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Chapter Author: Daniel L. McFadden

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7 Demographics, the Housing Market, and the Welfare of the Elderly

Daniel McFadden

7.1 Introduction

The birthrate in the United States has fluctuated sharply in the past century, as shown in figure 7.1, with "baby booms" in 1900–25 and 1947–62 and "baby busts" in 1930–46 and after 1962; Census Bureau "low" and "mid" projections are that the current bust will continue into the next century. The age composition of the population has varied in proportions reflecting the lagged birthrate, with smoothing and stretching due to immigration and changing life expectancy, as shown in figure 7.2. If fertility rates remain at current below-replacement levels over the coming century, as projected by many demographers, then the U.S. population will peak between 2030 and 2050. After this, it will under "low" projections decline by 2100 to approximately 1990 levels, or under "mid" projections remain almost stationary. The elderly population will peak around 2035, as the 1947–62 baby-boom cohorts pass age 65, but increasing longevity will keep the *elderly dependency ratio*[1] high through the end of the next century. The *total dependency ratio* will rise sharply after 2010, and although it will not reach the historic highs attained at the end of past baby booms, the relative shift in dependency toward the elderly will be drastic. If

Daniel McFadden is professor of economics at the University of California, Berkeley, and a research associate of the National Bureau of Economic Research.

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1. The elderly [resp. youth] dependency ratio equals the population age 65 and over [resp. the population age 0–19] divided by the population age 20–64. The total dependency ratio is the sum of the elderly and youth dependency ratios.

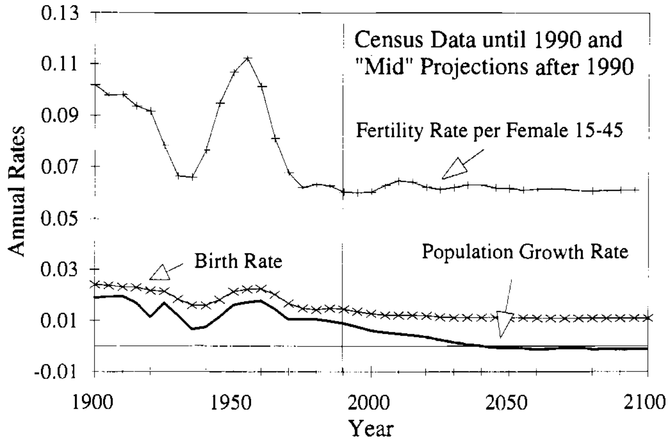

Fig. 7.1 U.S. population growth

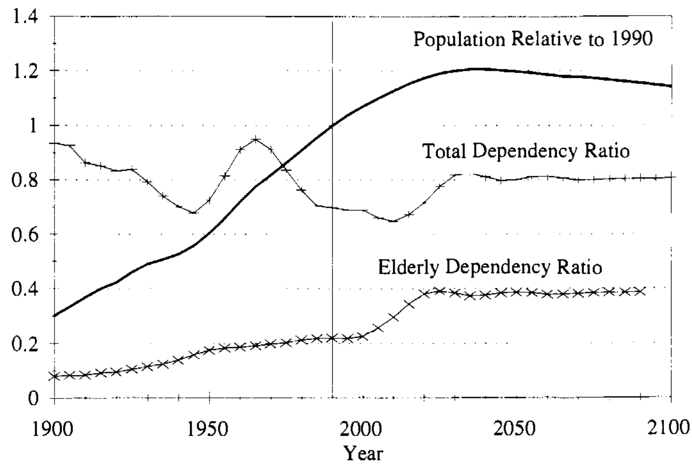

Fig. 7.2 Dependency ratios

these demographic projections are correct, then the United States faces a "regime shift" that will substantially change the characteristics of institutions influenced by demographic factors. These changes will in turn have some significant impacts on the welfare of elderly cohorts, particularly those that span the regime shift.

The institution that has perhaps the greatest impact on the welfare of the elderly is the Social Security/Medicare system. The implications of demographics for this program have been investigated in detail, for example, by Boskin and Shoven (1987), the Consulting Panel on Society Security (1976), Darby (1979), Diamond and Hausman (1984), Hurd (1991), Hurd and Shoven (1982), Kotlikoff and Smith (1983), and Poterba and Summers (1987).

Markets such as health services and housing are also likely to see substantial impacts. Recently, several economists have examined the impact of demographics on the housing market. In a seminal paper, Mankiw and Weil (1989) show that a simple age-specific housing demand function, combined with demographic profiles, generates aggregate *potential* housing demand with substantial intertemporal variation. Related studies have been done by Rosen (1984) and Russell (1982). Mankiw and Weil argue that real housing stocks are not very responsive to housing prices and that the price elasticity of demand is low. They conclude that the demographic swings will be converted in this relatively rigid market into large swings in housing prices and that the past pattern of housing wealth generated by real capital gains will be largely reversed in coming decades. Figures 7.3–7.5 give time series for real housing stock, the demographic component of potential housing demand as defined by Mankiw and Weil, and real housing prices. The construction of these series is detailed in section 7.3. The high correlations among these three series (.9668 between stock and the demographic factor, .8875 between stock and price, and .9423 between price and the demographic factor) are consistent with the economic hypothesis that demographics are causal to housing stock and price.

Housing equity is the most important asset of most elderly households, and for many is the *only* significant asset; see McFadden (1994). The 1983 Survey of Consumer Finances finds that in the population over age 65, 69 percent of net worth is in house equity. The 1984 Survey of Income and Program Participation finds that 73 percent of households over age 65 have equity in a home and that the median equity among holders was $46,192. The only other assets

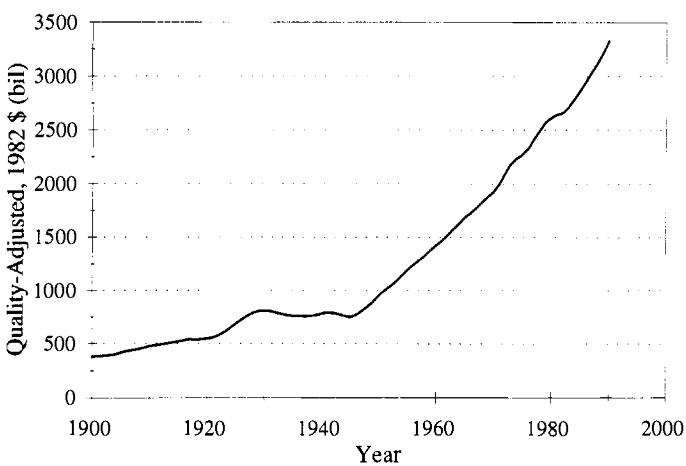

Fig. 7.3 Real housing stock

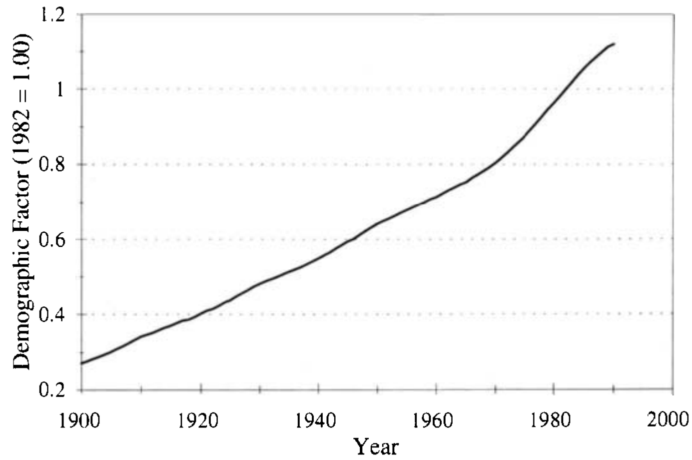

Fig. 7.4 Demographic factor in housing demand

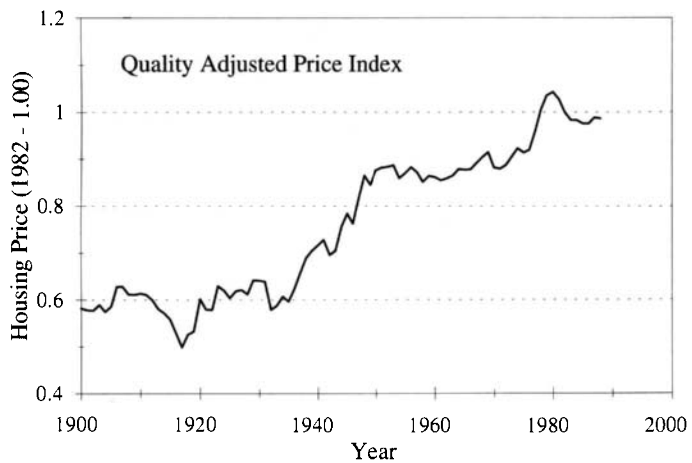

Fig. 7.5 Real housing price

held by a majority of households are bank accounts and equity in automobiles, and the medians among holders of these assets total less than $17,000. Further, a substantial fraction of home equity held by current elderly cohorts comes from capital gains. For example, from figure 7.5, real capital gains created more than a third of the equity of a household that purchased a house in 1945 at age 30 and that sold it in 1980 to finance retirement. Then, variations in real housing prices that affect net equity can have a significant impact on the wealth of the elderly and on intergenerational distribution of welfare. The increasing importance of housing equity as an asset in recent decades—from 22 percent of holdings in 1965, to a high of 34 percent in 1979, and to 31 percent in 1988, according to Federal Reserve Board balance sheets (C-9)—combined with the high volatility of housing prices, has increased the riskiness of consumers' asset portfolios. The potential welfare effects are particularly large if the price changes are unanticipated, so that households have a significant fraction of their assets at risk and are unable to adjust savings and bequest behavior in anticipation of market variations. It remains true if the price changes are predictable, but myopia or credit constraints prevent households from forming intertemporally consistent life-cycle savings plans.

This paper examines the long-run behavior of the housing market in response to demographic swings and the consequences of market characteristics for the welfare of current and future cohorts of the elderly. Section 7.2 uses a simple demographic model, along with U.S. Department of Commerce middle-range assumptions, to project population by age over the next century. Section 7.3 assembles measures of per capita income, quality-adjusted housing stock, real housing price, and the real user cost of owner-occupied housing. Section 7.4 examines the age distribution of housing consumption and income and its stability over time. Section 7.5 obtains estimates of demand and supply elasticities, using aggregate data and information from various censuses. Section 7.6 assembles these components and forecasts market-clearing housing prices and stocks. Section 7.7 analyzes the welfare impacts on successive elderly cohorts of these housing market variations.

7.2 Demographics

Estimates and "mid-range" forecasts of the U.S. population by age and sex, from the U.S. Census, are given in tables 7.1–7.3 for the years 1900–2100. Historical estimates are from *Historical Statistics of the United States* (U.S. Department of Commerce, 1975), and *Statistical Abstract* (U.S. Department of Commerce, various years). Projections are from Spencer (1989). For intercensus years after 2050, and all years after 2080, I complete the table using a cohort-component projection procedure plus the fertility rate lagged one period; see Haub (1987) for an explanation of this methodology. For years prior to 1940, it was necessary to disaggregate census tables for persons over age 65. This was done using contemporaneous life tables, as described below.

A critical component of projections of the elderly population is an assumption about mortality trends. I followed the actuarial approach used by Spencer (1989) and Palmer (1989), fitting Gompertz curves in each census year to age-specific death rates after age 55. The death rate H per 1,000 persons of age A and sex i in year t is approximated by the function

$$H = \exp(\alpha_{it} + \beta_{it}A). \qquad (1)$$

The estimates for the Gompertz coefficients, along with projections past 1990, are given in table 7.4.

Table 7.1 **U.S. Census Estimates and Projections of Male Population by Age, Middle Series P-25, 1989 (thousands)**

	Age Group									
Year	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
1900	4,655	4,500	4,102	3,767	3,642	3,339	2,914	2,629	2,266	1,846
1905	5,047	4,638	4,522	4,351	4,014	3,657	3,360	2,854	2,509	2,192
1910	5,420	4,959	4,635	4,560	4,613	4,275	3,683	3,391	2,803	2,396
1915	5,881	5,504	4,914	4,674	4,642	4,460	4,259	3,555	3,321	2,724
1920	5,910	5,805	5,417	4,716	4,568	4,579	4,168	4,111	3,315	3,146
1925	6,325	6,051	5,841	5,432	4,838	4,612	4,677	4,195	3,930	3,257
1930	5,826	6,403	6,090	5,778	5,355	4,877	4,578	4,696	4,150	3,685
1935	5,188	5,916	6,315	5,913	5,635	5,232	4,829	4,515	4,469	3,966
1940	5,378	5,442	5,987	6,206	5,716	5,474	5,092	4,766	4,438	4,227
1945	6,513	5,542	5,411	5,890	6,138	5,724	5,529	5,106	4,665	4,292
1950	8,314	6,778	5,713	5,361	5.659	6,028	5,678	5,570	5.118	4,569
1955	9,411	8,495	6,916	5,536	5,329	5,833	6,085	5,810	5,437	5,008
1960	10,337	9,563	8,600	6,802	5,568	5,422	5,903	6,139	5,731	5,396
1965	10,070	10,367	9,696	8,633	6,903	5,607	5,519	5.893	6,068	5,552
1970	8,869	10,312	10,741	9,771	8,029	6,715	5,675	5,489	5,902	5,934
1975	8,240	8,972	10,534	10,817	9,839	8.617	7,018	5,702	5,497	5,712
1980	8,423	8,601	9,384	10,833	10,711	9,776	8,740	6,912	5,750	5,427
1985	9,213	8,610	8,763	9,479	10,708	11,007	10,167	8,794	6,910	5,684
1990	9,426	9,408	8,858	8,900	9,427	10,818	11,260	10,072	8,713	6,815
1995	9,118	9,609	9,660	8,979	8,830	9,526	11,053	11,138	9,966	8,586
2000	8,661	9,683	10,073	9,765	8,799	8,881	9,664	11.020	11,036	9,824
2005	8,517	9,165	9,766	10,143	9,807	8,875	8,947	9,669	10,952	10,886
2010	8,668	9,062	9,247	9,834	10,178	9,871	8,941	8,957	9,616	10,802
2015	8,829	9,305	9,131	9,303	9,857	10,223	9,911	8,937	8,898	9,477
2020	8,768	9,546	9,401	9,211	9,350	9,928	10,293	9,934	8,902	8,793
2025	8,544	9,495	9,639	9,477	9,251	9,411	9,989	10,310	9,890	8,792
2030	8,357	9,283	9,589	9,719	9,521	9,314	9,471	10,008	10,266	9,769
2035	8,300	9,125	9,567	9,652	9,747	9,568	9,356	9,472	9,947	10,123
2040	8,308	9,123	9,399	9,624	9,675	9,790	9,607	9.353	9,410	9,803
2045	8,267	9,165	9,392	9,450	9,641	9,712	9,824	9,598	9,286	9,269
2050	8,143	9,122	9,431	9,439	9,463	9,675	9,742	9,811	9,526	9,143
2055	8,136	8,985	9,386	9,479	9,452	9,496	9,704	9,728	9,737	9,379
2060	7,916	8,853	9,246	9,434	9,492	9,485	9,526	9,692	9,656	9,587
2065	7,864	8,613	9,109	9,293	9,448	9,525	9,515	9,513	9,619	9,507
2070	7,823	8,777	9,059	9,171	9,320	9,496	9,570	9,517	9,457	9,486
2075	7,803	8,731	9,231	9,120	9,198	9,368	9,540	9,572	9,461	9,326
2080	7,661	8,679	9,012	9,101	9,141	9,239	9,406	9,537	9,510	9,324
2085	7,626	8,522	8,959	8.885	9,122	9,182	9,277	9,402	9,474	9,372
2090	7,586	8,483	8,797	8,833	8,905	9,162	9,219	9,273	9,341	9,338
2095	7,552	8,438	8,756	8,672	8,853	8,945	9,200	9,216	9,213	9,206
2100	7,525	8,401	8,710	8.633	8,692	8,893	8,982	9,197	9,156	9,080

Table 7.1 (continued)

Age Group											
50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95+	Total	Year
1,572	1,150	921	724	446	240	106	36	8	1	38,867	1900
1,670	1,382	990	753	508	300	147	54	13	2	42,965	1905
2,125	1,499	1,195	834	569	341	170	65	17	3	47,554	1910
2,181	1,890	1,252	953	657	399	203	80	22	3	51,573	1915
2,559	1,897	1,596	967	707	456	244	100	27	4	54,291	1920
2,813	2,272	1,612	1,213	845	517	259	96	23	3	58,813	1925
3,142	2,434	1,949	1,300	936	598	321	134	39	7	62,297	1930
3,360	2,780	2,060	1,486	1,098	720	397	171	51	9	64,110	1935
3,769	3,024	2,408	1,680	1,241	811	443	187	53	9	66,352	1940
3,941	3,413	2,734	1,930	1,419	935	526	236	76	15	70,035	1945
4,168	3,664	3,067	2,446	1,645	1,001	470	209	67	14	75,539	1950
4,317	3,825	3,317	2,711	1,914	1,166	550	258	91	21	82,030	1955
4,762	4,144	3,413	2,939	2,193	1,369	639	288	94	19	89,320	1960
5,087	4,578	3,639	2,934	2,342	1,514	734	336	112	24	95,609	1965
5,424	4,834	4,084	3,166	2,342	1,586	801	398	152	40	100,266	1970
5,737	5,048	4,368	3,596	2,441	1,653	904	455	173	44	105,366	1975
5,662	5,522	4,704	3,948	2,894	1,875	989	502	189	46	110,888	1980
5,284	5,383	5,118	4,254	3,213	2,135	1,086	566	220	55	116,648	1985
5,591	5,071	5,032	4,655	3,516	2,413	1,350	627	222	70	122,243	1990
6,705	6,386	4,763	4,603	3,873	2,668	1,548	752	275	84	127,123	1995
8,531	6,419	4,952	4,144	3,697	2,894	1,786	915	338	109	131,191	2000
9,580	8,169	6,000	4,444	3,498	2,879	1,988	1,016	411	145	134,858	2005
10,617	9,180	7,648	5,400	3,771	2,741	1,996	1,147	469	186	138,333	2010
10,520	10,158	8,583	6,881	4,586	2,965	1,908	1,161	538	223	141,393	2015
9,254	10,092	9,523	7,742	5,860	3,615	1,908	1,113	546	256	144,035	2020
8,581	8,872	9,455	8,585	6,590	4,616	2,325	1,112	523	260	145,717	2025
8,581	8,229	8,314	8,526	7,309	5,192	2,969	1,356	523	249	146,543	2030
9,518	8,215	7,697	7,483	7,245	5,748	3,333	1,728	636	248	146,711	2035
9,858	9,107	7,680	6.925	6,356	5,696	3,689	1,939	810	302	146,454	2040
9,541	9,426	8,509	6,906	5,878	4,994	3,653	2,145	909	385	145,950	2045
9,017	9,120	8,804	7,648	5,860	4,616	3,201	2,123	1,005	431	145,320	2050
8,895	8,619	8,518	7,913	6,490	4,602	2,959	1,861	994	490	144,824	2055
9,125	8,502	8,051	7,656	6,715	5,097	2,950	1,720	872	472	144,046	2060
9,327	8,722	7,942	7,236	6,497	5,274	3,268	1,715	806	430	143,224	2065
9,264	8,930	8,160	7,149	6,150	5,111	3,386	1,902	804	383	142,915	2070
9,244	8,869	8,354	7,346	6,076	4,838	3,282	1,971	892	401	142,621	2075
9,082	8,844	8,293	7,516	6,239	4,777	3,104	1,909	924	424	141,722	2080
9,080	8,690	8,269	7,461	6,384	4,905	3,065	1,806	895	470	140,847	2085
9,127	8,688	8,125	7,439	6,337	5,019	3,148	1,783	847	458	139,909	2090
9,094	8,733	8,123	7,309	6,319	4,982	3,221	1,831	836	437	138,937	2095
8,966	8,701	8,165	7,308	6,209	4,968	3,197	1,874	859	434	137,947	2100

Table 7.2 **U.S. Census Estimates and Projections of Female Population by Age, Middle Series P-25, 1989 (thousands)**

	Age Group									
Year	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
1900	4,594	4,450	4,047	3,854	3,757	3,246	2,688	2,378	2,016	1,637
1905	4,942	4,542	4,487	4,257	3,889	3,529	3,132	2,577	2,229	1,900
1910	5,283	4,866	4,532	4,563	4,504	3,960	3,335	3,047	2,490	2,103
1915	5,712	5,363	4,889	4,717	4,630	4,290	3,893	3,249	2,893	2,382
1920	5,762	5,690	5,314	4,795	4,788	4,585	3,972	3,731	3,085	2,667
1925	6,168	5,908	5,800	5,479	4,933	4,720	4,603	3,952	3,586	2,993
1930	5,655	6,246	5,954	5,811	5,551	4,988	4,573	4,543	3,866	3,380
1935	5,044	5,755	6,232	5,956	5,759	5,389	4,920	4,494	4,317	3,704
1940	5,200	5,279	5,808	6,168	5,910	5,660	5,185	4,812	4,380	4,056
1945	6,285	5,336	5,270	5,828	6,210	5,907	5,693	5,156	4,679	4,258
1950	7,955	6,508	5,478	5,324	5,897	6,292	5,913	5,749	5,152	4,570
1955	9,082	8,188	6,668	5,461	5,342	5,954	6,313	6,000	5,575	5,111
1960	10,002	9,245	8,323	6,640	5,566	5,512	6,079	6,403	5,946	5,535
1965	9,715	10,011	9,360	8,380	6,852	5,723	5,609	6,115	6,380	5,828
1970	8,415	9,768	10,230	9,517	8,547	6,915	5,872	5,680	6,148	6,277
1975	7,881	8,623	10,112	10,468	9,688	8,663	7,173	5,931	5,700	6,072
1980	8,005	8,181	8,948	10,438	10,681	9,840	8,906	7,121	5,975	5,716
1985	8,792	8,214	8,339	9,109	10,507	10,886	10,179	8,969	7,167	5,968
1990	8,982	8,971	8,427	8,518	9,262	10,694	11,154	10,148	8,964	7,132
1995	8,681	9,151	9,187	8,588	8,652	9,440	10,944	11,107	10,126	8,903
2000	8,604	9,131	9,503	9,234	8,397	8,566	9,411	10,795	11,016	9,994
2005	8,518	8,637	9,206	9,578	9,338	8,555	8,687	9,459	10,786	10,945
2010	8,774	8,541	8,716	9,287	9,715	9,497	8,681	8,744	9,465	10,725
2015	9,003	8,775	8,394	8,789	9,385	9,833	9,608	8,730	8,746	9,410
2020	8,960	8,990	8,630	8,470	8,888	9,506	9,956	9,669	8,738	8,701
2025	8,765	8,939	8,847	8,713	8,571	9,008	9,630	10,025	9,684	8,699
2030	8,637	8,740	8,800	8,936	8,821	8,690	9,129	9,701	10,045	9,645
2035	8,660	8,607	8,604	8,888	9,046	8,943	8,807	9,196	9,720	10,003
2040	8,729	8,629	8,476	8,693	9,001	9,174	9,067	8,875	9,218	9,683
2045	8,720	8,703	8,504	8,571	8,810	9,136	9,309	9,144	8,902	9,190
2050	8,621	8,704	8,582	8,604	8,692	8,948	9,275	9,393	9,177	8,881
2055	8,527	8,605	8,583	8,683	8,725	8,827	9,084	9,359	9,428	9,155
2060	8,498	8,513	8,478	8,666	8,786	8,842	8,943	9,147	9,374	9,385
2065	8,504	8,484	8,387	8,559	8,769	8,905	8,958	9,005	9,161	9,332
2070	8,496	8,479	8,346	8,464	8,667	8,893	9,027	9,026	9,025	9,126
2075	8,452	8,471	8,342	8,423	8,570	8,789	9,015	9,095	9,046	8,990
2080	8,395	8,422	8,339	8,435	8,538	8,690	8,909	9,083	9,115	9,011
2085	8,341	8,365	8,291	8,433	8,551	8,658	8,809	8,977	9,103	9,080
2090	8,310	8,312	8,235	8,384	8,548	8,671	8,777	8,876	8,996	9,067
2095	8,292	8,282	8,182	8,327	8,498	8,668	8,790	8,843	8,895	8,961
2100	8,267	8,263	8,152	8,274	8,441	8,618	8,787	8,856	8,862	8,861

Table 7.2 (continued)

Age Group											
50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95+	Total	Year
1,395	1,079	885	539	340	190	89	31	8	1	37,227	1990
1,465	1,236	929	709	494	304	157	61	16	2	40,857	1905
1,801	1,307	1,088	788	558	350	183	73	20	3	44,853	1910
1,916	1,627	1,131	899	641	406	216	89	25	4	48,973	1915
2,217	1,682	1,412	927	692	457	252	107	30	5	52,170	1920
2,467	2,033	1,461	1,147	826	525	276	108	27	3	57,016	1925
2,853	2,227	1,815	1,217	915	616	353	159	50	9	60,780	1930
3,123	2,605	1,923	1,372	1,067	746	444	208	68	13	63,140	1935
3,513	2,840	2,336	1,603	1,262	890	532	247	77	13	65,770	1940
3,834	3,269	2,812	1,821	1,433	1,024	633	312	110	23	69,893	1945
4,159	3,618	3,033	2,700	1,738	1,109	552	277	99	21	76,146	1950
4,373	3,932	3,491	2,947	2,196	1,407	678	358	138	33	83,246	1955
4,901	4,326	3,741	3,347	2,574	1,712	859	444	163	35	91,352	1960
5,343	4,916	4,053	3,532	2,981	2,057	1,039	549	206	45	98,694	1966
5,786	5,225	4,624	3,858	3,121	2,281	1,224	714	317	92	104,613	1970
6,235	5,598	5,031	4,536	3,344	2,593	1,506	905	419	128	110,606	1975
6,104	6,148	5,431	4,903	3,978	2,973	1,753	1,081	518	166	116,866	1980
5,661	5,960	5,877	5,176	4,352	3,360	2,017	1,265	623	209	122,631	1985
5,949	5,552	5,708	5,596	4,605	3,691	2,478	1,438	652	247	128,167	1990
7,102	5,842	5,333	5,453	5,001	3,939	2,766	1,682	799	321	133,016	1995
8,872	6,896	5,561	4,974	4,901	4,413	3,242	2,112	1,017	437	137,076	2000
9,864	8,671	6,655	5,255	4,561	4,312	3,595	2,311	1,229	583	140,746	2005
10,810	9,646	8,373	6,300	4,658	4,035	3,541	2,600	1,382	750	144,241	2010
10,582	10,559	9,306	7,921	5,803	4,286	3,322	2,579	1,576	896	147,504	2015
9,291	10,344	10,194	8,809	7,301	5,344	3,532	2,421	1,564	1,022	150,329	2020
8,597	9,088	9,993	9,656	8,125	6,728	4,406	2,576	1,469	1,015	152,535	2025
8,597	8,412	8,782	9,469	8,910	7,490	5,550	3,215	1,564	954	154,086	2030
9,532	8,412	8,129	8,322	8,737	8,213	6,178	4,049	1,951	1,015	155,014	2035
9,890	9,330	8,132	7,706	7,681	8,057	6,777	4,509	2,459	1,268	155,353	2040
9,581	9,689	9,027	7,715	7,118	7,089	6,653	4,950	2,740	1,598	155,150	2045
9,099	9,391	9,379	8,569	7,131	6,573	5,857	4,862	3,010	1,782	154,529	2050
8,792	8,918	9,091	8,903	7,920	6,584	5,431	4,280	2,957	2,041	153,893	2055
9,045	8,600	8,615	8,611	8,211	7,297	5,429	3,961	2,598	1,919	152,917	2060
9,272	8,847	8,308	8,160	7,942	7,566	6,017	3,959	2,403	1,780	152,318	2065
9,225	9,075	8,552	7,874	7,531	7,323	6,243	4,391	2,404	1,561	151,727	2070
9,022	9,029	8,772	8,106	7,267	6,944	6,042	4,555	2,666	1,666	151,262	2075
8,887	8,830	8,727	8,314	7,480	6,700	5,729	4,409	2,766	1,732	150,513	2080
8,908	8,698	8,535	8,272	7,673	6,897	5,528	4,181	2,677	1,902	149,877	2085
8,976	8,718	8,407	8,089	7,634	7,075	5,690	4,034	2,538	1,852	149,190	2090
8,963	8,784	8,427	7,968	7,465	7,038	5,837	4,152	2,449	1,767	148,592	2095
8,859	8,772	8,491	7,987	7,354	6,883	5,807	4,259	2,521	1,716	148,031	2100

Table 7.3 U.S. Census Estimates and Projections of Total Population by Age, Middle Series P-25, 1989 (thousands)

	Age Group									
Year	0–4	5–9	10–14	15–19	20–24	25–29	30–34	35–39	40–44	45–49
1900	9,249	8,950	8,149	7,621	7,398	6,586	5,603	5,007	4,282	3,484
1905	9,988	9,180	9,009	8,607	7,903	7,186	6,493	5,431	4,738	4,092
1910	10,702	9,826	9,167	9,123	9,117	8,234	7,018	6,439	5,293	4,499
1915	11,593	10,867	9,803	9,391	9,271	8,750	8,151	6,805	6,213	5,106
1920	11,672	11,495	10,732	9,511	9,356	9,163	8,140	7,841	6,400	5,813
1925	12,494	11,959	11,641	10,911	9,771	9,333	9,280	8,147	7,516	6,250
1930	11,481	12,649	12,044	11,589	10,906	9,865	9,150	9,239	8,016	7,065
1935	10,232	11,670	12,547	11,869	11,394	10,621	9,749	9,009	8,786	7,670
1940	10,578	10,721	11,796	12,374	11,626	11,134	10,276	9,578	8,818	8,283
1945	12,797	10,878	10,680	11,718	12,348	11,632	11,222	10,262	9,344	8,550
1950	16,269	13,287	11,192	10,685	11,556	12,321	11,591	11,320	10,270	9,139
1955	18,493	16,683	13,584	10,996	10,672	11,787	12,398	11,810	11,011	10,119
1960	20,339	18,808	16,923	13,442	11,134	10,934	11,982	12,542	11,677	10,931
1965	19,785	20,378	19,056	17,013	13,755	11,330	11,128	12,008	12,448	11,380
1970	17,285	20,081	20,972	19,288	16,577	13,630	11,548	11,169	12,050	12,211
1975	16,121	17,595	20,646	21,285	19,527	17,280	14,191	11,633	11,197	11,784
1980	16,428	16,782	18,332	21,272	21,391	19,616	17,646	14,033	11,725	11,143
1985	18,005	16,824	17,102	18,588	21,215	21,893	20,346	17,763	14,077	11,652
1990	18,408	18,379	17,285	17,418	18,689	21,512	22,414	20,220	17,677	13,947
1995	17,799	18,760	18,847	17,567	17,482	18,966	21,997	22,245	20,092	17,489
2000	17,265	18,814	19,576	19,000	17,196	17,447	19,074	21,816	22,052	19,818
2005	17,035	17,802	18,973	19,722	19,144	17,431	17,634	19,128	21,737	21,831
2010	17,442	17,604	17,964	19,121	19,894	19,368	17,621	17,701	19,081	21,528
2015	17,832	18,080	17,525	18,092	19,242	20,057	19,520	17,666	17,644	18,887
2020	17,728	18,536	18,031	17,681	18,238	19,433	20,248	19,603	17,640	17,494
2025	17,309	18,434	18,486	18,191	17,822	18,419	19,619	20,335	19,574	17,491
2030	16,994	18,023	18,389	18,655	18,342	18,004	18,600	19,709	20,311	19,414
2035	16,960	17,733	18,170	18,540	18,793	18,511	18,163	18,669	19,667	20,126
2040	17,037	17,752	17,875	18,318	18,675	18,964	18,674	18,227	18,628	19,487
2045	16,987	17,867	17,896	18,022	18,452	18,848	19,133	18,742	18,188	18,459
2050	16,764	17,825	18,013	18,043	18,155	18,622	19,017	19,204	18,703	18,024
2055	16,663	17,590	17,969	18,161	18,177	18,323	18,788	19,088	19,164	18,534
2060	16,414	17,365	17,723	18,100	18,278	18,328	18,468	18,838	19,029	18,972
2065	16,368	17,097	17,496	17,852	18,217	18,430	18,473	18,518	18,780	18,839
2070	16,319	17,256	17,405	17,634	17,987	18,388	18,597	18,543	18,481	18,612
2075	16,255	17,202	17,573	17,542	17,768	18,157	18,555	18,667	18,507	18,316
2080	16,056	17,102	17,351	17,536	17,679	17,929	18,315	18,620	18,625	18,335
2085	15,968	16,887	17,250	17,317	17,673	17,840	18,086	18,379	18,577	18,452
2090	15,897	16,795	17,031	17,216	17,453	17,834	17,996	18,149	18,337	18,405
2095	15,845	16,720	16,939	17,000	17,352	17,614	17,990	18,059	18,108	18,168
2100	15,793	16,664	16,862	16,907	17,134	17,511	17,769	18,053	18,018	17,940

Table 7.3 (continued)

Age Group											
50–54	55–59	60–64	65–69	70–74	75–79	80–84	85–89	90–94	95+	Total	Year
2,968	2,230	1,806	1,264	786	430	195	68	16	2	76,094	1900
3,135	2,618	1,920	1,463	1,002	605	303	116	29	4	83,822	1905
3,926	2,806	2,282	1,622	1,127	691	353	139	37	6	92,407	1910
4,097	3,517	2,384	1,852	1,298	805	419	169	47	7	100,546	1915
4,775	3,579	3,008	1,894	1,399	913	496	207	57	9	106,461	1920
5,280	4,305	3,073	2,360	1,672	1,042	535	205	51	6	115,829	1925
5,994	4,661	3,764	2,516	1,851	1,214	674	294	89	16	123,077	1930
6,483	5,384	3,983	2,858	2,165	1,466	841	379	120	22	127,250	1935
7,282	5,864	4,744	3,283	2,503	1,702	975	433	130	22	132,122	1940
7,775	6,681	5,547	3,751	2,852	1,959	1,159	549	186	38	139,928	1945
8,327	7,282	6,099	5,146	3,383	2,111	1,022	485	166	35	151,685	1950
8,691	7,757	6,807	5,658	4,110	2,573	1,228	616	229	54	165,276	1955
9,663	8,470	7,154	6,285	4,767	3,081	1,498	732	257	54	180,672	1960
10,430	9,494	7,692	6,466	5,323	3,571	1,773	885	318	69	194,303	1965
11,210	10,059	8,708	7,023	5,463	3,867	2,024	1,112	469	133	204,879	1970
11,972	10,646	9,399	8,132	5,785	4,246	2,410	1,360	592	172	215,972	1975
11,766	11,670	10,135	8,850	6,872	4,848	2,742	1,582	708	213	227,754	1980
10,945	11,343	10,995	9,430	7,565	5,495	3,103	1,831	843	264	239,279	1985
11,540	10,623	10,740	10,251	8,121	6,104	3,828	2,065	874	317	250,410	1990
13,807	12,228	10,096	10,056	8,874	6,607	4,314	2,434	1,074	405	260,139	1995
17,403	13,315	10,513	9,118	8,598	7,307	5,029	3,027	1,355	546	268,267	2000
19,444	16,840	12,656	9,699	8,059	7,192	5,583	3,327	1,640	728	275,604	2005
21,427	18,826	16,022	11,700	8,429	6,775	5,536	3,748	1,851	937	282,574	2010
21,102	20,718	17,888	14,802	10,389	7,251	5,230	3,740	2,114	1,118	288,897	2015
18,544	20,436	19,717	16,551	13,161	8,959	5,440	3,534	2,110	1,278	294,364	2020
17,178	17,960	19,448	18,242	14,715	11,344	6,731	3,688	1,992	1,275	298,252	2025
17,179	16,641	17,096	17,995	16,218	12,682	8,519	4,570	2,086	1,203	300,629	2030
19,050	16,627	15,826	15,805	15,982	13,961	9,512	5,777	2,587	1,264	301,725	2035
19,748	18,437	15,813	14,631	14,037	13,752	10,466	6,448	3,269	1,570	301,807	2040
19,123	19,115	17,537	14,621	12,997	12,083	10,306	7,095	3,649	1,983	301,100	2045
18,116	18,511	18,183	16,217	12,990	11,189	9,059	6,985	4,015	2,213	299,849	2050
17,687	17,537	17,609	16,816	14,409	11,186	8,391	6,141	3,951	2,532	298,717	2055
18,170	17,102	16,666	16,268	14,926	12,394	8,379	5,681	3,469	2,391	296,963	2060
18,600	17,569	16,249	15,397	14,439	12,840	9,285	5,674	3,209	2,210	295,542	2065
18,489	18,005	16,712	15,024	13,681	12,434	9,629	6,293	3,209	1,944	294,642	2070
18,265	17,898	17,126	15,451	13,343	11,782	9,324	6,527	3,559	2,066	293,883	2075
17,969	17,674	17,020	15,830	13,720	11,477	8,834	6,318	3,690	2,155	292,235	2080
17,988	17,387	16,804	15,732	14,057	11,802	8,593	5,987	3,572	2,372	290,724	2085
18,103	17,406	16,532	15,529	13,971	12,093	8,838	5,817	3,385	2,311	289,098	2090
18,057	17,518	16,550	15,278	13,784	12,020	9,057	5,983	3,286	2,204	287,529	2095
17,824	17,473	16,656	15,295	13,562	11,851	9,004	6,133	3,380	2,150	285,978	2100

Table 7.4 **Gompertz Approximation to Death Rate per 1,000 Population, exp(α + β Age), with Linear Spline Extrapolation**

	Male		Female	
Year	α	β	α	β
1900	−1.010	0.073	−1.323	0.076
1905	−1.091	0.074	−1.411	0.077
1910	−1.171	0.075	−1.498	0.078
1915	−1.251	0.076	−1.586	0.079
1920	−1.332	0.077	−1.674	0.080
1925	−1.304	0.076	−1.777	0.081
1930	−1.277	0.075	−1.881	0.082
1935	−1.249	0.075	−1.985	0.082
1940	−1.222	0.074	−2.089	0.083
1945	−1.189	0.074	−2.339	0.085
1950	−1.156	0.073	−2.589	0.088
1955	−1.122	0.072	−2.839	0.090
1960	−1.089	0.071	−3.090	0.092
1965	−1.227	0.072	−3.130	0.092
1970	−1.365	0.074	−3.170	0.092
1975	−1.503	0.075	−3.210	0.092
1980	−1.641	0.076	−3.250	0.091
1985	−1.779	0.078	−3.290	0.091
1990	−2.007	0.080	−3.343	0.092
1995	−2.078	0.081	−3.364	0.092
2000	−2.149	0.082	−3.386	0.091
2005	−2.220	0.082	−3.407	0.091
2010	−2.291	0.083	−3.428	0.091
2015	−2.362	0.084	−3.449	0.091
2020	−2.433	0.084	−3.471	0.091
2025	−2.504	0.085	−3.492	0.091
2030	−2.576	0.086	−3.513	0.091
2035	−2.647	0.086	−3.535	0.091
2040	−2.718	0.087	−3.556	0.091
2045	−2.789	0.088	−3.577	0.091
2050	−2.860	0.088	−3.598	0.091
2055	−2.931	0.089	−3.620	0.091
2060	−3.002	0.090	−3.641	0.091
2065	−3.073	0.090	−3.662	0.091
2070	−3.144	0.091	−3.683	0.091
2075	−3.215	0.092	−3.705	0.091
2080	−3.286	0.092	−3.726	0.091
2085	−3.357	0.093	−3.747	0.091
2090	−3.428	0.094	−3.769	0.091
2095	−3.499	0.094	−3.790	0.091
2100	−3.570	0.095	−3.811	0.091

For interpolation or extrapolation of population by the cohort-component method, the survivor rates implied by the Gompertz model can be used directly. Reconstruction of the elderly age distribution requires further assumptions. Suppose one starts with a population with a stationary age distribution growing at rate g; this ignores the drift in the life tables, the age distribution of immigrants, and variations in birth and immigration rates. Then, the population $N(i, A, t)$ of sex i and age A at date t satisfies

$$\text{(2)} \qquad \partial \log N(i, A, t)/\partial A = -g - \exp(\alpha_i + \beta_i A)/1000,$$

implying that the age distribution past age A_0 satisfies

$$\text{(3)} \qquad N(i, A, t_0)/N(i, A_0, t_0) = \exp\left[-g(A - A_0) + \left(e^{\alpha_i + \beta_i A_0} - e^{\alpha_i + \beta_i A}\right)\Big/1000\beta_i\right].$$

This formula with g equal to the average population growth rate over the past 30 years and the contemporary Gompertz coefficients was used to estimate the age distribution past age 65 from 1900 to 1940. There are two potential biases in these estimates. Increasing life expectancy over time leads one to overestimate the number of very old, while the effect of immigration at mostly younger ages leads one to underestimate the number of very old.

Figures 7.6 and 7.7 show survivor curves at various dates, obtained using equation (3) with Gompertz distribution parameters projected by fitting a linear spline to the coefficients in table 7.4. Table 7.5 compares the survivor rates implied by the Gompertz trend fits with the Census Bureau "mid" mortality assumptions. The Gompertz curves give slightly lower survivor rates for males and substantially lower rates for females, in comparison to the Census Bureau projections. Manton, Stallard, and Singer (chap. 2 in this volume) emphasize that there is considerable uncertainty in these actuarial trend approaches that do not take into account the structural impacts on mortality of shifts in environmental hazards or in disease-specific treatments.

Adopting low rather than mid projections would increase the cohort welfare shifts found in the final section of this paper. However, the pressures for immigration of workers created by high dependency ratios in the next century are likely to push population closer to the mid projections.

7.3 Economic Data

The economic data for this study are drawn from standard sources, mostly *Historical Statistics of the United States* (U.S. Department of Commerce, 1975), and *Statistical Abstract* (U.S. Department of Commerce, various years). Where necessary, I have spliced and interpolated to construct complete series from 1869 through 1989. Table 7.6 gives GNP per capita, and the GNP implicit price deflator. These are given by historical series F4 and F5, with the Burgess

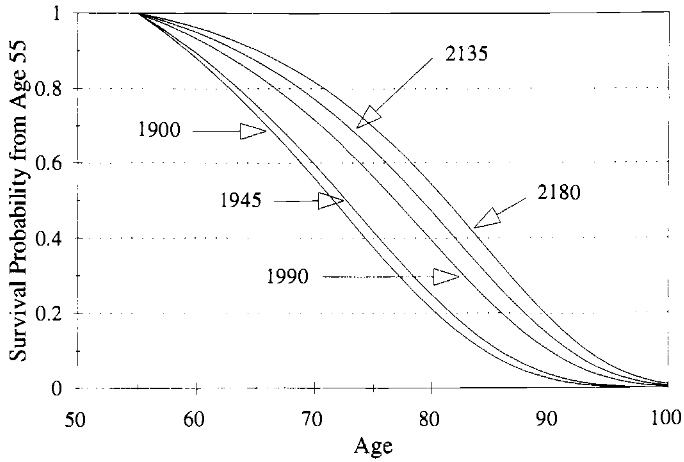

Fig. 7.6 Male survivor rates (Gompertz approximations)

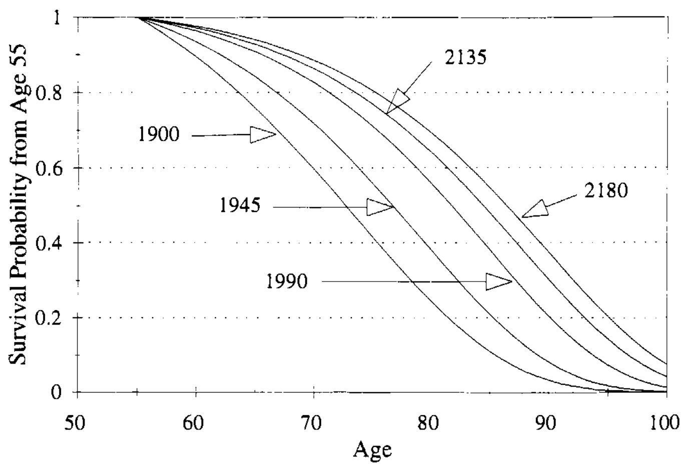

Fig. 7.7 Female survivor rates (Gompertz approximations)

cost-of-living index (Historical Series E184) used to interpolate within each decade from 1869 to 1888.

Table 7.7 gives, in successive columns, the residential investment component of the GNP implicit price deflator, a construction cost index (in current dollars), a constant-quality construction cost index (in current dollars), a quality-adjusted housing price index (in 1982 dollars), real housing investment (in 1982 dollars), and real housing stock (in 1982 dollars). The construction cost index is the Boeckh construction cost index (Historical Series N121) for small residential buildings after 1914. From 1889 through 1914, the Blank

Table 7.5 **Survivor Rates**

		1990		2020	
Start Age	End Age	Census[a]	Gompertz[b]	Census[a]	Gompertz[b]
		Males			
65–69	70–74	0.826	0.794	0.853	0.836
75–79	80–84	0.659	0.640	0.703	0.685
85–89	90–94	0.400	0.396	0.480	0.431
		Females			
65–69	70–74	0.907	0.851	0.923	0.892
75–79	80–84	0.784	0.725	0.829	0.783
85–89	90–94	0.518	0.484	0.616	0.567

[a]Share of individuals in one cohort who survive in the following cohort, Census P-25 assumptions, 1988.

[b]Projections from Gompertz distribution trends.

Table 7.6 **Population and GNP**

Year	GNP Price Deflator	GNP per Capita (1982 dollars)	Population (thousands)	Year	GNP Price Deflator	GNP per Capita (1982 dollars)	Population (thousands)
1869	10.68	1060	37,779	1896	6.74	2787	70,388
1870	10.10	1197	38,558	1897	6.77	2996	71,773
1871	9.49	1333	39,585	1898	6.95	3006	73,186
1872	10.52	1470	40,640	1899	7.20	3222	74,626
1873	9.25	1606	41,723	1900	7.54	3257	75,995
1874	9.08	1743	42,835	1901	7.48	3560	76,094
1875	8.87	1880	43,976	1902	7.73	3521	77,580
1876	8.52	2016	45,148	1903	7.82	3628	79,096
1877	8.43	2153	46,351	1904	7.92	3518	80,641
1878	7.60	2289	47,586	1905	8.10	3702	82,216
1879	7.51	2426	48,854	1906	8.29	4053	83,822
1880	7.79	2439	50,156	1907	8.63	4043	85,473
1881	8.06	2453	51,282	1908	8.57	3641	87,156
1882	8.31	2467	52,433	1909	8.88	4156	88,872
1883	7.83	2480	53,610	1910	9.13	4185	90,622
1884	7.25	2494	54,813	1911	9.03	4230	92,407
1885	7.06	2507	56,043	1912	9.41	4401	93,980
1886	7.13	2521	57,301	1913	9.34	4353	95,580
1887	7.14	2534	58,588	1914	9.53	4082	97,208
1888	7.37	2548	59,903	1915	9.96	3988	98,863
1889	7.88	2561	61,247	1916	11.17	4243	100,546
1890	7.73	2693	62,622	1917	13.87	4220	101,702
1891	7.64	2758	63,854	1918	15.61	4739	102,872
1892	7.33	2964	65,111	1919	17.82	4514	104,054
1893	7.48	2767	66,392	1920	20.30	4237	105,251
1894	7.01	2639	67,698	1921	16.92	3792	106,461
1895	6.92	2900	69,030	1922	15.55	4333	108,272

(continued)

Table 7.6 (continued)

Year	GNP Price Deflator	GNP per Capita (1982 dollars)	Population (thousands)	Year	GNP Price Deflator	GNP per Capita (1982 dollars)	Population (thousands)
1923	15.92	4775	110,114	1958	31.04	8277	171,984
1924	15.89	4671	111,987	1959	31.54	8660	174,882
1925	16.11	4990	113,892	1960	32.06	8695	177,830
1926	15.86	5216	115,829	1961	32.47	8718	180,671
1927	15.52	5135	117,244	1962	32.84	9150	183,691
1928	15.77	5103	118,676	1963	33.27	9382	186,538
1929	15.71	5383	120,125	1964	33.77	9755	189,242
1930	15.30	4800	121,592	1965	34.42	10245	191,889
1931	13.91	4394	123,077	1966	35.35	10786	194,303
1932	12.48	3718	123,901	1967	36.50	10947	196,560
1933	12.20	3628	124,730	1968	37.96	11344	198,712
1934	13.10	3930	125,564	1969	39.79	11534	200,706
1935	13.22	4288	126,404	1970	41.97	11453	202,677
1936	13.25	4852	127,250	1971	44.36	11993	204,879
1937	13.81	5077	128,210	1972	46.44	12460	207,661
1938	13.63	4781	129,177	1973	49.46	12972	209,896
1939	13.41	5148	130,151	1974	53.96	12769	211,909
1940	13.63	5541	131,133	1975	59.25	12478	213,854
1941	14.65	6369	132,122	1976	63.04	12950	215,972
1942	16.45	7113	133,648	1977	67.27	13411	218,035
1943	17.63	7941	135,191	1978	72.18	13972	220,239
1944	18.07	8412	136,752	1979	78.60	14166	222,585
1945	18.53	8177	138,331	1980	85.67	13993	225,055
1946	20.70	7123	139,928	1981	93.98	14117	227,754
1947	23.16	6927	142,204	1982	100.00	13616	229,945
1948	24.71	7113	144,517	1983	103.90	13966	232,171
1949	24.55	6998	166,868	1984	107.74	14774	234,296
1950	24.89	7545	149,257	1985	110.98	15123	236,343
1951	26.57	8006	151,685	1986	113.86	15387	239,279
1952	27.16	8109	154,878	1987	117.51	15798	204,658
1953	27.41	8335	157,553	1988	121.38	16337	242,820
1954	27.81	8074	160,184	1989	126.09	16612	245,051
1955	28.22	8537	163,026	1990	130.33	16937	247,350
1956	29.18	8544	165,276				
1957	30.26	8512	168,903				

residential construction cost index (Historical Series N139) is spliced in, and from 1869 through 1888, the Riggleman building cost index (Historical Series N138) is spliced in. Taking the quality adjustment in the GNP implicit price component for housing as correct, the ratio of the construction cost index to the GNP residential investment deflator gives an index of housing quality for the years 1929–88. The annual growth rate of housing quality over this period, 0.26 percent, is assumed to have prevailed over the period 1869–1928. Then,

Table 7.7 Housing Price, Investment, and Stock

Year	Residential Investment Component of GNP Implicit Price Deflator	Construction Cost Index	Constant-Quality Construction Cost Index	House Price Index (1982 = 1)	Real Housing Investment (1982 $)	Real Housing Stock (1982 $)
1869		4.99	0.0642	0.6006	6,771	107.7
1870		4.52	0.0579	0.5727	7,508	112.3
1871		4.71	0.0602	0.6342	7,217	116.5
1872		4.70	0.0599	0.5696	7,251	120.6
1873		4.60	0.0584	0.6317	7,435	124.8
1874		4.27	0.0542	0.5971	8,344	129.8
1875		3.89	0.0491	0.5541	9,564	135.9
1876		3.74	0.0472	0.5543	10,329	142.6
1877		3.49	0.0439	0.5204	11,520	150.3
1878		3.30	0.0414	0.5452	12,625	158.8
1879		3.19	0.0399	0.5312	14,098	168.7
1880		3.47	0.0433	0.5560	13,906	178.1
1881		3.68	0.0458	0.5680	14,013	187.3
1882		3.86	0.0480	0.5770	14,199	196.4
1883		3.88	0.0481	0.6139	14,987	206.2
1884		3.47	0.0429	0.5917	18,213	218.8
1885		3.46	0.0427	0.6050	19,742	232.7
1886		3.70	0.0455	0.6377	19,869	246.3
1887		3.69	0.0452	0.6327	21,350	261.0
1888		3.56	0.0436	0.5910	23,548	277.6
1889		3.56	0.0434	0.5504	20,532	290.6
1890		3.58	0.0435	0.5629	20,112	302.9
1891		3.46	0.0420	0.5494	16,542	311.4
1892		3.36	0.0406	0.5547	20,748	323.7
1893		3.35	0.0404	0.5403	16,380	331.4
1894		3.23	0.0389	0.5543	17,283	339.8
1895		3.18	0.0382	0.5524	19,773	350.4
1896		3.20	0.0384	0.5694	17,809	358.8
1897		3.14	0.0375	0.5540	19,178	368.4
1898		3.28	0.0390	0.5613	16,554	375.0
1899		3.51	0.0417	0.5796	16,267	381.2
1900		3.70	0.0439	0.5821	11,457	382.4
1901		3.66	0.0432	0.5782	15,792	387.9
1902		3.79	0.0446	0.5776	14,515	392.0
1903		3.92	0.0461	0.5898	14,977	396.5
1904		3.88	0.0455	0.5746	17,325	403.1
1905		4.06	0.0475	0.5863	26,611	418.9
1906		4.46	0.0521	0.6282	24,606	432.3
1907		4.66	0.0543	0.6288	21,157	441.8
1908		4.52	0.0524	0.6119	21,898	451.8
1909		4.69	0.0543	0.6116	25,600	465.3
1910		4.85	0.0561	0.6142	25,691	478.5
1911		4.79	0.0552	0.6108	20,101	485.7
1912		4.91	0.0564	0.5996	21,653	494.3
1913		4.74	0.0543	0.5807	22,375	503.4

(continued)

Table 7.7 (continued)

Year	Residential Investment Component of GNP Implicit Price Deflator	Construction Cost Index	Constant-Quality Construction Cost Index	House Price Index (1982 = 1)	Real Housing Investment (1982 $)	Real Housing Stock (1982 $)
1914		4.76	0.0544	0.5712	21,808	511.7
1915		4.88	0.0556	0.5584	23,886	521.8
1916		5.19	0.0591	0.5285	25,892	533.7
1917		6.10	0.0692	0.4987	20,075	539.5
1918		7.26	0.0821	0.5259	13,617	538.6
1919		8.42	0.0950	0.5329	22,359	546.5
1920		10.86	0.1222	0.6018	18,672	550.4
1921		8.73	0.0980	0.5791	22,487	558.1
1922		8.04	0.0900	0.5788	38,651	581.8
1923		8.98	0.1003	0.6296	45,304	611.5
1924		8.86	0.0986	0.6204	52,666	647.7
1925		8.76	0.0973	0.6040	58,128	688.4
1926		8.86	0.0981	0.6184	58,487	728.4
1927		8.73	0.0965	0.6215	55,157	764.0
1928		8.76	0.0965	0.6123	51,022	794.5
1929	38.1	9.17	0.1008	0.6416	37,433	810.6
1930	37.1	8.92	0.0981	0.6412	22,237	811.0
1931	33.6	8.23	0.0889	0.6391	18,275	807.5
1932	27.3	6.95	0.0722	0.5786	9,058	794.9
1933	27.1	6.95	0.0717	0.5876	6,962	780.5
1934	30.1	7.57	0.0796	0.6078	8,303	767.8
1935	29.8	7.38	0.0788	0.5961	13,589	760.8
1936	31.3	7.63	0.0828	0.6246	19,823	760.2
1937	34.3	8.54	0.0907	0.6568	21,771	761.5
1938	35.5	8.79	0.0939	0.6890	22,036	763.1
1939	35.7	8.95	0.0944	0.7041	29,507	772.1
1940	36.9	9.26	0.0976	0.7162	32,072	783.4
1941	40.3	9.98	0.1066	0.7275	34,639	797.0
1942	43.3	10.58	0.1145	0.6961	16,154	791.7
1943	47.0	11.01	0.1243	0.7051	8,093	778.5
1944	51.6	11.98	0.1365	0.7554	6,763	764.4
1945	54.9	12.86	0.1452	0.7836	9,477	753.3
1946	59.7	14.11	0.1579	0.7627	42,155	775.2
1947	71.7	17.08	0.1896	0.8190	54,864	809.3
1948	80.8	19.21	0.2137	0.8649	64,717	852.2
1949	78.5	18.71	0.2076	0.8456	63,150	892.5
1950	82.5	19.71	0.2182	0.8765	86,014	954.5
1951	88.6	21.28	0.2343	0.8819	70,610	999.5
1952	90.8	21.81	0.2401	0.8842	68,574	1041.2
1953	91.9	22.22	0.2431	0.8868	70,818	1084.0
1954	90.4	22.03	0.2391	0.8597	78,460	1133.4
1955	92.9	22.69	0.2457	0.8708	91,204	1194.1
1956	97.4	23.69	0.2576	0.8829	80,383	1242.4
1957	99.8	24.16	0.2640	0.8722	74,040	1283.1
1958	100.0	24.38	0.2645	0.8521	74,822	1323.4

Table 7.7 (continued)

Year	Residential Investment Component of GNP Implicit Price Deflator	Construction Cost Index	Constant-Quality Construction Cost Index	House Price Index (1982 = 1)	Real Housing Investment (1982 $)	Real Housing Stock (1982 $)
1959	103.1	25.19	0.2727	0.8647	88,936	1376.8
1960	104.5	25.60	0.2764	0.8620	83,127	1422.9
1961	105.0	25.69	0.2777	0.8553	83,207	1467.9
1962	106.7	26.10	0.2822	0.8593	89,121	1517.6
1963	108.9	26.66	0.2880	0.8656	96,778	1573.6
1964	112.3	27.44	0.2970	0.8795	94,306	1625.6
1965	114.2	28.29	0.3020	0.8774	100,103	1682.0
1966	117.4	29.51	0.3105	0.8783	92,145	1729.0
1967	123.1	31.29	0.3256	0.8919	91,336	1773.9
1968	129.7	33.58	0.3430	0.9036	99,617	1825.8
1969	137.7	36.36	0.3642	0.9152	102,183	1878.9
1970	140.0	38.30	0.3703	0.8823	96,855	1925.3
1971	147.6	41.55	0.3903	0.8798	124,309	1997.9
1972	155.8	45.62	0.4121	0.8874	147,269	2091.5
1973	169.4	49.82	0.4480	0.9057	145,286	2180.6
1974	188.4	53.82	0.4982	0.9232	112,349	2234.3
1975	204.9	57.42	0.5420	0.9147	95,170	2269.4
1976	219.3	62.02	0.5799	0.9199	117,727	2326.2
1977	244.3	67.79	0.6460	0.9604	142,412	2406.1
1978	274.6	73.89	0.7261	1.0061	151,261	2492.7
1979	307.8	80.70	0.8140	1.0356	143,049	2568.8
1980	337.9	87.40	0.8938	1.0432	112,310	2612.1
1981	365.3	92.20	0.9662	1.0280	102,714	2644.6
1982	378.1	100.00	1.0000	1.0000	84,676	2658.2
1983	386.4	105.90	1.0220	0.9836	122,819	2709.6
1984	400.7	111.90	1.0598	0.9836	145,166	2782.0
1985	409.5	115.10	1.0831	0.9760	146,311	2853.5
1986	420.2	117.30	1.1113	0.9760	168,406	2945.3
1987	439.5	119.70	1.1624	0.9892	167,459	3033.6
1988	452.7	122.70	1.1973	0.9864	165,459	3117.5

deflating the construction cost index by the quality index gives the constant-quality construction cost index. This is divided by the GNP total implicit price deflator to give the housing price index. Note that for the period 1929–88, the housing price index coincides with the ratio of the GNP residential investment implicit price index to the GNP total implicit price index. This housing price index does *not* include land cost and hence probably systematically understates the growth in real housing prices. If prices of existing dwellings were determined by the cost of new dwellings at the margin, this index would be reasonably accurate for all housing. However, the substantial urbanization and growth of cities over the last century, with increased transportation cost from the periphery to the center, has probably increased the value of sites near the center of cities relative to sites at the edge and hence increased the gap between average prices of existing dwellings and of new dwellings, adjusting for quality. In addition, population migration between regions creates a gap between sales-weighted prices of existing dwellings and prices of new dwellings. Taken together, these reservations suggest that the housing price index be treated with caution.

Real housing investment in table 7.5 is obtained by first splicing expenditures for new residential construction (Historical Series N72, 1869–1914) to value of new residential construction put in place (Historical Series N32, 1915–1988), and then deflating these by the constant-quality construction cost index. This is then a constant-quality real residential investment series. This series is then accumulated to obtain a constant-quality residential real capital stock. For this accumulation, a depreciation rate of 2.687 percent and a growth rate of real investment prior to 1869 of 3.6 percent were assumed. These rates were chosen so that the stock series is commensurate with the Department of Commerce's value of net stocks of residential structures (Historical Series N208) between 1925 and 1970. With this construction, the two series have the same mean (in 1982 dollars) and a correlation of 0.99964 over this period.

In the absence of capital market imperfections and transactions costs, there is a simple relationship between housing prices and the user cost, or implicit rent, for housing. Let P_t denote nominal housing price in year t, π_t denote the GNP implicit price deflator, r_t denote the nominal interest rate, m_t denote the marginal income tax rate, δ denote the depreciation/maintenance rate, τ denote the property tax rate, θ denote the proportion of property mortgaged, and g denote the rate of nominal capital gains, $g_t = (P_{t+1} - P_t)/P_t$. Then, the nominal present value of the outlay from a purchase followed by a sale one year later is

$$C_t = (1 - \theta)P_t + r_t\theta P_t + \delta P_t + \tau_t P_t - m_t(r_t\theta + \tau_t)P_t + (1 - r_t)(\theta P_t - P_{t+1}). \tag{4}$$

The first term in this expression is the down payment, the second is the mortgage interest payment, the third is the maintenance (to offset depreciation), the fourth is the property tax payment, the fifth is the income tax offset from the deductability of mortgage interest and property taxes, and the sixth is the net outlay from selling the dwelling and repaying the mortgage, discounted to period t. Neglecting products of small rates and converting to real user cost, equation (4) simplifies to

$$C_t = (P_t/\pi_t)[r_t(1 - \theta m_t) + \tau_t(1 - m_t) + \delta - g_t]. \tag{5}$$

Ex ante, the consumer must form expectations regarding the nominal capital gains rate g_t. I consider four simplistic models of expectations: (1) naive expectations that last year's rate will continue (LAG1), (2) naive expectations that the average rate over the past three years will prevail (LAG3), (3) perfect foresight regarding the rate over the next year (LEAD1), and (4) perfect foresight regarding the rate over the next three years (LEAD3). The perfect foresight models should capture some of the behavioral response one would expect if consumers have forward-looking rational expectations, although of course they neglect the statistical properties of rational expectations.

Table 7.8 gives the real user cost of housing under each of the expectations models. The home mortgage interest rate in this table is the Federal Home Loan Bank Board new home mortgage rate after 1962. From 1919 to 1962, it is approximated by the Moody's Aaa corporate Bond Rate (Historical Series X447), plus the net risk premium that prevailed between these rates in 1963–88. From 1869 to 1918, it is approximated by the unadjusted index of yields on American railroad bonds (Historical Series 476), plus the sum of the previous net risk premium and the net risk premium between corporate and railroad bonds that prevailed in 1919–36. This construction has some obvious flaws. The protected status of the home mortgage rate from the 1930s through the late 1970s produced lower net risk premiums in this era than presumably prevailed at other times. Then, the splicing used probably overstates home mortgage rates from 1936 to 1962 and understates them earlier than 1936.

The marginal income tax rate in table 7.8 was calculated by computing in each year average nominal family income for a married couple with two dependents and, for this income level, taking the marginal tax rate from U.S. Treasury data (U.S. Department of Commerce, *Statistical Abstract* 1989, table 511). Prior to 1954, the effective (average) tax rate (Historical Series Y426–439) was used, scaled by the ratio of marginal to average rates in 1954–70. This construction is biased because adjusted gross income of families is somewhat overstated and the progressivity of the tax has changed over time, in addition to the obvious bias in using a "representative" family size and income level for a rate that is nonlinear over sizes and incomes.

The nominal annual capital gains rates in table 7.8 are computed from the real housing price index in table 7.7 and the GNP implicit price deflator in table 7.6, for each of the expectations models described earlier. The real user costs are then calculated for each expectations model using equation (5) and assuming that 70 percent of home purchases are mortgage financed, that the depreciation rate is 2.687 percent, and that the property tax rate is 2 percent.[2] The real user costs are denominated in 1982 dollars, with the price of housing indexed to one in this year.

7.4. The Age Distribution of Income and Housing Assets

Mankiw and Weil (1989) have used the 1970 1-in-1,000 Public Use Sample from the U.S. Census, containing 203,190 individuals grouped into 74,565 households, to run the regression

2. The property tax rate varies widely across states, and its national average has fallen from 2.02 in 1974 to 1.36 in 1984, a period of extraordinary increases in real housing prices.

Table 7.8 **User Cost of Housing**

Year	Home Mortgage Interest Rate	Marginal Income Tax Rate	Nominal Annual Capital Gains Rate LAG1	LAG3	LEAD1	LEAD3	Real User Cost of Housing LAG1	LAG3	LEAD1	LEAD3
1869	8.093	0.000			−9.817	−2.279			0.136	
1870	7.883	0.000	−10.333		4.031	0.329			0.049	
1871	7.743	0.000	3.952		−0.460	−3.494			0.082	
1872	7.563	0.000	−0.461	−2.279	−2.472	−6.601	0.072	0.083	0.084	0.107
1873	7.723	0.000	−2.503	0.329	−7.252	−7.095	0.094	0.076	0.124	0.123
1874	7.493	0.000	−7.528	−3.494	−9.327	−7.032	0.118	0.094	0.128	0.115
1875	7.023	0.000	−9.791	−6.601	−3.909	−5.672	0.119	0.101	0.087	0.096
1876	6.643	0.000	−3.987	−7.095	−7.077	−5.597	0.085	0.102	0.102	0.094
1877	6.583	0.000	−7.340	−7.032	−5.545	−0.441	0.097	0.095	0.088	0.061
1878	6.413	0.000	−5.704	−5.672	−3.694	3.316	0.092	0.091	0.081	0.042
1879	5.943	0.000	−3.764	−5.597	8.484	6.115	0.076	0.086	0.011	0.024
1880	5.563	0.000	8.144	−0.441	5.736	3.480	0.012	0.059	0.025	0.038
1881	5.153	0.000	5.577	3.316	4.753	−2.158	0.024	0.037	0.029	0.068
1882	5.203	0.000	4.644	6.115	0.230	−3.882	0.030	0.022	0.056	0.079
1883	5.193	0.000	0.230	3.480	−10.733	−1.842	0.059	0.039	0.127	0.072
1884	5.113	0.000	−11.354	−2.158	−0.532	1.724	0.125	0.071	0.061	0.048
1885	4.853	0.000	−0.533	−3.882	6.563	0.683	0.061	0.081	0.018	0.054
1886	4.513	0.000	6.356	−1.842	−0.643	−1.562	0.018	0.070	0.063	0.069
1887	4.613	0.000	−0.645	1.724	−3.593	−1.264	0.063	0.048	0.082	0.067
1888	4.553	0.000	−3.659	0.683	−0.387	−1.255	0.076	0.051	0.057	0.062
1889	4.393	0.000	−0.388	−1.562	0.252	−2.193	0.052	0.059	0.049	0.062
1890	4.513	0.000	0.252	−1.264	−3.567	−2.454	0.050	0.059	0.072	0.066
1891	4.673	0.000	−3.633	−1.255	−3.155	−2.532	0.071	0.058	0.069	0.065

1892	4.493	0.000	−3.205	−2.193	−0.531	−2.025	0.069	0.063	0.054	0.062
1893	4.613	0.000	−0.532	−2.454	−3.793	−1.744	0.053	0.064	0.071	0.060
1894	4.373	0.000	−3.866	−2.532	−1.668	−1.214	0.072	0.064	0.059	0.057
1895	4.233	0.000	−1.682	−2.025	0.312	0.681	0.059	0.060	0.048	0.046
1896	4.303	0.000	0.311	−1.744	−2.249	2.819	0.049	0.061	0.064	0.035
1897	4.073	0.000	−2.274	−1.214	4.089	5.258	0.061	0.055	0.026	0.019
1898	3.993	0.000	4.008	0.681	6.964	3.425	0.026	0.045	0.010	0.029
1899	3.813	0.000	6.732	2.819	5.181	2.239	0.010	0.033	0.109	0.036
1900	3.853	0.000	5.051	5.258	−1.488	1.653	0.020	0.019	0.058	0.040
1901	3.793	0.000	−1.499	3.425	3.223	1.676	0.058	0.029	0.030	0.039
1902	3.803	0.000	3.172	2.239	3.345	2.064	0.031	0.036	0.030	0.037
1903	3.993	0.000	3.291	1.653	−1.419	4.022	0.032	0.041	0.060	0.027
1904	3.943	0.000	−1.430	1.676	4.434	5.877	0.058	0.040	0.024	0.016
1905	3.853	0.000	4.339	2.064	9.602	3.286	0.025	0.038	−0.006	0.031
1906	3.963	0.000	9.169	4.022	4.228	1.401	−0.003	0.029	0.028	0.046
1907	4.233	0.000	4.141	5.877	−3.383	1.081	0.030	0.019	0.077	0.049
1908	4.183	0.000	−3.441	3.286	3.569	1.700	0.075	0.034	0.032	0.044
1909	4.033	0.000	3.507	1.401	3.233	1.260	0.032	0.045	0.034	0.046
1910	4.143	0.000	3.182	1.081	−1.572	−1.084	0.035	0.048	0.064	0.061
1911	4.153	0.000	−1.585	1.700	2.210	−0.451	0.064	0.044	0.040	0.057
1912	4.193	0.000	2.186	1.260	−3.782	−0.446	0.040	0.046	0.076	0.056
1913	4.403	0.000	−3.855	−1.084	0.317	2.820	0.075	0.059	0.051	0.036
1914	4.403	0.000	0.316	−0.451	2.224	7.990	0.050	0.054	0.039	0.006
1915	4.583	0.000	2.200	−0.446	6.134	12.956	0.039	0.054	0.018	−0.021
1916	4.453	0.000	5.953	2.820	17.165	15.815	0.017	0.033	−0.042	−0.035
1917	4.753	0.000	15.841	7.990	18.665	18.932	−0.032	0.007	−0.046	−0.047
1918	5.193	0.000	17.114	12.956	15.647	5.883	−0.038	−0.016	−0.030	0.021
1919	6.277	0.000	14.537	15.815	28.661	−1.779	−0.019	−0.026	−0.094	0.068
1920	6.907	0.000	25.201	18.932	−19.805	−6.581	−0.082	−0.044	0.189	0.109
1921	6.757	0.000	−22.071	5.883	−8.124	0.214	0.194	0.032	0.113	0.065
1922	5.887	0.000	−8.474	−1.779	11.383	2.595	0.110	0.072	−0.005	0.046
1923	5.907	0.000	10.781	−6.581	−1.650	−0.727	−0.001	0.108	0.077	0.071

(continued)

Table 7.8 (continued)

Year	Home Mortgage Interest Rate	Marginal Income Tax Rate	Nominal Annual Capital Gains Rate				Real User Cost of Housing			
			LAG1	LAG3	LEAD1	LEAD3	LAG1	LAG3	LEAD1	LEAD3
1924	5.787	0.000	−1.664	0.214	−1.317	−0.734	0.075	0.064	0.073	0.070
1925	5.667	0.000	−1.326	2.595	0.809	−0.260	0.071	0.047	0.058	0.064
1926	5.517	0.000	0.806	−0.727	−1.669	0.897	0.058	0.068	0.073	0.058
1927	5.357	0.000	−1.684	−0.734	0.098	0.572	0.073	0.067	0.062	0.059
1928	5.337	0.000	0.098	−0.260	4.371	−2.761	0.061	0.063	0.035	0.078
1929	5.517	0.000	4.278	0.897	−2.625	−11.100	0.038	0.060	0.082	0.137
1930	5.337	0.000	−2.660	0.572	−9.434	−10.459	0.081	0.061	0.125	0.131
1931	5.367	0.000	−9.909	−2.761	−18.750	−3.663	0.128	0.082	0.184	0.088
1932	5.797	0.000	−20.764	−11.100	−0.733	2.918	0.181	0.125	0.065	0.044
1933	5.277	0.000	−0.735	−10.459	11.070	4.798	0.063	0.120	−0.006	0.030
1934	4.787	0.000	10.499	−3.663	−0.997	4.350	−0.006	0.080	0.064	0.031
1935	4.387	0.000	−1.002	2.918	5.034	5.828	0.060	0.037	0.024	0.019
1936	4.027	0.000	4.911	4.798	9.585	4.380	0.024	0.024	−0.005	0.027
1937	4.047	0.000	9.153	4.350	3.499	2.433	−0.003	0.029	0.034	0.041
1938	3.977	0.000	3.439	5.828	0.563	4.223	0.036	0.020	0.056	0.031
1939	3.797	0.000	0.562	4.380	3.361	6.427	0.056	0.029	0.036	0.014
1940	3.627	0.000	3.306	2.433	9.214	8.056	0.036	0.042	−0.006	0.002
1941	3.557	3.393	8.814	4.223	7.444	8.231	−0.005	0.028	0.005	−0.001
1942	3.617	13.672	7.180	6.427	8.545	7.904	0.004	0.009	−0.006	−0.002
1943	3.517	16.840	8.199	8.056	9.787	7.965	−0.005	−0.004	−0.016	−0.004
1944	3.507	19.231	9.337	8.231	6.395	10.955	−0.015	−0.007	0.007	−0.027
1945	3.407	19.224	6.199	7.904	8.743	12.869	0.008	−0.005	−0.012	−0.044
1946	3.317	15.660	8.382	7.965	20.101	9.116	−0.008	−0.005	−0.097	−0.014

1947	3.397	15.866	18.316	10.955	12.692	4.672	−0.089	−0.029	−0.043	0.022
1948	3.607	12.812	11.949	12.869	−2.847	3.069	−0.037	−0.045	0.091	0.040
1949	3.447	12.749	−2.888	9.116	5.096	4.847	0.088	−0.013	0.021	0.023
1950	3.407	13.405	4.970	4.672	7.394	3.593	0.022	0.025	0.001	0.034
1951	3.647	18.103	7.133	3.069	2.483	0.670	0.003	0.039	0.044	0.060
1952	3.747	19.524	2.453	4.847	1.211	0.761	0.045	0.024	0.056	0.060
1953	3.987	19.655	1.204	3.593	−1.632	1.936	0.058	0.037	0.083	0.051
1954	3.687	17.993	−1.646	0.670	2.765	3.294	0.079	0.059	0.041	0.037
1955	3.847	19.754	2.728	0.761	4.844	2.452	0.042	0.060	0.024	0.045
1956	4.147	19.889	4.730	1.936	2.464	1.894	0.028	0.052	0.048	0.053
1957	4.677	20.022	2.434	3.294	0.200	1.532	0.051	0.044	0.071	0.059
1958	4.577	22.000	0.200	2.452	3.100	1.625	0.067	0.048	0.043	0.055
1959	5.167	22.000	3.053	1.894	1.358	1.143	0.048	0.058	0.063	0.065
1960	5.197	22.000	1.349	1.532	0.478	1.373	0.063	0.061	0.070	0.063
1961	5.137	22.000	0.477	1.625	1.619	2.238	0.069	0.060	0.060	0.054
1962	5.117	22.000	1.606	1.143	2.062	2.262	0.060	0.064	0.056	0.054
1963	5.890	22.000	2.041	1.373	3.122	2.503	0.062	0.068	0.053	0.058
1964	5.820	22.000	3.074	2.238	1.692	3.058	0.054	0.061	0.066	0.054
1965	5.810	22.000	1.678	2.262	2.802	4.238	0.066	0.061	0.056	0.043
1966	6.250	22.201	2.764	2.503	4.855	5.311	0.059	0.062	0.041	0.037
1967	6.460	22.494	4.741	3.058	5.361	4.284	0.044	0.059	0.039	0.048
1968	6.970	24.190	5.223	4.238	6.168	4.296	0.043	0.052	0.035	0.051
1969	7.800	25.043	5.985	5.311	1.670	4.117	0.042	0.049	0.082	0.060
1970	8.450	25.600	1.657	4.284	5.400	6.344	0.083	0.060	0.050	0.042
1971	7.740	27.267	5.259	4.296	5.600	8.128	0.045	0.054	0.042	0.020

(continued)

Table 7.8 (continued)

Year	Home Mortgage Interest Rate	Marginal Income Tax Rate	Nominal Annual Capital Gains Rate				Real User Cost of Housing			
			LAG1	LAG3	LEAD1	LEAD3	LAG1	LAG3	LEAD1	LEAD3
1972	7.600	28.783	5.449	4.117	8.700	9.122	0.042	0.054	0.013	0.009
1973	7.960	30.827	8.342	6.344	11.200	8.597	0.018	0.036	−0.008	0.016
1974	8.920	32.367	10.616	8.128	8.800	8.657	0.003	0.026	0.020	0.021
1975	9.000	34.000	8.434	9.122	7.000	9.741	0.022	0.016	0.035	0.010
1976	9.000	35.441	6.766	8.597	11.400	11.291	0.037	0.020	−0.006	−0.005
1977	9.020	37.045	10.796	8.657	12.400	10.809	−0.002	0.019	−0.017	−0.002
1978	9.560	39.034	11.689	9.741	12.100	9.510	−0.008	0.011	−0.013	0.014
1979	10.780	41.000	11.422	11.291	9.800	6.852	0.001	0.003	0.018	0.049
1980	12.660	42.000	9.349	10.809	8.100	4.464	0.036	0.021	0.049	0.087
1981	14.700	42.000	7.789	9.510	3.500	3.080	0.066	0.048	0.110	0.115
1982	15.140	42.000	3.440	6.852	2.200	2.659	0.111	0.077	0.123	0.119
1983	12.570	42.000	2.176	4.464	3.700	2.789	0.104	0.081	0.089	0.098
1984	12.380	38.000	3.633	3.080	2.200	3.077	0.092	0.098	0.106	0.098
1985	11.550	38.000	2.176	2.659	2.600	3.337	0.100	0.095	0.096	0.089
1986	10.170	30.000	2.567	2.789	4.600		0.093	0.091	0.073	
1987	9.310	30.000	4.497	3.077	3.000		0.069	0.083	0.084	
1988	9.190	30.000	2.956	3.337			0.083	0.079		

(6) $$v_{ht} = \sum_{a=0}^{99} \alpha_{at} n_{aht} + \varepsilon_{ht},$$

where h indexes households, t indexes census years, v is the (self-reported) value of the residence, with the value of rental property imputed to be 100 times gross monthly rent, and n_{aht} is the number of persons of age a in household h. Then, the α_{at} estimate the consumption of housing by age in census year t. This formulation does not adjust for economies of scale in household formation and thus is likely to overpredict the demand of large households and underpredict the demand of small ones; on household formation and housing consumption, see Börsch-Supan (1989).

I extend this approach to the allocation of income, as well as the allocation of housing consumption, and address the econometric problem of endogenous selection of tenure status. Analogously to equation (6), consider the regression

(7) $$y_{ht} = \sum_{i=1}^{20} \psi_{it} K_{hit} + \eta_{ht},$$

where y_{ht} is the income of household h in census year t, and K_{hit} is the number of household members in cohort i. Cohort i contains ages a satisfying the inequalities $5(i - 1) \le a < 5i$, for $i = 1, \ldots, 19$, or the inequality $a \ge 95$ when $i = 20$. The coefficient ψ_{it} can be interpreted as the marginal contribution to household income from an individual in cohort i in census year t. Determining age-specific income by this imputation method has several advantages. First, it avoids the misspecification that occurs when household income is associated with the age of the head of the household, since household size, income contributions from other household members, and the age distribution of household members are all likely to be correlated with the age of the head. Second, it avoids the selection bias that occurs because income of an individual may endogenously enter the determination of whether the individual lives alone or as a member of a larger household, say, with children.

In setting up a model of housing demand, we will start from an age-specific individual indirect utility function and explicitly aggregate to obtain market demand. Then, aggregate demand will depend not only on aggregate income but also on the age distribution of this income. Let N_{it} denote the population in cohort i in year t, and let N_t denote the total population. Then average real income per capita satisfies $Y_t = \sum_i N_{it}\psi_{it}/N_t$. Define an aggregation factor relative to a base census year 0,

(8) $$\psi_t = \left[\sum_i \psi_{i0} N_{it} / N_t\right] / \left[\sum_i \psi_{i0} N_{i0} / N_0\right].$$

If the age distribution of relative income is stationary, so that an increase in aggregate income "raises all boats," then age-specific relative income satisfies

(9) $$\psi_{it}/\psi_{i0} = (Y_t/Y_0)/\psi_t;$$

the deflator ψ_t adjusts for changes in the population age distribution so that aggregation is consistent.

To examine the assumption that the age distribution of relative income is stationary, I run the regression (7) on the U.S. Census Public Use Samples for 1940, 1960, 1970, and 1980.[3] The estimation results are given in table 7.9. Figure 7.8 shows the age distributions of income, and figure 7.9 shows these distributions normalized by income in the 40–44 age bracket, for each census year. There is stability in the relative income distributions between 1960 and 1980. However, the elderly are substantially poorer in the 1940 relative income profile. This is due in part to the lingering effects of a decade of depression but shows primarily the contrast of the status of the elderly before and after full implementation of the Social Security system. Figure 7.10 shows the 1970 income distribution with 95 percent confidence bounds. One sees that the distribution is tightly determined up to age 75, but that the confidence bounds are larger for older individuals, so that trends are less reliably determined for the very old.

I conclude from this analysis that the age distribution of income is indeed stable after World War II. Provided there are no major changes in the Social Security system over the next century, it is not unreasonable to assume that the age distribution of income will remain stable. Factors that could alter this conclusion would be (1) high immigration rates of relatively unskilled workers, which would tend to flatten the income distribution at younger ages, (2) a declining share of manufacturing and unskilled jobs, which would tend to postpone the peak, and (3) delays in retirement, which would postpone the decline after the peak.[4]

I next examine the age distribution of housing consumption in the 1940, 1960, 1970, and 1980 Census Public Use Samples, using the Mankiw-Weil model (6) adapted to five-year cohorts,

$$(10) \qquad v_{ht} = \sum_{i=0}^{20} \alpha_{it} K_{iht} + \varepsilon_{ht}.$$

Rather than impute a value to rental property, I run these regressions only on home owners. To correct for selection bias caused by endogenous choice of tenure, I estimate probit models of tenure choice, of the form

$$(11) \qquad Prob(\text{owner}) = \Phi(\gamma_0 + \gamma_1 y_{ht} + \gamma_2 (y_{ht})^2/1000 + \sum_{i=0}^{20} \beta_{it} K_{iht}).$$

Then, an inverse Mills ratio calculated from this probit equation is added to equation (10) to absorb the nonzero conditional expectation of ε_{ht} in the presence of selection; see Henderson and Ioannides (1983) for a discussion of selection due to tenure choice.

Table 7.10 gives the probit model estimates. In specification (11), the proba-

3. Income and house value were not collected in the 1950 Public Use Sample.

4. Note that under retirement policies prevailing over the past several decades, average retirement age is falling and length of life in retirement is rising sharply. It is possible that policy changes in the next several decades to reduce the burden of the Social Security system will reverse these trends.

Table 7.9 **Individual Income by Age (thousand 1982 $)**

	1940		1960		1970		1980	
Age	Coefficient	Standard Deviation	Coefficient	Standard Deviation	Coefficient	Standard Deviation	Coefficient	Standard Deviation
0–4	−0.877	0.061	−0.619	0.086	−0.651	0.171	−1.285	0.124
5–9	−0.924	0.060	−0.753	0.092	−1.013	0.110	−1.477	0.124
10–14	−0.730	0.059	−0.657	0.097	−0.380	0.110	−1.071	0.117
15–19	−0.049	0.058	0.786	0.110	1.511	0.119	0.735	0.111
20–24	2.683	0.058	6.076	0.117	7.640	0.121	7.393	0.115
25–29	3.990	0.060	9.117	0.121	12.460	0.138	11.775	0.120
30–34	4.609	0.063	10.478	0.117	13.940	0.155	14.626	0.127
35–39	4.764	0.065	11.464	0.113	14.702	0.157	16.052	0.143
40–44	4.642	0.068	11.281	0.116	15.200	0.148	16.213	0.151
45–49	4.265	0.071	10.712	0.116	14.875	0.139	15.704	0.150
50–54	3.651	0.074	10.226	0.119	13.638	0.143	14.679	0.139
55–59	2.785	0.084	8.932	0.126	12.371	0.149	13.746	0.139
60–64	2.098	0.092	7.816	0.141	10.596	0.160	11.630	0.155
65–69	0.806	0.103	5.509	0.152	7.396	0.179	8.027	0.175
70–74	0.368	0.125	3.932	0.176	5.971	0.205	7.390	0.207
75–79	0.246	0.168	3.198	0.225	5.727	0.252	6.156	0.269
80–84	0.321	0.238	3.097	0.336	4.667	0.342	6.484	0.389
85–89	0.437	0.408	3.235	0.536	4.411	0.553	4.789	0.582
90–94	−0.586	0.787	0.500	1.109	5.180	1.059	3.862	0.888
95+	−1.735	1.440	0.523	2.225	5.043	2.125		
Observations	51,159		52,982		63,408		58,706	
Standard Error	8.016		12.775		16.316		15.869	
Mean Income	7.748		18.013		22.754		26.225	

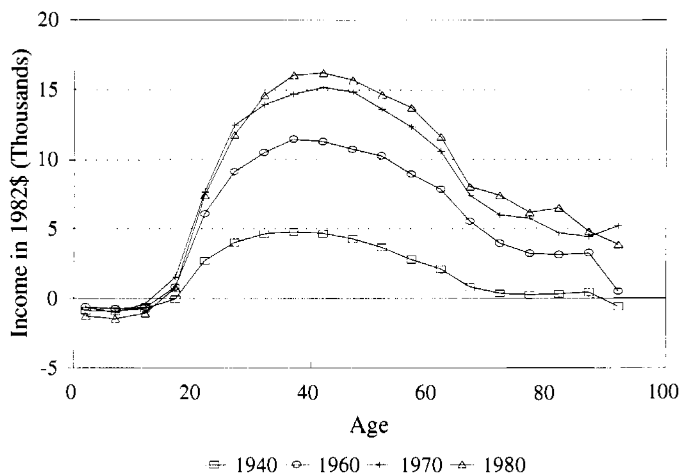

Fig. 7.8 Age distribution of income

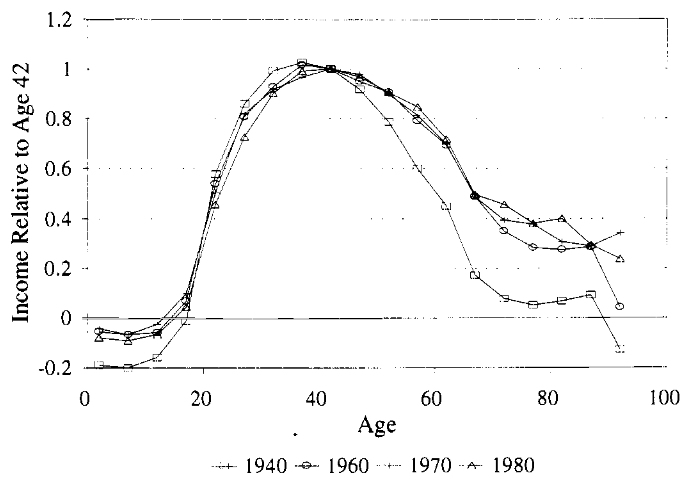

Fig. 7.9 Relative income by age

bility of ownership is related to income and, via the terms K_{iht}, to the size and age composition of the household. The estimates for 1960, 1970, and 1980 are qualitatively similar. Small children living at home have a small positive impact on ownership. Individuals between the ages of 20 and 30 have a negative impact, obviously because they are forming new households without the wealth required for home purchase. This effect became significantly stronger in 1980, compared with the earlier census years. There is a sharply increasing positive impact beginning at age 30 and peaking around age 70. The model

Table 7.10 **Probability of Home Ownership (binomial probit)**

	1940		1960		1970		1980	
Variables	Coefficient	Standard Deviation	Coefficient	Standard Deviation	Coefficient	Standard Deviation	Coefficient	Standard Deviation
Number aged 0–4	−0.043	0.010	0.081	0.009	0.105	0.010	0.060	0.011
Number aged 5–9	−0.015	0.010	0.086	0.010	0.097	0.009	0.044	0.011
Number aged 10–14	0.008	0.009	0.088	0.011	0.071	0.010	0.004	0.011
Number aged 15–19	0.017	0.009	0.016	0.012	0.048	0.011	−0.020	0.011
Number aged 20–24	−0.057	0.010	−0.201	0.015	−0.159	0.013	−0.166	0.013
Number aged 25–29	−0.044	0.011	0.042	0.016	0.080	0.014	−0.247	0.015
Number aged 30–34	0.049	0.012	0.205	0.016	0.265	0.016	0.210	0.016
Number aged 35–39	0.138	0.013	0.306	0.016	0.360	0.017	0.331	0.018
Number aged 40–44	0.242	0.013	0.351	0.016	0.462	0.016	0.393	0.019
Number aged 45–49	0.317	0.013	0.414	0.016	0.509	0.015	0.440	0.019
Number aged 50–54	0.395	0.013	0.453	0.016	0.554	0.016	0.475	0.018
Number aged 55–59	0.446	0.015	0.452	0.017	0.576	0.016	0.516	0.018
Number aged 60–64	0.519	0.016	0.518	0.018	0.626	0.017	0.543	0.020
Number aged 65–69	0.518	0.018	0.587	0.020	0.644	0.018	0.601	0.021
Number aged 70–74	0.521	0.021	0.618	0.021	0.671	0.020	0.522	0.023
Number aged 75–79	0.525	0.028	0.597	0.027	0.630	0.024	0.529	0.027
Number aged 80–84	0.487	0.039	0.610	0.040	0.602	0.031	0.555	0.041
Number aged 85–89	0.529	0.068	0.574	0.064	0.709	0.050	0.430	0.058
Number aged 90–94	0.477	0.133	0.386	0.128	0.495	0.092	0.361	0.090
Number aged 95+	0.417	0.231	0.011	0.234	0.962	0.236	NA	NA
Constant	−0.618	0.017	−0.685	0.020	−0.829	0.018	−0.818	0.026
HH income	−0.014	0.002	0.024	0.001	0.024	0.001	0.052	0.001
HH income SQ/1000	0.529	0.048	−0.148	0.019	−0.131	0.001	−0.248	0.016
Observations	51,159		50,795		61,534		57,549	
Share owners	0.564		0.645		0.648		0.751	
Percent correct	0.640		0.704		0.719		0.796	

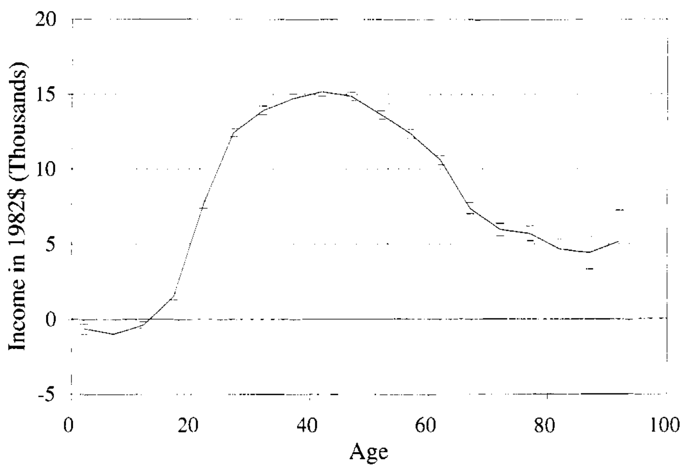

Fig. 7.10 1970 Income by age (with 95% confidence bounds)

implies that the impact of household size is the sum of the impacts of its members of various ages. This specification is likely to miss scale effects with family size and thus to overpredict ownership for large families and underpredict ownership for small ones. In the range of the data, the marginal effect of income on ownership is positive but decreasing and is near zero over age 80. In part, the last phenomenon may be due to the fact that ownership is closely tied to permanent income, and current income for the elderly is not necessarily a good proxy for permanent income. The 1940 estimates show a somewhat different pattern, with the number of individuals between ages 30 and 39 having a small impact on ownership, presumably because these individuals did not have the assets required to form households or purchase property during the depression, in what would otherwise have been a prime decade for house purchase. The marginal effect of income is positive and increasing.

Table 7.11 reports the house value regression (10) for owners, with and without the inverse Mills ratio correction for selection bias. I have not corrected the standard errors of the coefficients to account for the fact that the inverse Mills ratio is estimated, but the probit model coefficients are so precisely determined in samples of this size that the corrections would be negligible. Table 7.12 gives the housing regression estimates, relative to age 40–44, for 1970, unadjusted and adjusted for selection. The table includes cohort averages of the estimates obtained by Mankiw and Weil. These profiles are plotted in figure 7.11. I find that the regressions in table 7.12 give a sharper peak than do the Mankiw-Weil estimates. One possible explanation for this is that the procedure that Mankiw and Weil use to impute value to rental units overstates the value of these units for the very young or for the elderly, relative to middle-aged individuals. Another is that the inverse Mills ratio, which depends on household income, is correlated with an omitted income effect on housing consumption in equation (10), so that the adjusted regression overcorrects for selection. Investigation of these alternatives is left for future research.

One would expect that individuals with relatively high demand for housing services are more likely to select ownership, so that selection would lead a regression on owners to overstate population mean housing consumption. Further, the selection correction should be weakest for population cohorts where ownership rates are very high, and strongest for cohorts where rates are near one-half. I find a relatively small correction for selection, which goes in the expected direction, reducing the consumption levels of the young and the old relative to the middle-aged.

In analysis of housing demand, I use the 1970 housing consumption relatives, obtained from the regression adjusted for selection. Figure 7.12 shows 95 percent confidence bounds for this profile. The curve is precisely determined for individuals up to age 85, but is less accurate for the very old. Following Mankiw and Weil, I will make the assumption that the profile in figure 7.12 is stationary through time, with aggregate income and price affecting aggregate housing demand but not age-specific relative demand. Microeconomic considerations suggest that this assumption cannot be correct, as housing markets embody substantial transactions costs that will to some degree "lock in" individuals to historical housing units and induce a profile of consumption that is sensitive to history. In particular, periods of high income growth, not fully anticipated, will in the presence of transactions costs lead the elderly to lag further behind in relative housing consumption, while periods of unanticipated capital gains will tend to raise the consumption of individuals holding housing assets at the start of the period relative to individuals who enter the market later.

An empirical assessment of the importance of transaction cost effects, and the consequent instability in the profile of relative housing consumption, can be made by comparing profiles estimated for different census years. Figure 7.13 shows housing consumption profiles, in real dollars, obtained from the adjusted regressions in table 7.11. These profiles show an upward drift over time, as expected given real per capita income growth over this period. It is perhaps noteworthy that there is no systematic increase for the very young or very old, but the statistics for the latter group are not determined very precisely. Recall from figure 7.8 that real income increased substantially from 1960 to 1970, across all cohorts, but increased very little from 1970 to 1980. On the other hand, real housing consumption increased substantially in both decades. This suggests either that user cost of housing was lower in the decade of the 1970s, and demand was sensitive to user cost, or else that transactions costs were sufficient to "lock in" consumers to unintended housing consumption at the end of the 1970s.

Figure 7.14 shows the housing consumption profiles for 1940, 1960, 1970, and 1980 relative to consumption at ages 40–44. These profiles are remarkably stable between 1960 and 1980. The profile for 1940 shows less relative housing

Table 7.11 Housing Consumption by Age

Variable: Age Cohort	1940 Unadjusted Coefficient	1940 Standard Deviation	1940 Adjusted Coefficient	1940 Standard Deviation	1960 Unadjusted Coefficient	1960 Standard Deviation	1960 Adjusted Coefficient	1960 Standard Deviation
0–4	−0.583	0.435	−2.717	0.437	3.034	0.309	2.430	0.308
5–9	−2.497	0.404	−3.378	0.400	0.733	0.307	0.841	0.304
10–14	−2.149	0.365	−2.525	0.360	−0.324	0.311	−0.188	0.309
15–19	−2.030	0.346	−2.479	0.342	−1.295	0.364	−1.575	0.362
20–24	2.754	0.376	0.893	0.377	4.792	0.484	0.745	0.513
25–29	6.859	0.419	3.129	0.438	14.354	0.445	10.335	0.476
30–34	12.012	0.429	7.319	0.461	18.321	0.396	15.229	0.417
35–39	15.170	0.414	10.699	0.444	20.593	0.366	18.015	0.381
40–44	17.156	0.407	13.081	0.432	20.598	0.367	18.222	0.379
45–49	17.478	0.405	14.022	0.421	18.583	0.362	16.550	0.370
50–54	15.994	0.408	13.222	0.416	17.376	0.367	15.499	0.374
55–59	12.877	0.443	10.475	0.447	15.612	0.394	13.377	0.404
60–64	12.863	0.469	11.010	0.468	15.441	0.432	13.226	0.440
65–69	11.536	0.524	9.522	0.522	13.016	0.467	10.847	0.473
70–74	10.601	0.629	8.718	0.625	12.145	0.538	9.918	0.543
75–79	11.408	0.840	9.265	0.831	9.342	0.690	7.152	0.692
80–84	9.093	1.190	7.430	1.175	10.973	1.029	9.244	1.024
85–89	12.170	2.020	11.652	1.991	8.656	1.659	7.244	1.648
90–94	7.040	3.842	6.109	3.787	6.946	3.514	5.360	3.488
95+	−1.875	7.279	−3.857	7.175	5.985	7.140	3.073	7.087
Mills	NA	NA	13.029	0.509	NA	NA	13.113	0.584
Observations	22,310		22,310		32,772		32,772	
Standard error	32.538		32.071		33.468		33.214	

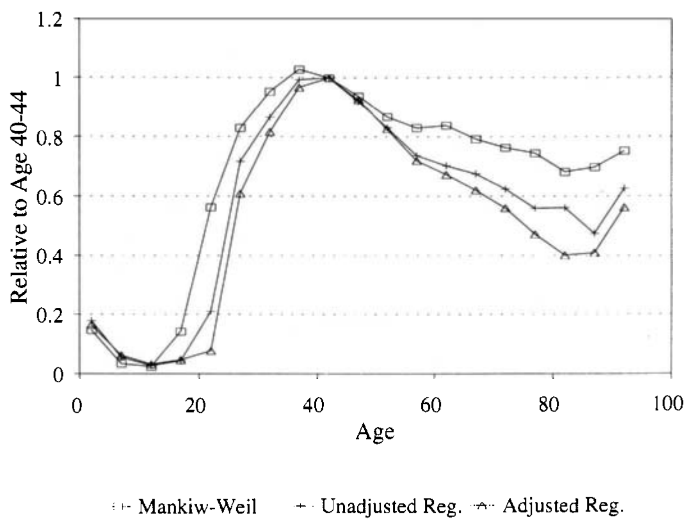

Fig. 7.11 1970 housing consumption

1970				1980				
Unadjusted Coefficient	Standard Deviation	Adjusted Coefficient	Standard Deviation	Unadjusted Coefficient	Standard Deviation	Adjusted Coefficient	Standard Deviation	Variable: Age Cohort
4.350	0.384	3.751	0.386	2.708	0.473	4.074	0.493	0–4
1.344	0.314	1.418	0.312	−0.069	0.444	0.917	0.459	5–9
0.665	0.297	0.707	0.296	0.941	0.404	1.701	0.418	10–14
1.064	0.325	1.052	0.324	−1.033	0.377	−0.315	0.389	15–19
5.098	0.433	1.764	0.463	5.300	0.433	6.341	0.493	20–24
17.393	0.435	13.849	0.469	19.507	0.435	20.237	0.513	25–29
20.983	0.439	. 18.552	0.454	27.391	0.432	27.338	0.470	30–34
24.092	0.274	21.990	0.438	30.287	0.473	30.159	0.500	35–39
24.267	0.391	22.754	0.410	29.293	0.491	29.068	0.515	40–44
22.339	0.362	21.066	0.366	26.156	0.477	26.068	0.498	45–49
20.159	0.369	18.796	0.373	23.423	0.432	23.578	0.454	50–54
17.860	0.385	16.357	0.390	22.585	0.423	22.464	0.449	55–59
17.050	0.414	15.291	0.421	20.601	0.462	20.543	0.502	60–64
16.396	0.473	14.123	0.483	19.124	0.510	18.553	0.575	65–69
15.143	0.544	12.746	0.555	18.461	0.598	17.466	0.700	70–74
13.570	0.681	10.734	0.692	16.785	0.749	14.208	0.900	75–79
13.630	0.940	9.143	0.301	17.202	1.050	14.651	1.277	80–84
11.520	1.486	9.326	1.482	14.009	1.535	10.304	1.917	85–89
15.215	2.912	12.787	2.901	11.855	2.427	8.033	2.935	90–94
15.134	5.240	15.251	5.214	NA	NA	NA	NA	95+
NA	NA	11.122	0.552	NA	NA	−6.746	0.935	Mills
39,851		39,851		52,280		47,745		Observations
36.670		36.479		48.148		48.003		Standard error

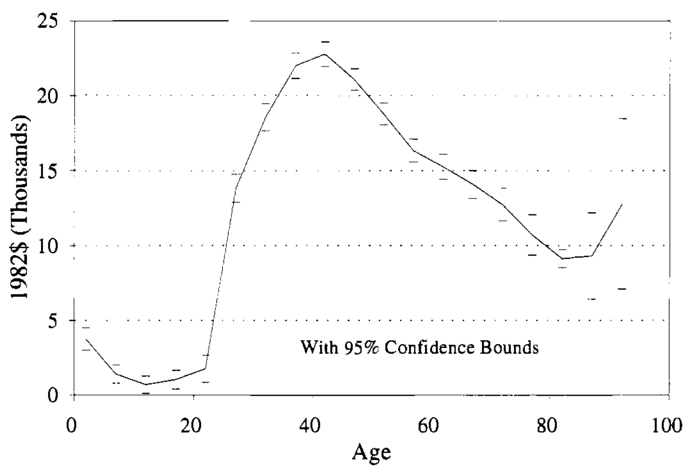

Fig. 7.12 1970 housing consumption (adjusted for selection)

Table 7.12 1970 Housing Consumption Relative to Age 40–44

Age cohort	Mankiw-Weil	Unadjusted Regression	Adjusted Regression
0–4	0.147	0.179	0.165
5–9	0.034	0.055	0.062
10–14	0.024	0.027	0.031
15–19	0.143	0.044	0.046
20–24	0.563	0.210	0.078
25–29	0.829	0.717	0.609
30–34	0.952	0.865	0.815
35–39	1.028	0.993	0.966
40–44	1.000	1.000	1.000
45–49	0.938	0.921	0.926
50–54	0.867	0.831	0.826
55–59	0.829	0.736	0.719
60–64	0.838	0.703	0.672
65–69	0.792	0.676	0.621
70–74	0.762	0.624	0.560
75–79	0.743	0.559	0.472
80–84	0.681	0.562	0.402
85–89	0.697	0.475	0.410
90–94	0.752	0.627	0.562
95+	0.459	0.624	0.670

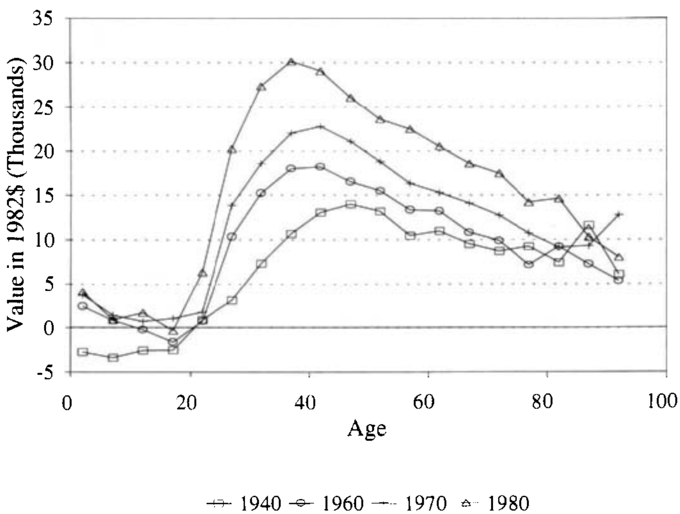

Fig. 7.13 Housing consumption by census year

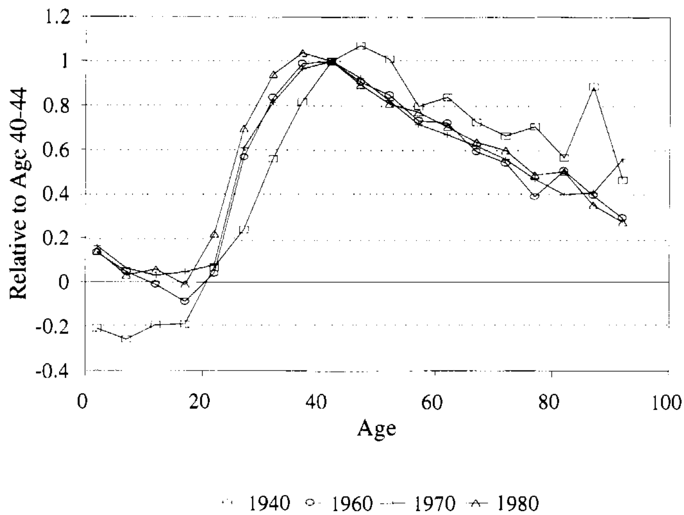

Fig. 7.14 Relative housing consumption

consumption for the cohorts between ages 25 and 39 than is observed in the later censuses. This is almost certainly attributable to the lack of consumer confidence and shortage of liquidity during the depression, when these cohorts might normally have been rapidly increasing their housing consumption. From this figure, I conclude that there is empirical justification for an assumption that the relative housing consumption profile is stable over time.

I use the 1970 adjusted regression coefficients, relative to the age 40–44 cohort, multiplied by the U.S. population from tables 7.1–7.3, to form estimates of housing demand at 1970 income and prices. Table 7.13 gives this demographic factor, normalized to one in 1982. Also calculated in this table is the aggregation factor ψ_t that will appear when individual income effects are aggregated. Figure 7.15 plots the demographic factor.

7.5 Supply and Demand for Housing

Supply of new housing per capita is modeled as a log linear function of current housing price, GNP per capita, and the mortgage interest rate,

$$\log\left[\frac{\text{Invest}_t}{\text{Pop}_t}\right] = \theta_1 + \theta_2 \log\left[\text{Housing price}_t\right] + \theta_3 \log\left[\text{GNP per capita}_t\right] + \theta_4 \, \text{Intr}_t, \tag{12}$$

where the variables

Table 7.13 **Income Aggregation Factor and Demographic Demand Factor**

Year	Income Aggregation	Demographic Demand	Year	Income Aggregation	Demographic Demand	Year	Income Aggregation	Der D
1900	0.926	0.277	1950	1.099	0.668	2000	1.183	
1901	0.929	0.283	1951	1.091	0.677	2001	1.185	
1902	0.931	0.289	1952	1.082	0.687	2002	1.187	
1903	0.934	0.296	1953	1.074	0.696	2003	1.190	
1904	0.937	0.302	1954	1.065	0.706	2004	1.192	
1905	0.939	0.309	1955	1.057	0.716	2005	1.194	
1906	0.945	0.317	1956	1.048	0.724	2006	1.195	
1907	0.951	0.325	1957	1.038	0.732	2007	1.196	
1908	0.958	0.333	1958	1.029	0.740	2008	1.197	
1909	0.964	0.341	1959	1.020	0.749	2009	1.198	
1910	0.970	0.350	1960	1.012	0.757	2010	1.198	
1911	0.973	0.357	1961	1.007	0.763	2011	1.197	
1912	0.975	0.365	1962	1.002	0.769	2012	1.196	
1913	0.978	0.373	1963	0.997	0.775	2013	1.195	
1914	0.981	0.381	1964	0.992	0.780	2014	1.194	
1915	0.984	0.389	1965	0.988	0.786	2015	1.193	
1916	0.986	0.395	1966	0.990	0.793	2016	1.191	
1917	0.989	0.401	1967	0.993	0.800	2017	1.188	
1918	0.992	0.407	1968	0.995	0.807	2018	1.186	
1919	0.995	0.413	1969	0.998	0.814	2019	1.184	
1920	0.997	0.419	1970	1.000	0.821	2020	1.181	
1921	0.999	0.427	1971	1.008	0.832	2021	1.179	
1922	1.000	0.435	1972	1.015	0.843	2022	1.176	
1923	1.001	0.443	1973	1.023	0.855	2023	1.173	

1924	1.002	0.452	1974	1.031	0.867	2024	1.171
1925	1.004	0.460	1975	1.039	0.878	2025	1.168
1926	1.009	0.468	1976	1.048	0.894	2026	1.167
1927	1.014	0.475	1977	1.057	0.911	2027	1.165
1928	1.020	0.483	1978	1.066	0.927	2028	1.163
1929	1.025	0.490	1979	1.076	0.944	2029	1.162
1930	1.031	0.498	1980	1.085	0.961	2030	1.160
1931	1.038	0.504	1981	1.094	0.980	2031	1.160
1932	1.046	0.511	1982	1.103	1.000	2032	1.159
1933	1.054	0.517	1983	1.112	1.020	2033	1.159
1934	1.061	0.523	1984	1.121	1.040	2034	1.159
1935	1.069	0.530	1985	1.130	1.061	2035	1.158
1936	1.076	0.537	1986	1.136	1.080	2036	1.159
1937	1.082	0.544	1987	1.142	1.099	2037	1.159
1938	1.088	0.551	1988	1.147	1.118	2038	1.159
1939	1.095	0.559	1989	1.153	1.138	2039	1.159
1940	1.101	0.566	1990	1.158	1.158	2040	1.160
1941	1.104	0.575	1991	1.163	1.174	2041	1.160
1942	1.108	0.584	1992	1.168	1.190	2042	1.160
1943	1.111	0.594	1993	1.173	1.207	2043	1.160
1944	1.115	0.603	1994	1.178	1.223	2044	1.161
1945	1.118	0.613	1995	1.183	1.241	2045	1.161
1946	1.114	0.623	1996	1.183	1.249	2046	1.161
1947	1.111	0.634	1997	1.183	1.257	2047	1.161
1948	1.107	0.645	1998	1.183	1.266	2048	1.161
1949	1.103	0.657	1999	1.183	1.275	2049	1.161

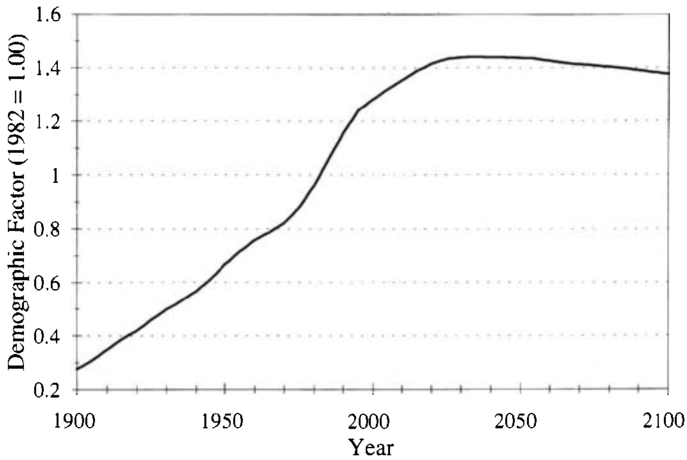

Fig. 7.15 Housing demand demographic factor

Invest =	real constant-quality housing investment (in 1982 dollars),
Pop =	U.S. population (in thousands),
Housing price =	real quality-adjusted price (in 1982 dollars), and
Intr =	home mortgage interest rate,

are taken from tables 7.1–7.3, 7.7, and 7.8. This model is loosely justified by an argument that the economy has a production frontier for housing and other goods, and competition will result in observations on this frontier where marginal revenue equals price. A C.E.S. frontier, for example, will yield a relationship like equation (12).[5]

Equation (12) was estimated by generalized least squares (GLS), with a correction for first-order serial correlation, using data for the years 1947–88. To handle endogeneity of housing price, the model was also estimated by GLS after replacing log housing price with a fitted value from a regression on a constant, the home mortgage interest rate, the rate of inflation, log GNP per capita, log population, log demographic demand factor, and log real housing stock. The standard errors in the two-stage procedure are not corrected for the first-stage estimation. The model was also estimated by an instrumental variables (IV) procedure, ignoring serial correlation. The estimates for these models are given in table 7.14. This table also gives estimates for the observation

5. Suppose housing H and nonhousing goods N are produced subject to a C.E.S. frontier $Z = [H^{1+\sigma} + AN^{1+\sigma}]^{1/(1+\sigma)}$, where Z is the primary input. Assume competitive industries maximize revenue $G = pH + N$, where p is the real price of housing. Then $G = Z\pi(p)$, where $\pi(\cdot)$ is a revenue function, and one has $H = G\pi_p(p)/\pi(p)$ is linear in G and increasing in p. Equation (14) is of this form, with an added parameter to allow for nonconstant returns to scale.

Table 7.14 Housing Supply Regressions—Dependent Variable: Log Real Housing Investment per Capita (Standard errors in parentheses)

	Model					
	(1)	(2)	(3)	(4)	(5)	(6)
Observation period						
Estimator	1947–88	1947–88	1947–88	1900–88	1900–88	1900–88
Variables	GLS	2SGLS	IV	GLS	2SGLS	IV
Constant	−10.120	−8.783	−8.759	−17.240	−2.236	−3.323
	(2.833)	(2.274)	(1.548)	(3.941)	(74.03)	(5.870)
Log GNP per capita	1.085	0.977	0.959	1.899	0.299	0.332
	(0.303)	(0.286)	(0.165)	(0.425)	(7.854)	(0.632)
Log real housing price	1.200	2.510	1.982	−0.486	2.997	1.678
	(1.001)	(1.340)	(0.780)	(0.904)	(15.028)	(1.178)
Nominal interest rate	−0.079	−0.094	−0.082	−0.125	−0.101	−0.034
	(0.020)	(0.024)	(0.014)	(0.040)	(0.120)	(0.024)
Rate of inflation	−0.008	−0.007	−0.006	−0.008	−0.004	−0.002
	(0.007)	(0.007)	(0.005)	(0.006)	(0.023)	(0.011)
Rho	0.405	0.379	NA	0.887	0.883	NA
Observations	42.000	42.000	42.000	81.000	81.000	81.000
Standard error	0.088	0.084	0.102	0.232	0.236	0.263

period 1900–88, excluding the war years 1917–18 and 1941–46 when supply restrictions were in place.

The estimates for 1947–88 imply that new housing investment is approximately homogeneous in GNP and responds negatively to the mortgage interest rate, reflecting the impact of the cost of working capital. Supply is found to be quite price elastic, with an elasticity value of 1.98 in the IV regression. This is in the range found by other authors using different data constructions and time periods (see Poterba 1984; Topel and Rosen 1988). The estimates for the longer observation period are less well determined. The IV regression gives a comparable price elasticity of supply but shows a much weaker elasticity with respect to GNP. These results provide mixed support for the stability of the supply relationship. In further analysis, I use the IV estimates of equation (12) based on post–World War II data (model [3]). An important feature of this model, which plays a critical role in the final results in this paper, is that at fixed real housing prices, housing investment expands nearly in proportion to GNP. This implies that if housing demand at fixed real prices grows less than linearly in GNP, due to demographic factors or a low income elasticity, then there will necessarily be downward movement of prices, even with growing demand for housing.

The specification of demand starts from a simple age-specific individual demand function. Consider an individual in cohort i in year t, and assume that his or her real housing demand, denoted D_{it}, differs from the demand of a person of the same cohort in base year 0 only because of differences in real income or real user cost of housing, with the functional form

$$D_{it} = \alpha_{i0}(\psi_{it}/\psi_{i0})^{\gamma}\exp(\lambda(u_t - u_0)), \tag{13}$$

where ψ_{it} is real income, u_t is real user cost, and the α_{i0} are the age-specific selection-adjusted housing demand coefficients obtained using the 1970 census and given in table 7.12. This equation can be derived from the indirect utility function

$$V_{it} = \psi_{it}^{1-\gamma}/(1 - \gamma) - \lambda^{-1}\alpha_{i0}\exp(C + \lambda u_t), \tag{14}$$

where C is a constant that collects the base-year variable values.

Recall from equation (8) that $\psi_{it}/\psi_{i0} = (Y_t/Y_0)/\psi_t$. The demographic factor constructed in table 7.13 can be defined, except for normalization, as

$$F_t = \sum_{i=1}^{20} N_{it}\alpha_{i0} \Big/ \sum_{i=1}^{20} N_{i0}\alpha_{i0}. \tag{15}$$

The individual demand functions can then be aggregated across cohorts, given the population profile, to obtain aggregate housing demand,

$$D_t = A\ F_t\ Y_t^{\gamma}\ \exp(\lambda u_t)\ \psi_t^{-\gamma}, \tag{16}$$

where A is a constant. For econometric analysis, I work with the model

$$\log(D_t/F_t) = \log(A) + \lambda u_t + \gamma\log(Y_t/\psi_t) + \nu_t. \tag{17}$$

Because of transactions costs, consumers are likely to adjust slowly toward desired housing consumption levels. To incorporate this effect, I consider a partial adjustment version of model (17),

$$\begin{aligned}\log(D_t/F_t) &= \theta\log(D_{t-1}/F_{t-1}) + (1 - \theta)\log(A) \\ &\quad + (1-\theta)\lambda u_t + (1 - \theta)\gamma\log(Y_t),\end{aligned} \tag{18}$$

where $1 - \theta$ is the adjustment rate.

I estimate equations (17) and (18) using data from tables 7.7 and 7.8, with demand defined as the real constant-quality housing stock. The fitted demand equations for the four models of expectations described earlier (denoted LAG1, LAG3, LEAD1, and LEAD3) and the corresponding user cost measures are given in tables 7.15–7.18. Each equation is estimated for the period 1900–88, excluding the war years, and also for the period 1947–88.

Let $y = X\beta + \varepsilon$ denote equation (17), with ε assumed to follow an autoregressive process of order one (AR1), process with serial correlation ρ. First, I estimate this equation by GLS. Next, to accommodate possible endogenicity of the price of housing that enters user cost, I apply Durbin's transformation,

$$y = \rho y_{-1} + X\beta - X_{-1}(\rho\beta) + \nu, \tag{19}$$

and estimate this equation by instrumental variables (IV), without imposing the nonlinear constraint on parameters, and use this equation to estimate ρ. The instruments used are a constant, log population, the home mortgage interest rate, the inflation rate, the log of aggregation-adjusted GNP per capita and its lagged value, and one and two period lags of the dependent variable. This method is consistent even if user cost and the lagged dependent variable are correlated with the disturbance. Finally, I do IV estimation of the ρth difference equation

$$y - \rho y_{-1} = (X - \rho X_{-1})\beta + \nu, \tag{20}$$

using the estimate of ρ from the preceeding IV regression.

A potential problem with these demand estimates is that some of the instruments, such as GNP per capita and the mortgage rate, are in fact jointly determined along with housing prices by macroeconomic equilibrium and thus may themselves be correlated with the disturbances in these regressions.

I first summarize the results in tables 7.15 and 7.16 for the demand equation (17) without partial adjustment. The income elasticities, as measured by the endogenity-corrected ρth difference estimates, are relatively insensitive to the definition of user cost or to the observation period, with values between 0.2 and 0.5. There is no consistent pattern to the coefficients of user cost, with the regressions for the full period giving responses that are insignificant or of unexpected sign, and the regressions for 1950–88 giving responses that are mostly of expected sign, but not consistently significant.

If the partial adjustment effect θ introduced in equation (18) is significant, then equation (17) is misspecified, and its estimated coefficients are biased.[6] Equation (18) has the form

$$y = \theta y_{-1} + X\beta + \varepsilon,$$

and Durbin's transformation yields

$$y = (\theta + \rho)y_{-1} - \theta\rho y_{-2} + X\beta - X_{-1}(\rho\beta) + \nu.$$

I report the GLS results, but they are biased due to the lagged dependent variable. To obtain consistent estimates, I apply IV to Durbin's transformation of equation (18), using the same instruments as for equation (17), without imposing nonlinear parameter restrictions. The coefficients of y_{-1} and y_{-2} define a quadratic whose roots are estimates of θ and ρ; I use these, with the relative coefficients of X and X_{-1} used to identify which root estimates ρ. I then use this estimate to form the ρth difference equation,

6. The bias in IV estimates of model (17) when the specification (18) is true can be worked out by rewriting equation (17) as

$$y = [y_{-1}|X|X_{-1}]\left\{\begin{bmatrix}\theta + \rho \\ \beta \\ \beta\rho\end{bmatrix} - \rho\theta\begin{bmatrix}y'_{-1}y_{-1} & y'_{-1}X & y'_{-1}X_{-1} \\ X'y_{-1} & X'X & X'X_{-1} \\ X'_{-1}y_{-1} & X'_{-1}X & X'_{-1}X_{-1}\end{bmatrix}^{-1}\begin{bmatrix}y'_{-1}y_{-2} \\ X'y_{-2} \\ X'_{-1}y_{-2}\end{bmatrix}\right\} + \eta,$$

where lags are denoted by subscripts and the disturbance η is orthogonal to the right-hand-side variables.

Table 7.15 **Demand Functions for Model (17): Observations 1900–88, except 1917–18 and 1941–4**

	Regression							
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Expectations model	LAG1	LAG1	LAG1	LAG3	LAG3	LAG3	LEAD1	LEAD1
Estimation method	GLS	IV	IV on ρ-Diff	GLS	IV	IV on ρ-Diff	GLS	IV
Constant	4.880	0.367	0.550	5.212	0.358	0.597	5.233	0.213
	1.276	0.127	0.051	1.269	0.070	0.043	1.184	0.070
User cost	0.219	−0.094	0.457	0.492	0.167	0.451	0.038	0.310
	0.208	0.130	0.164	0.482	0.111	0.222	0.206	0.152
Adjusted income	0.295	−0.022	0.495	0.256	0.079	0.446	0.225	0.170
	0.143	0.107	0.032	0.143	0.030	0.029	0.134	0.045
User cost, LAG1		0.156			0.234			−0.046
		0.304			0.139			0.080
Adjusted income,		0.130			0.023			−0.099
LAG1		0.128			0.036			0.047
Dependent variable,		0.822			0.831			0.887
LAG1		0.047			0.023			0.021
Observations	81	79	79	81	79	79	80	78
R^2	0.899	0.995	0.728	0.890	0.998	0.736	0.886	0.996
Standard error	0.087	0.019	0.028	0.091	0.013	0.026	0.091	0.018
Rho	0.928	0.822	NC	0.932	0.831	NC	0.917	0.887

Table 7.16 **Demand Functions for Model (17): Observations 1947–88 (standard errors below coef**

	Regression							
	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20
Expectations model	LAG1	LAG1	LAG1	LAG3	LAG3	LAG3	LEAD1	LEA
Estimation method	GLS	IV	IV on ρ-Diff	GLS	IV	IV on ρ-Diff	GLS	
Constant	−0.460	0.191	0.367	−0.571	0.290	0.349	−0.834	0.1
	0.459	0.066	0.046	0.460	0.079	0.027	0.414	0.0
User cost	0.337	−0.015	0.117	0.212	−0.222	−0.236	−0.009	−0.1
	0.120	0.058	0.074	0.264	0.109	0.105	0.128	0.0
Adjusted income	0.887	0.203	0.411	0.890	0.172	0.247	0.920	0.2
	0.050	0.062	0.052	0.050	0.046	0.044	0.045	0.0
User cost, LAG1		0.019			0.303			0.0
		0.091			0.120			0.0
Adjusted income, LAG1		−0.145			−0.151			−0.1
		0.063			0.049			0.0
Dependent variable LAG1		0.908			0.938			9.9
		0.035			0.040			0.0
Observations	42	42	42	42	42	42	41	
R^2	0.990	0.999	0.553	0.989	0.999	0.517	0.990	0.9
Standard error	0.025	0.006	0.011	0.026	0.007	0.007	0.025	0.0
Rho	0.764	0.908		0.725	0.938		0.703	0.9

$$y - \rho y_{-1} = \theta(y_{-1} - \rho y_{-2}) + (X - \rho X_{-1})\beta + \nu,$$

which I estimate by IV.

Summarizing the estimates of the partial adjustment model (18) in tables 7.17 and 7.18, there are again substantial differences between the coefficients from regressions run on the full period 1900–88 and on the truncated period 1947–88. This may reflect a regime change in macroeconomic structure or housing finance after World War II, special problems of disequilibrium in the 1930s, or problems in consistent measurement of variables early in the century. Another factor that may be important is the fairly rapid decrease in household size over the 1960–88 period, due to reduced number of children and to increased household formation from delayed marriage, increased divorce rates, and increased rates of elderly living alone. In several cases, the estimation method applied to the 1900–88 observation period does not yield a real estimate for the serial correlation coefficient, and the ρth difference regression cannot be run. Whenever these regressions are available, in either the full or post–World War II data, they give income elasticities near 0.2, no matter what the expectations model. Estimates of the partial adjustment parameter θ vary from 0.3 to 0.6 in the 1947–88 data, depending on the expectations model. The one consistent estimate for the full data is 0.8. The postwar data estimates then imply long-run income elasticities between 0.2 and 0.6. The coefficients of user cost vary with both the expectations model and the observation period but are generally insignificant for the longer period. Concentrating on the regressions from the 1947–88 period, the long-run response to a unit increase in user cost ranges from −0.2 to −0.3. These values imply very small elasticities with respect to housing price: In the LEAD3 expectations model, a uniform 100 percent increase in housing price yields, on average over 1947–88, a long-run decrease of 1.4 percent in housing demand.

There are insufficient differences in overall fit to sharply discriminate between the different expectations models. The lack of strong evidence supporting forward-looking rather than naive expectations is consistent with the findings of Ai et al. (1990) from panel data that households are relatively insensitive to user costs, particularly the capital gains component. Skinner (1989) also finds myopic behavior. The possibility that households make substantial intergenerational gifts or bequests, mitigating the cross-cohort effects of housing price variations, has been examined by Skinner (1989) and M. Hurd (personal communication). They find dissaving among the elderly too low to be easily explained by one-generation life-cycle behavior unless risk aversion is very strong. On the other hand, this behavior does not appear to be systematically related to bequest motives, as it does not depend on number of children or children's economic status.

On the basis of the results in tables 7.15–7.18, I selected the LEAD3 model, fitted to post–World War II data, for further analysis. It appears unlikely that the choice of expectations model would have much impact on the long-run

Table 7.17 **Demand Functions for Model (18): Observations 1900–88, except 1917–18 and 1941–**

	Regression							
	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32
Expectations model	LAG1	LAG1	LAG1	LAG3	LAG3	LAG3	LEAD1	LEA
Estimation method	GLS	IV	IV on ρ-Diff	GLS	IV	IV on ρ-Diff	GLS	
Constant	0.230	0.071	0.088	0.273	0.099		0.185	0.
	0.112	0.070	0.048	0.114	0.047		0.127	0.0
User cost	0.017	0.087	0.202	0.109	0.121		−0.039	0.0
	0.023	0.065	0.091	0.049	0.059		0.021	0.0
Adjusted income	0.080	0.124	0.243	0.085	0.084		0.072	0.
	0.014	0.053	0.028	0.013	0.016		0.014	0.0
User cost, LAG1		−0.115			−0.106			0.0
		0.159			0.083			0.0
Adjusted income, LAG1		−0.107			−0.059			−0.0
		0.067			0.021			0.0
Dependent variable, LAG1	0.876	1.652	0.641	0.864	1.625		0.891	1.
	0.026	0.108	0.064	0.025	0.091		0.026	0.0
Dependent variable, LAG2		−0.682			−0.668			−0.6
		0.087			0.076			0.0
Observations	80	79	79	80	79		79	
R^2	0.999	0.999	0.894	0.999	0.999		0.999	0.9
Standard error	0.009	0.009	0.015	0.008	0.007		0.009	0.0
Rho	0.776	0.848	0.848	0.783	NC		0.801	[illegible]
Theta	0.876	0.804	0.641	0.864	NC		0.891	[illegible]

Table 7.18 **Demand Functions for Model (18): Observations 1947–88 (standard errors below coeffi**

	Regression							
	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)
Expectations model	LAG1	LAG1	LAG1	LAG3	LAG3	LAG3	LEAD1	LEAD1
Estimation method	GLS	IV	IV on ρ-Diff	GLS	IV	IV on ρ-Diff	GLS	IV
Constant	0.023	0.175	0.240	0.058	0.219	0.261	−0.003	0.141
	0.101	0.078	0.033	0.102	0.072	0.040	0.102	0.051
User cost	0.006	−0.135	−0.020	0.062	−0.166	0.228	−0.052	−0.142
	0.037	0.078	0.046	0.062	0.096	0.099	0.035	0.046
Adjusted income	0.162	0.025	0.196	0.157	0.147	0.200	0.160	0.176
	0.046	0.091	0.038	0.040	0.041	0.041	0.042	0.031
User cost, LAG1		0.240			0.230			0.083
		0.126			0.107			0.033
Adjusted income, LAG1		−0.001			−0.136			−0.133
		0.086			0.043			0.032
Dependent variable, LAG1	0.804	1.463	0.526	0.805	1.261	0.234	0.810	1.219
	0.048	0.171	0.041	0.041	0.121	0.079	0.043	0.100
Dependent variable, LAG2		−0.514			−0.302			−0.287
		0.154			0.109			0.089
Observations	42	42	42	42	42	42	41	41
R^2	0.999	0.999	0.931	0.999	0.999	0.628	0.999	1.000
Standard error	0.007	0.008	0.006	0.007	0.006	0.006	0.007	0.005
Rho	0.610	0.877		0.600	0.939		0.582	0.899
Theta	0.804	0.586		0.805	0.322		0.810	0.319

conclusions of the study, although short-run dynamics will obviously depend on this choice. It is also unlikely that the analysis would be much affected by using rational expectations rather than the LEAD3 perfect foresight expectations. In the equilibrium I obtain, the LEAD3 expectations are highly predictable from the information set at each time period, and the equilibrium does not have change points or sharp breaks where rational expectations might differ significantly from the LEAD3 expectations.

For projections, I need auxiliary forecasts of the inflation rate, real GNP per capita, the home mortgage rate, the property tax rate, and the marginal income tax rate. The following regressions are used; *t*-Statistics are given in parentheses. Log price index for GNP (LPGNP):

$$\text{(21)}\quad \underset{}{\text{LPGNP}} = \underset{(2.86)}{0.2516} + \underset{(2.77)}{0.0023}(\text{year} - 1990) + \underset{(12.05)}{1.77049}\ \text{LPGNP}_{-1}$$
$$- \underset{(-3.96)}{1.1747}\ \text{LPGNP}_{-2} + \underset{(2.14)}{0.70223}\ \text{LPGNP}_{-3} - \underset{(-0.92)}{0.2591}\ \text{LPGNP}_{-4}$$
$$\underset{(-0.71)}{-0.0909}\ \text{LPGNP}_{-5},$$

1950–88 sample, $R^2 = 0.9995$.

Log GNP per capita (LGNPC):

$$\text{(22)}\quad \text{LGNPC} = \underset{(2.49)}{2.5513} + \underset{(2.34)}{0.00516}\ (\text{year} - 1990) + \underset{(7.02)}{0.73946}\ \text{LGNPC}_{-1},$$

1950–88 sample, $R^2 = 0.9893$.

Nominal mortgage interest rate (MORTR):

$$\text{(23)}\quad \text{MORTR} = \underset{(0.96)}{0.25365} + \underset{(4.58)}{0.2151}\ (\text{inflation rate, GNP index}) + \underset{(23.66)}{0.8718}\ \text{MORTR}_{-1},$$

1950–88 sample, $R^2 = 0.9617$.

I assume the property tax rate and marginal income tax rate remain at 1989 levels. The annual *growth rates* of the auxiliary variables follow:

Variable	Growth Rate 1950–89	Growth Rate 1990–2100
GNP price deflator (PGNP)	4.06	4.37
Real GNP per capita (GNPC)	1.97	1.98
Nominal mortgage interest rate (MORTR)	2.76	0.00
Demographic factor in housing demand	1.41	0.02

A potential problem with the preceding analysis of the market for housing is that the estimated serial correlation coefficients in the demand and supply functions are near one, suggesting that these variables may have unit roots and cointegrating relationships. I have tested log real GNP per capita, log housing investment, log housing stock, the GNP implicit price deflator, and the home mortgage interest rate for unit roots, using augmented Dickey-Fuller tests on annual observations from 1869 through 1989. I do the tests with and without the maintained hypothesis of a deterministic trend. To take partial account of moving-average effects introduced by demographic factors, I include five years of lagged first differences in the variable being tested. I reject the hypothesis of a unit root for the GNP price deflator with a deterministic trend and otherwise accept the unit root hypothesis, at the 5 percent significance level. For forecasting, I use the previous point estimates of autoregression coefficients but note, in light of the unit root tests, that the standard errors for regression coefficients, and confidence bounds for forecasts, may be severely underestimated.

7.6 Housing Market Projections

The estimated supply and demand models for the housing market, combined with auxiliary forecasts, define a system that can be solved for market-clearing housing prices, user costs, investment, and stocks. I use supply model (3) from table 7.14, demand model (48) from table 7.18, and the LEAD3 expectations model. The following method is used to determine equilibrium in the model: Starting from a trial real housing price sequence from 1989 to 2100, I calculate nominal capital gain rates, imposing a transversality condition that real capital gains rates in 2098–2100 are zero. For these fixed capital gains rates, I solve the model by forward recursion, obtaining a modified price sequence. I then adjust nominal capital gains rates partially to the new price sequence and repeat the process. The method converges in a few-score iterations and takes about 10 seconds on a fast workstation.

The results of the forecasting exercise are given in table 7.19. It should be noted that the price forecast is much smoother than the historical series, which is highly volatile. The forecast is for continued growth in housing demand, fueled by rising income, which offsets the slow decline in the demographic factor. However, rising income also increases supply of new housing investment, leading to steadily declining real housing prices. The model does not predict a precipitious decline, although it does suggest a substantial fall through the 1990s. It is likely that a rational expectations model with more forward-looking consumers would react more quickly to pending declines and accelerate their onset.

The results of the projections are summarized in figures 7.16–7.18. Figure 7.16 shows that real housing prices fell about 7 percent from a peak in 1980 until 1988, with a small rebound after 1986. The projections show a brief increase in 1989 and 1990, followed by a decline that is relatively sharp in the late 1990s, shallow in the 2010s, and sharper again after 2020. Figure 7.17

Table 7.19 **Forecasts of Housing Market Real Stocks and Real Prices**

Year	Price	Stock	Year	Price	Stock
1869	0.601	107.7	1910	0.614	478.5
1870	0.573	112.3	1911	0.611	485.7
1871	0.634	116.5	1912	0.600	494.3
1872	0.570	120.6	1913	0.581	503.4
1873	0.632	124.8	1914	0.571	511.7
1874	0.597	129.8	1915	0.558	521.8
1875	0.554	135.9	1916	0.528	533.7
1876	0.554	142.6	1917	0.499	539.5
1877	0.520	150.3	1918	0.526	538.6
1878	0.545	158.9	1919	0.533	546.5
1879	0.531	168.7	1920	0.602	550.5
1880	0.556	178.1	1921	0.579	558.1
1881	0.568	187.3	1922	0.579	581.8
1882	0.577	196.5	1923	0.630	611.5
1883	0.614	206.2	1924	0.620	647.7
1884	0.592	218.8	1925	0.604	688.4
1885	0.605	232.7	1926	0.618	728.4
1886	0.638	246.3	1927	0.621	764.0
1887	0.633	261.0	1928	0.612	794.5
1888	0.591	277.6	1929	0.642	810.6
1889	0.550	290.6	1930	0.641	811.0
1890	0.563	303.0	1931	0.639	807.5
1891	0.549	311.4	1932	0.579	794.9
1892	0.555	323.7	1933	0.588	780.5
1893	0.540	331.4	1934	0.608	767.8
1894	0.554	339.8	1935	0.596	760.8
1895	0.552	350.4	1936	0.625	760.2
1896	0.569	358.8	1937	0.657	761.5
1897	0.554	368.4	1938	0.689	763.1
1898	0.561	375.0	1939	0.704	772.1
1899	0.580	381.2	1940	0.716	783.4
1900	0.582	382.4	1941	0.728	797.0
1901	0.578	387.9	1942	0.696	791.7
1902	0.578	392.0	1943	0.705	778.5
1903	0.590	396.5	1944	0.755	764.4
1904	0.575	403.1	1945	0.784	753.3
1905	0.586	418.9	1946	0.763	775.2
1906	0.628	432.3	1947	0.819	809.3
1907	0.629	441.8	1948	0.865	852.3
1908	0.612	451.8	1949	0.846	892.5
1909	0.612	465.3	1950	0.877	954.5

(continued)

Table 7.19 (continued)

Year	Price	Stock	Year	Price	Stock
1951	0.882	999.5	1992	0.985	3,547.9
1952	0.884	1,041.2	1993	0.965	3,665.5
1953	0.887	1,084.0	1994	0.952	3,784.2
1954	0.860	1,133.4	1995	0.943	3,904.5
1955	0.871	1,194.1	1996	0.907	4,012.5
1956	0.883	1,242.4	1997	0.883	4,113.2
1957	0.872	1,283.1	1998	0.865	4,208.4
1958	0.852	1,323.4	1999	0.854	4,300.6
1959	0.865	1,376.8	2000	0.846	4,391.1
1960	0.862	1,422.9	2001	0.834	4,476.8
1961	0.855	1,467.9	2002	0.827	4,559.6
1962	0.859	1,517.6	2003	0.822	4,640.3
1963	0.866	1,573.6	2004	0.819	4,719.6
1964	0.879	1,625.6	2005	0.817	4,798.2
1965	0.877	1,682.0	2006	0.815	4,875.6
1966	0.878	1,729.0	2007	0.813	4,952.3
1967	0.892	1,773.9	2008	0.812	5,028.7
1968	0.904	1,825.8	2009	0.811	5,105.1
1969	0.915	1,878.9	2010	0.810	5,181.4
1970	0.882	1,925.3	2011	0.809	5,258.1
1971	0.880	1,997.9	2012	0.807	5,335.1
1972	0.887	2,091.5	2013	0.804	5,412.3
1973	0.906	2,180.6	2014	0.801	5,490.0
1974	0.923	2,234.3	2015	0.797	5,568.2
1975	0.915	2,269.4	2016	0.790	5,645.3
1976	0.920	2,326.2	2017	0.784	5,722.2
1977	0.960	2,406.1	2018	0.775	5,797.9
1978	1.006	2,492.7	2019	0.769	5,873.7
1979	1.036	2,568.8	2020	0.762	5,949.8
1980	1.043	2,612.1	2021	0.748	6,021.8
1981	1.028	2,644.6	2022	0.737	6,091.4
1982	1.000	2,658.2	2023	0.725	6,158.3
1983	0.984	2,709.6	2024	0.716	6,224.3
1984	0.984	2,782.0	2025	0.708	6,290.0
1985	0.976	2,853.5	2026	0.693	6,350.3
1986	0.976	2,945.3	2027	0.681	6,407.5
1987	0.989	3,033.6	2028	0.671	6,461.9
1988	0.986	3,119.7	2029	0.662	6,514.9
1989	0.991	3,204.8	2030	0.655	6,567.3
1990	1.008	3,313.3	2031	0.644	6,616.1
1991	0.997	3,428.6	2032	0.636	6,662.5

Table 7.19 (continued)

Year	Price	Stock	Year	Price	Stock
2033	0.629	6,707.3	2074	0.469	8,250.5
2034	0.623	6,751.2	2075	0.467	8,291.3
2035	0.618	6,794.5	2076	0.462	8,330.8
2036	0.612	6,836.4	2077	0.459	8,369.6
2037	0.607	6,877.3	2078	0.455	8,407.9
2038	0.602	6,917.7	2079	0.452	8,446.1
2039	0.598	6,957.8	2080	0.449	8,484.3
2040	0.595	6,997.7	2081	0.446	8,522.4
2041	0.591	7,037.4	2082	0.443	8,560.6
2042	0.588	7,077.1	2083	0.440	8,598.6
2043	0.585	7,116.7	2084	0.437	8,636.6
2044	0.582	7,156.3	2085	0.434	8,674.9
2045	0.579	7,196.0	2086	0.430	8,712.3
2046	0.575	7,235.5	2087	0.427	8,749.1
2047	0.572	7,274.8	2088	0.424	8,785.7
2048	0.568	7,314.0	2089	0.421	8,822.5
2049	0.565	7,353.3	2090	0.417	8,859.2
2050	0.561	7,392.5	2091	0.414	8,895.6
2051	0.557	7,431.3	2092	0.412	8,932.7
2052	0.553	7,470.2	2093	0.408	8,969.4
2053	0.548	7,508.0	2094	0.405	9,005.7
2054	0.544	7,545.8	2095	0.404	9,044.3
2055	0.541	7,583.9	2096	0.400	9,082.1
2056	0.533	7,618.8	2097	0.396	9,118.3
2057	0.527	7,651.9	2098	0.398	9,161.8
2058	0.522	7,684.2	2099	0.393	9,202.5
2059	0.517	7,716.1	2100	0.385	9,243.3
2060	0.513	7,747.7			
2061	0.509	7,779.8			
2062	0.505	7,812.1			
2063	0.502	7,845.1			
2064	0.498	7,878.2			
2065	0.495	7,911.6			
2066	0.492	7,946.2			
2067	0.489	7,981.6			
2068	0.486	8,017.9			
2069	0.483	8,054.7			
2070	0.479	8,091.5			
2071	0.478	8,130.1			
2072	0.475	8,169.9			
2073	0.472	8,210.0			

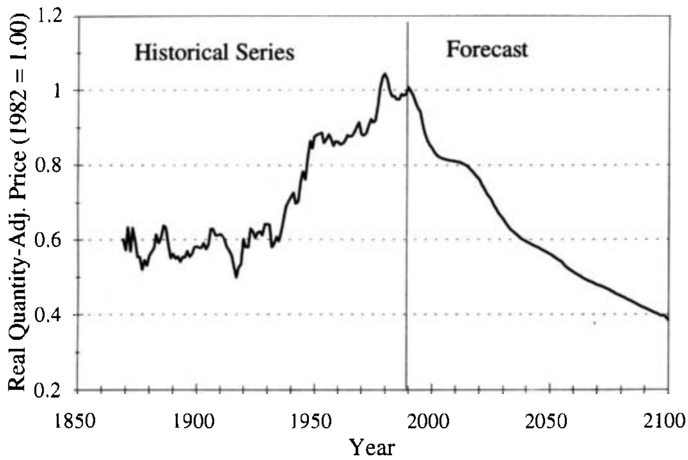

Fig. 7.16 Housing price forecast

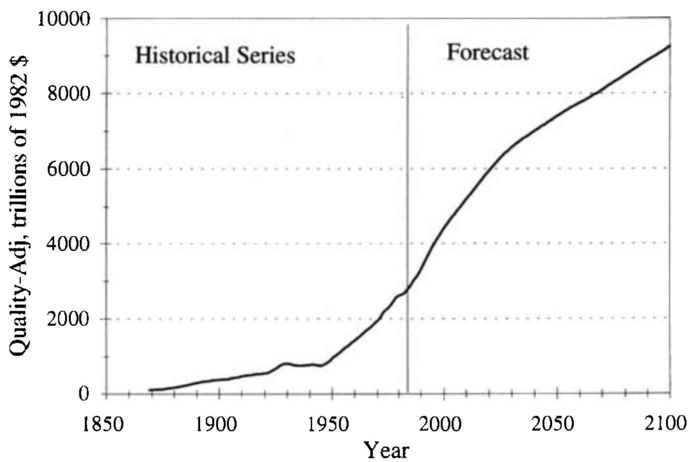

Fig. 7.17 Housing stock forecast

shows the real, constant-quality housing stock continuing a trend that began in 1950, with some slowing between 2020 and 2040 as the baby-boom cohorts disappear.

The patterns in these figures suggest that demographic factors will slow housing market growth over the next 60 years. The offsetting effect of rising income will be to increase housing demand, but not rapidly enough to keep pace with increasing supply of new housing at constant price, leading to steady price erosion. Under these projections, there will be no periods of rapid capital gains matching the sharp increases of 1938–55 or 1974–80. On the other hand, there will be no periods of precipitous capital losses that could impose an unanticipated heavy burden on some elderly cohorts, except for a few years around the present.

Figure 7.18 gives a more detailed picture of housing price behavior in the near term, as projected by the model. The feature of a small upturn in the first two forecast years is certainly related to the persistence in demand shocks and the use of the LEAD3 expectation model and makes no allowance for macroeconomic cyclic conditions. More important are the market fundamentals driving the longer-run forecast, particularly the declines after 1995.

7.7 Welfare Implications for the Elderly

Population cohorts that are able to "buy low and sell high" in the housing market gain relative to cohorts in the opposite circumstance. I examine the implications of housing market changes on intergenerational distribution by comparing rates of real capital gains, proportion of income spent on shelter, and the income adjustments (compensating variations) necessary to equate utilities of different cohorts. This analysis gives a picture of the effects of the housing market on individuals who anticipate the housing price changes and adjust savings behavior to achieve desired life-cycle consumption and bequests.

There are further, and perhaps more significant, welfare implications of housing price changes for consumption and welfare in old age. Unanticipated price changes can cause consumption squeezes or unintended bequests; the risk penalty, and cost of carrying precautionary assets, may be an important welfare effect. A significant source of financing of consumption among the very old is extraction of housing equity. Although several authors (Feinstein and McFadden 1989; Venti and Wise 1990) have noted that housing transactions prior to age 70 on average do not result in extraction of equity, Ai et al. (1990) find that equity extraction is substantial in transactions after age 75. This is particularly important as an income source for surviving spouses. Housing price volatility that translates into a volatility of 1–3 percent in lifetime income, if concentrated into the last decade of life without compensating adjustments in savings or steps to reduce risk, will lead to volatility of about 12 percent in final decade consumption.

To calculate the rate of real capital gains for a cohort, I assume that the individual purchases housing at age 30, levering the purchase with a 30 percent equity investment and 70 percent mortgage, and resells this housing at age 70. The formula

$$RCG_t = [(P_{t+40}/P_t)^{1/40} - 1]/0.3, \tag{24}$$

where P_t is real housing price, is used to calculate the rate of real capital gains. Figure 7.19 shows this rate for population cohorts with birth years between 1840 and 2030. For birth years past 1918, these calculations use the projected

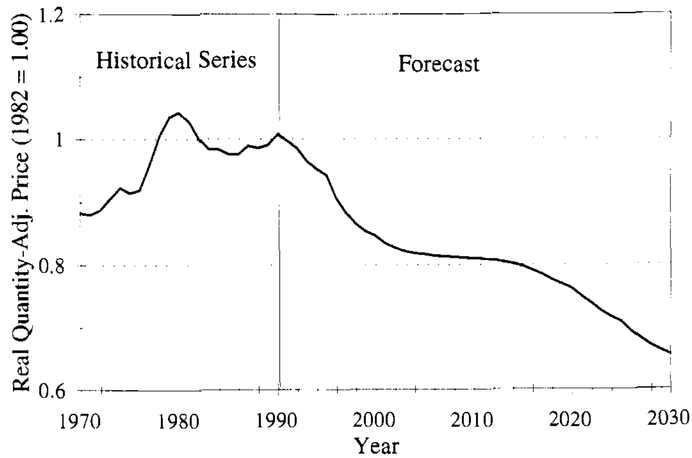

Fig. 7.18 Near-term housing prices

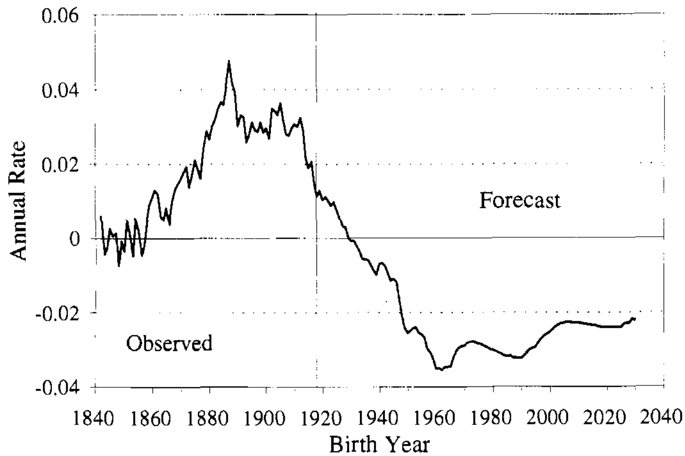

Fig. 7.19 Real rate of capital gains

prices from figure 7.16. Cohorts born in 1880–1910, who purchased housing in 1910–40, and sold it in 1950–80, achieved real returns around 3 percent per year. For cohorts born between 1915 and 1945, real capital gain rates decline steadily from +1 percent to −1 percent. There is then a sharp drop to a minimum annual rate near −3 percent for the 1960 cohort. Thereafter, the rate remains low for cohorts born through 1990 and then rises slightly to the range of −2 percent for cohorts born thereafter. The most disadvantaged cohorts by this measure will then be the baby boomers that become elderly in the years 2005–2020, and their children born between 1980 and 1990. This suggests the possible policy inference that substantial intergenerational redistribution to offset housing market effects is not needed but that it may be useful to dampen expectations of positive future housing capital gains that could distort life-cycle savings for consumption in old age.

A high share of income spent on shelter tends to reduce welfare, as it lowers consumption of other goods, and reflects mostly higher housing cost rather than increased housing consumption. I have calculated a measure of shelter share of income for each cohort by the following method. Equation (13) gives age-specific housing demand, which when combined with the assumption from equation (9) on the stability of the age distribution of income, implies

$$D_{it} = \alpha_{i0}(Y_t/\psi_t Y_0)^{\gamma}\exp(\lambda(u_t - u_0)), \tag{25}$$

where Y_t is per capita income in period t and i is the cohort. Then, the present value of the stream of service costs (PVSC) incurred by an individual born in year v is

$$\text{PVSC}_v = \sum_{t=v}^{v+L} \delta^{t-v} u_t D_{i(t-v),t}, \tag{26}$$

where $i(t - v)$ is the five-year cohort into which an individual of age $t - v$ falls and δ is a discount factor. For this calculation, I use a constant discount rate of 2.16 percent, equal to the growth rate of real GNP per capita estimated and projected over the period 1869–2100. Corresponding to equation (26), the present value of the individual income stream is

$$\text{PVINC}_v = \sum_{t=v}^{v+L} \delta^{t-v}\psi_{i(t-v),0}(Y_t/\psi_t Y_0), \tag{27}$$

where ψ_{i0} is the income of cohort i in the base year of 1970. In principle, L should be taken to be length of life, but I truncate the present value calculations at $L = 70$ to facilitate computation; the discount rate is sufficient to make the error in this approximation small. I then take the ratio of (26) to (27), normalized in 1989 to equal the share of housing in personal consumption expenditures from the *Survey of Current Business* (U.S. Department of Commerce, 1990). The lifetime share of income spent on housing, by birth cohort, is graphed in figure 7.20. The share was high for cohorts born before 1890, then dropped sharply, reaching a minimum around 1910, rose to 0.3 in 1925, and then remained between 0.2 and 0.3 until the end of the baby-boom cohorts. The share then falls steadily for cohorts after 1960. This shape can be explained by the relatively low income elasticity of demand for housing, near 0.3, and the additional effect of falling housing prices.

The housing demand equation I have estimated integrates to an explicit utility function (14), within which the utility impacts of changing income or user cost of housing can be calculated (see also Smeeding 1989). Then, the following question can be addressed: If an individual born in year t faced, instead of his or her actual stream of housing user costs, the stream of user costs that

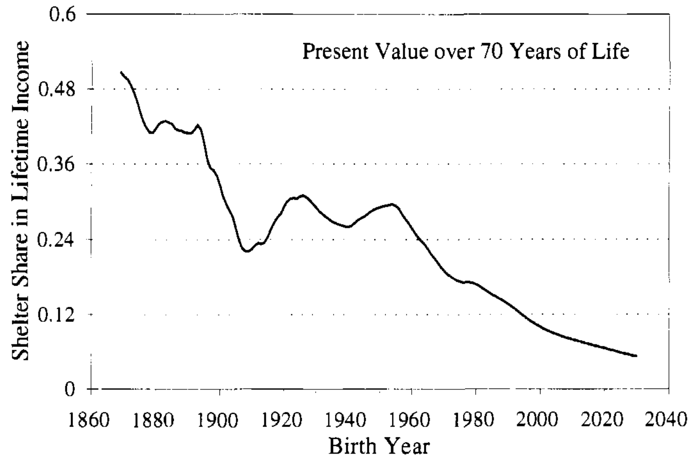

Fig. 7.20 Shelter share of income

individuals born in 1950 faced, by what percentage would income have to be adjusted (compensated) to keep the cohort-t individual as well off as before?

To answer this question, I calculate the change in income in each year necessary to compensate for the change in service cost and then take the present value of these compensating changes. For small changes, the compensation can be calculated from the total differential, yielding the crude consumer surplus formula

$$(28) \qquad \Delta\psi_{it} = \alpha_{i0}\psi_{it}^{\gamma}\exp(C + \lambda u_t)\,\Delta u_t = D_{it}\Delta u_t.$$

Substituting the expression (9) for age-specific income into the age-specific demand equation (14) and forming the present value of the compensating changes in income yields the present value of the compensation,

$$(29) \qquad \text{PVCOMP} = \sum_{t=v}^{v+L} \delta^{t-v}\Delta\psi_{it} = \sum_{t=v}^{v+L} \delta^{t-v}\alpha_i\left(\frac{Y_t}{\psi_t Y_0}\right)e_{\lambda(u_t-u_0)}\Delta u_t.$$

Figure 7.21 plots the present value of the compensation, expressed as a percentage of the present value of income, for cohorts born between 1869 and 2030. Cohorts born between 1869 and 1915 would have required a lifetime income reduction of about 0.7 percent to offset the more favorable housing user costs they faced than were faced by the 1950 cohort. Beginning in 1910, the magnitude of the compensating variation is reduced sharply, remaining at around a 0.2 percent income reduction for the 1920–40 cohorts. There are no current or future cohorts that are worse off than the baby-boom cohorts, and only minor compensating variations are required for cohorts after 1980.

To provide some perspective on the calculations of compensating variations for housing cost differences, I have also calculated the percentage adjustments

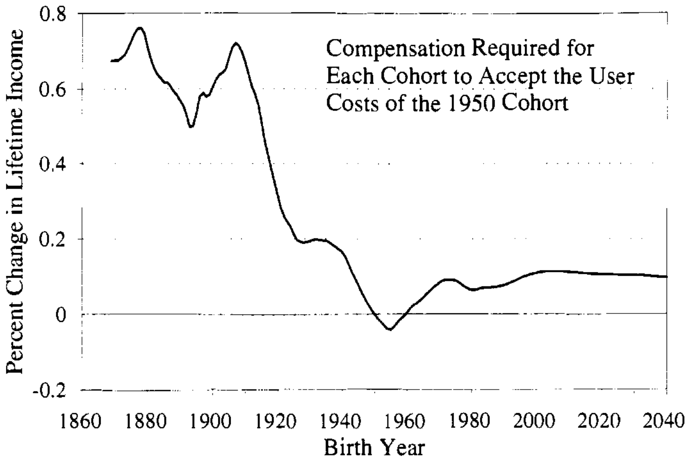

Fig. 7.21 Compensating variations

in income necessary to equate the present value of utility for different cohorts, under the assumption that all cohorts face the housing user cost series starting in 1950. The results suggest that intercohort inequality generated by real income growth dwarfs the effects of housing market variations. Thus, these calculations suggest that the policy issues arising from housing market volatility are primarily the risk exposure and ex post mistakes in life-cycle savings behavior of individuals that such volatility may cause, and insurance or other correctives for these mistakes, rather than large-scale distributional inequities between cohorts.

The compensating variation calculations could be refined further. Obvious corrections are to eliminate the truncation of the utility calculation at age 70 and to take account of individual mortality rates in forming discounted utility. Deeper issues are the treatment of bequest motives and the adequacy of the additively separable model of intertemporal utility. In fact, a strongly concave transformation of the utility function (14) prior to formation of the present value of utility is probably justified, to reflect what are likely to be relatively low elasticities of intertemporal substitution of consumption. If, in addition, the utility function is given a von Neumann–Morgenstern interpretation to assess the welfare effects of risk, then these transformations should reflect the degree of risk aversion. (As is well known, it is unlikely that intertemporal substitution and risk aversion can both be described satisfactorily by an additively separable utility function.)

7.8 Summary

This paper has developed a framework for projecting housing market prices and stocks in response to demographics and income and, from these projections, calculated the welfare effects of housing market volatility. The results suggest that cohorts born in the last baby boom and after, from 1950 on, are all in roughly the same boat, without major cohort inequities arising from housing opportunities. However, these cohorts are slightly worse off than cohorts born in 1920–40. The only cohorts that were substantially better off than the post-1950 cohorts in terms of housing were those born before 1920.

The relatively modest compensating variations for housing cost differences across cohorts may mask more serious problems caused by the effects of housing price risk on life-cycle saving and consumption levels of the elderly. Quantification of these effects will have to await further research.

Topics for further research include construction of a demographic model of household formation and control for the effects of household size on housing demand. Further work is needed on savings behavior and expectations. A promising approach is to combine macroeconomic and demographic data with the 1989 wave of the Panel Study for Income Dynamics, which contains wealth inventories in 1984 and 1989 for about 2,000 elderly households. This should permit assessment of some major open questions about behavioral response to housing variables, particularly evidence about the degree of myopia in housing decisions, about adjustments in savings in response to anticipated capital gains, and about intergenerational transfers.

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Comment N. Gregory Mankiw

In this paper Daniel McFadden offers a grand theory—or, more precisely, a grand prediction. He presents and estimates an econometric model of the housing market, and he then simulates the model into the future, given the dramatic (and largely uncontroversial) changes that are occurring in U.S. demography. McFadden predicts that real housing prices will fall about 2 or 3 percent per year for the next 112 years. When David Weil and I made a similar prediction in a paper several years ago, we were bold enough to forecast out only 20 years (Mankiw and Weil 1989). McFadden has outdone us by 92 years.

The Coming Real Estate Bust

The prediction that housing prices are going to fall over the next couple of decades is based on a simple story about supply and demand. Cross-sectional data tell us that the demand for housing is closely related to the number of adults in a household: as McFadden's figure 7.11 shows, children do not generate much housing demand. This finding implies, at the aggregate level, that the demand for housing is roughly proportional to the adult population. There is little doubt that, because of low birthrates in the 1970s, the adult population will grow more slowly in the future than it has in the past. Hence, housing demand will grow more slowly as well.

The impact of demand on prices depends, of course, on the elasticity of supply. If the supply elasticity were very large, then fluctuations in demand would not influence prices much. Yet experience suggests that this is not the case. In the 1970s, when the baby-boom generation of the 1950s was reaching adulthood, housing prices rose substantially. This experience suggests that the elasticity of supply is not very large, and that housing prices will fall when the baby-bust generation reaches adulthood.

This is the essence of my paper with David Weil. It is also, I believe, the essence of this paper by Dan McFadden. These two papers are similar in the "big pictures" they present. Yet, in their methodologies, the papers are quite different. In the most general terms, the difference between the two papers is that between structural and reduced-form estimation.

Two Approaches

The approach that McFadden takes is to estimate a structural model of the housing market. That is, he estimates the demand for the stock of housing and the supply of residential investment. He then simulates this model into the future under standard demographic assumptions. By contrast, although David

N. Gregory Mankiw is professor of economics at Harvard University and a research associate of the National Bureau of Economic Research.

Weil and I presented and were guided by a theoretical model similar to McFadden's, we did not try to estimate it. In our empirical analysis, we relied more on the estimation of simple reduced-form regressions.

As we all learned in basic econometrics, structural and reduced-form estimation each has its own advantages. Structural estimation links empirical analysis closer to a particular economic theory, which is an advantage if one believes the theory. Yet structural estimation imposes more restrictions on the data than does reduced-form estimation; any forecast from a structural model is based on those restrictions as well as on past experience. For the purpose of forecasting, one might want to avoid imposing any prior theoretical restrictions, since those restrictions are open to dispute. Thus one might prefer reduced-form estimation.[1]

In the case at hand, however, the situation is not this simple. Since McFadden's model is dynamic, forward-looking, and nonlinear, its reduced-form is complicated. It is far easier to estimate the structural model, as McFadden does, than to solve for and estimate the model's reduced form. For forecasting, therefore, it is not clear which method to prefer. One way to view the regressions that Weil and I ran is that they are approximations to the reduced-form of a structural model such as McFadden's; whether they are good approximations is hard to tell.

One might be tempted to conclude that McFadden's structural model is picking up the same phenomenon that Weil and I emphasized in our paper, since the predictions are so similar. Yet I am reticent to endorse McFadden's model as confirmation for our view, for the paper presents few model diagnostics. In particular, I would like to see how well McFadden's model explains housing prices in sample. As a crude specification test, one could examine whether this structural model does better at explaining history than do much simpler reduced-form equations. If it does better fitting the data in sample, that would provide a compelling case for the structural model; if it does worse, that would constitute a rejection.

I also think McFadden could do more with his model. For example, he could use it to explain historical fluctuations in the housing market, such as the large increase in prices in the 1970s. David Weil and I argued that this increase was driven largely by demographic changes, whereas Jim Poterba (1984) has argued that it was driven largely by changes in the user cost due to rising inflation and the nonindexed tax system. One could consider several historical counterfactuals. What would have happened to housing prices if there had been no postwar baby boom? Or what would have happened if inflation had not risen in the 1970s? One advantage of estimating a structural model of the housing market is that it can be used to answer these questions.

1. This is similar to the argument that Sims (1980) makes for the use of vector autoregressions rather than structural macroeconomic models.

The Generational Distribution

McFadden does use his model to gauge the intergenerational impact of changes in housing prices. I am somewhat skeptical about his conclusion. Comparing the lucky and unlucky generations, McFadden finds a small compensating variation: less than 1 percent of lifetime income.

A back-of-the-envelope calculation, however, suggests a much larger impact. Consider McFadden's figure 7.19. According to this figure, someone born in 1958 (like me) can expect a real capital loss of about 3 percent per year over his life. His grandfather, born in 1900, received a real capital gain of 3 percent per year. Therefore, the increase in user cost of housing (from this change alone) is about 6 percent per year. Using the conservative estimate that house value is about one year's income, one reaches a compensating variation of 6 percent of income, almost 10 times McFadden's estimate. McFadden's estimate differs from mine in part because it incorporates various macroeconomic factors that influence the user cost of housing, such as changes over time in tax rates and interest rates. It seems more natural, however, to separate the impact of housing prices from that of these other factors.

A more difficult question is what policymakers should make of all this. Here I agree with McFadden: probably nothing. Many things influence the relative income of different generations; the price of housing is only one of them. Moreover, given the importance of bequests in wealth accumulation, it is not clear how to interpret these intergenerational redistributions. It is noteworthy, however, that the generations that are hurt by the trends in housing prices are, coincidentally, also those that are hurt by the increases in Social Security in the 1970s and the large budget deficits of the 1980s. Nineteen fifty-eight was not a good year to be born.

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