Land Registry, where all housing transactions are registered; they are not adjusted by quality and start in 1992. The CPI (NSA) comes from *Danmarks Statistik*.

**France**  The housing price index comes from INSEE (National Institute for Statistics and Economic Studies) and corresponds to existing single-family homes. The data are not quality adjusted and start in 1994. The index covers all regions, and comes also disaggregated into 4 regions. The CPI (NSA) comes from the same source.

**Ireland**  The housing price index comes from *Permanent TSB*, which accounts for about 20 percent of residential mortgage loans in the country, starting in 1996; the index is adjusted by the size of the property, dwelling type (detached, semi-detached, terrace, or apartment), and heating system. The number of transactions (loans) comes from the same source. The CPI (NSA) comes from the Central Statistical Office in Ireland.
Netherlands  The housing price index comes from the Dutch Land Registry; it is a repeat-sale index, starting in 1993. The CPI (NSA) comes from the CBS (Statistics Netherlands).

New Zealand  The housing price index comes from the Reserve Bank of New Zealand, starts in 1968, and is not adjusted by quality; the CPI (NSA) comes from the same source.

Norway  The housing price index comes from Statistics Norway, starting in 1992; the data are not adjusted by quality as meticulously as in the U.K., however, the properties considered need to satisfy a set of broadly defined) characteristics to be included in the index; the CPI (NSA) comes from the same source.

South Africa  The housing price index comes from ABSA, a commercial bank that covers around 53 percent of the mortgage market in South Africa. The data are recorded at the application stage of the mortgage lending process and the series starts in 1975. There is no quality adjustment, although the properties considered need to satisfy a set of (broadly defined) characteristics to be included in the index. The CPI (NSA) comes from Statistics South Africa.

Sweden  The housing price index comes from *Statistika Centralbyrån*; the data correspond to one and two-dwelling properties and are not quality-adjusted; the series starts in 1986; data on transactions and CPI (NSA) come from the same source.