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The demand for domestic services, capital services, wife's home time, and other inputs: an econometric analysis of technical and other changes affecting U.S. households, 1900-1985

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The demand for domestic services, capital services, wife's home time, and other inputs: An econometric analysis of technical and other changes affecting U.S. households, 1900-1985

by

Chiho Kim

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I. INTRODUCTION

A. Issues

Implications derived from the productive household framework are still being unpacked 20 years after Becker's 1965 article and 50 years after Margaret G. Reid presented the original conceptual framework. Although these models have been applied to better understand households decisions on health, fertility, and labor supply, no research has focused on the long-term effects of technical change in household production. This is closely related to demand for labor, especially the services of domestic servants and wife's home time, by households, and the demand for the services of household durable goods. Advances in knowledge have resulted in the price of services of (constant quality) durable goods declining which causes substitution effects in household production. Other advances in knowledge are not directly embodied in consumer goods, but they can still change the technology of household production. The general rise in the price of human time and increased market opportunities of women may have induced changes that are relatively labor-saving in the technology of household production. The implications from the productive household models go far beyond the traditional model of household demand theory in providing insights into the changes in behavior of households over the long run.

According to tradition, technical change is confined to firms and does not occur in households. However, with Becker's (1965) model of households, households produce goods and services similar to firms. As a rational behavior unit, households optimally combine and manage their resources (time and income) to produce commodities and services to maximum satisfaction (utility) subject to technology and resource constraints. In this framework, households can be the site of technical change. Households can also instigate technical change. The latter is closely associated with human capital development by the household.

If the households are productive in nature, and technical change occurs in them, how can we measure it? In economics, tools are already established for measuring technical change in firms. For empirical analyses, such methodologies require data on outputs, inputs, and their prices. This information is not available for the household sector. Therefore, we need to develop another analytical framework which can attack the measurement issue directly, or to find a promising alternative route to address the issue indirectly.

One way of attacking this issue is to focus on the demand for inputs into household production, especially for domestic services. The next step is to relate the household's demand for inputs to technical change. Technical change in the consumer goods industry lowers the prices of their services to household or changes the available technology for household production. Patenting of consumer goods is one indicator of inventive activities that may lead to one form or the other of technical change that increase consumer welfare.

The share of household expenditures on services of domestic servants has declined by 20 percentage points since 1900. We suspect that this change is due to technical change in consumer goods and other forces. Thus, attempting to explain long-term changes in the demand for domestic services is one way of indirectly explaining the effects of technical change on household behavior.

Several economic forces have been important factors in causing changes in the market for inputs used in household production, especially for domestic services. The first one is the dramatic increase in the female labor force participation rate during the last several decades. Economically, a large part of female labor force participation, is based on pecuniary purposes, i.e., maximization of the household welfare, subject to a household resource constraints. In this optimization process, households must confront the choice of doing housework themselves, employing domestics, purchasing substitute goods and services in the market, or substituting capital services for them.

Second, time-saving household appliances and nondurable goods (e.g., instant foods, efficient detergent) have become available and their real prices have fallen. Inventive activity in the industrial sector has been responsible for development of these goods. Households also must choose between purchasing time-saving goods and buying domestic services to complete labor intensive tasks.

We need to derive a model which integrates household decisions on labor supply, consumption, and production, including the demand for domestic services. For these purposes, the household production model developed in the mid-1960s by several economists (Mincer, 1962, 1963; Becker, 1965; Lancaster, 1966) is available and will provide the conceptual framework for this study.

B. Resources and Literatures

The dominant portion of existing literature on the subject of domestic services is about the socioeconomic, or demographic characteristics of these workers. Quite a few studies about the demand and the market for domestics are available. The literature is more limited on studies of technical change and how it relates to the demand for domestic services and other inputs.

Studies in sociology and allied behavior sciences have focused on the social demographic characteristics of domestics, defining them as a social class in the context of the social class structure and social mobility (Katzman, 1978; Sutherland, 1981; Martin and Segrave, 1985; Rollins, 1985). Much of their research concentrated upon the 60 year period starting right after the end of Civil War in 1865. They focus on social structure, or mobility due to the dramatic industrialization and concomitant urbanization that occurred during this period. This is a time when the status of a large share of the black slaves was changed from being slave domestics to paid or live-in domestics.

Government publications, reports, and short papers based on the surveys of domestic service workers are available. The report of the national sample survey of domestic service employees conducted by the Census Bureau in 1974 is one of most creditable sources of information (U.S. Department of Labor, 1979).[1] Some other studies, mainly based on the Current Population Survey (CPS) were published in the Bulletins of Labor Statistics, the Monthly Labor Reviews, or in the publications of the Women's Bureau (Waggaman, 1945; Wolfbein, 1945; Grossman, 1980; Crew, 1987). Information is also available from Social Security Bulletins, which were prepared mainly to evaluate the effects of social welfare programs, such as OASDHI (Old-Age, Survivors, Disability, Health Insurance) and AFDC (Alling and Leisey, 1950; Tacker,

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[1] The original purposes of the survey was to evaluate: i) the effect of the extension of the federal minimum wage and maximum hours standards under the Fair Labor Standards Act, and ii) the impact of extending the Act's provisions to domestic service employees excluded from coverage.

1970; Mugge, 1963; Duvall et al., 1982).

Some early economic studies examined the role of domestic service workers in the changing structure of the U.S. labor force and contribution to economic growth (Bancroft, 1958; Lebergott, 1964). Recently, as the concern for persons employed in lower-level occupations has risen, some valuable studies have been completed, e.g., Wool (1976), Wallace (1980). Studies about some specific female dominant occupations, such as the clerical job, give insights into related issues (Rotella, 1977).

Relatively little information exists about the demand for and supply of domestic services or domestic servants. Some studies pointed out that the markets for domestics are not highly organized and that a significant share of wage income is not reported. Stigler (1946) provides an early statistical analysis of the demand for domestic servants. Also, Mattila (1973, 1975) used cross-sectional data for Standard Metropolitan Statistical Areas (SMSAs) to estimate a simultaneous demand-supply equation model.

Since the early 1960s, the female labor force participation has increased steadily. The increased concern about child-care has resulted in some studies (Duncan and Hill, 1975a,b; Dickinson, 1975; Gronau, 1973; Waite et al., 1977).

Some studies about technical change in the household sector were completed by sociologists and home economists

(Vanek, 1978; Robinson, 1980; Kleinberg, 1983; Bryant, 1986). Overall their studies provide few insights into the technology of household production, or on the demand for domestic services, and the households' welfare. Bryant, however, provided a number of testable proposition about changes in household production over the long run. In the context of the household production model, a few studies have tried to measure household welfare (Bockstael and McConnell, 1983; Kokoski, 1987; Scoggins, 1987), but fail to integrate issues that are central to this study.

C. Purposes and Organization of the Study

There are many important issues about the household sector that have been neglected. The main focus of this study is to examine the long-term changes in household production caused by technical change and other changes in the U.S. economy. A conceptual model of household production is developed which helps organize the thinking about the change in the demand for inputs such as domestic services, services of consumer durable goods and other inputs that are substitutes and complements to these inputs when prices, income, and technical change occurs. The econometric analysis follows two routes. First, Vector Autoregression (VAR) analysis is applied to a set of 6 variables, total number of U.S. immigrants, U.S. real price of household durable goods, U.S. unemployment rate, average U.S. household income, annual real earnings of U.S. domestic household workers, and number of U.S. domestic service workers, spanning the time period 1900-1985. Second, an almost-ideal-demand-system (AIDS) is fitted to data for 1948-1985 demand for domestic services, capital services, purchased laundry and cleaning services, food purchased away from home, and wife's home time. In empirical studies, the cumulative number of patents for consumer goods is used as a proxy for technical change that might affect household decisions.

The dissertation has the following organization. Chapter 2 presents a historical overview. It reviews long run trends in: i) the immigration laws and immigrants, ii) the number of domestic service workers and their wage rates, iii) average family size and female labor force participation, and iv) patenting activity and prices of household durable goods. In Chapter 3, a model of the markets for the domestic services and other inputs is derived for individual household decisions and aggregate to the market level. Chapters four, and five report the econometric analyses, including estimation of models and implications from the results. The last chapter summarizes conclusions and suggestions for further research.

II. A HISTORICAL OVERVIEW

This chapter presents a historical overview of long-term trends in major variables that affect the demand by U.S. households for inputs into household production and the supply of domestic services and new consumer durable goods.

A. Immigration Laws and Immigrants

During the first 20 years of the 20th century, a great influx of female immigrants was a major source of supply of domestic services. The newly arrived foreign white women largely replaced the native white female domestics. Another aspect of immigration is the increasing illegal immigrants due to the continued restrictions toward the unskilled and uneducated. These illegal immigrants entered the market of domestic services. So we focus on the immigration laws and immigrants as a major potential source for the supply of domestic services. The historical trend is given in Figure 2-1.

The annual inflow of female immigrants since 1900 rose steadily and mounted to record levels, averaging 320,000 per year between 1905 and 1914, the beginning of World War I. The number sharply dropped during the War period. Another interesting fact is that during the 1910s proportionately more immigrants from Russia, Poland, Hungary, and Italy were

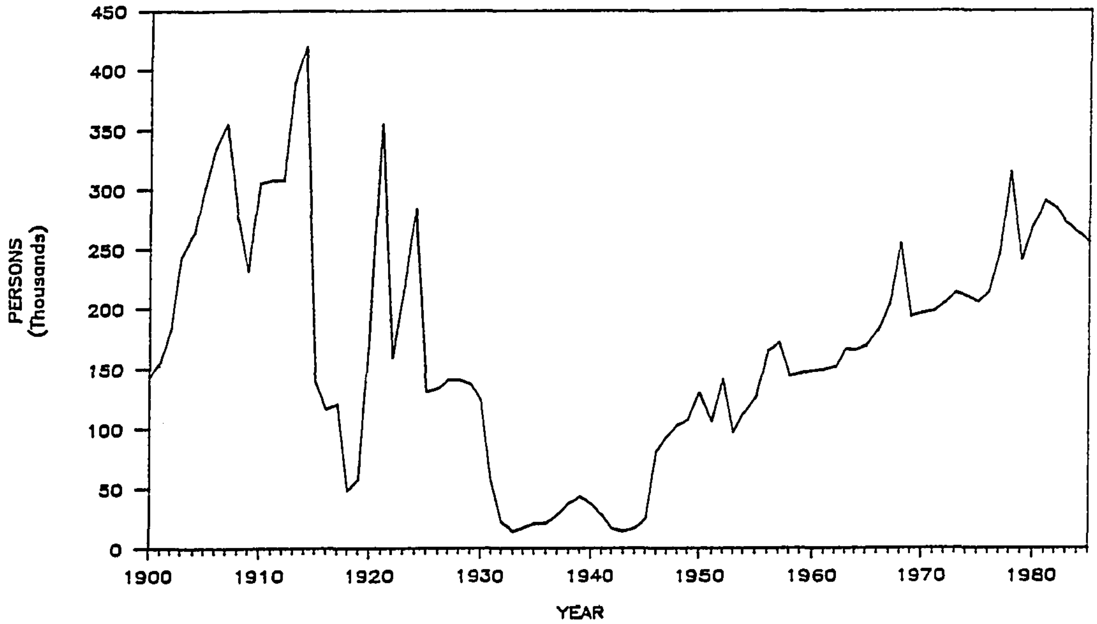

Figure 2-1. Number of Female Immigrants

entering the country than during earlier decades, and they were less inclined to be domestic service workers than the women from Germany, Ireland, and Scandinavian countries who had been in the forefront of earlier waves of immigrants. The 1900 census showed that among female employed, 60.5 % of Irish-born women, 61.9 % of Scandinavian-born women, and 42.6 % of German-born women worked as domestic workers. Russian-, Polish-, and Italian-born women, on the other hand, had relatively low reported proportion in domestic work: 20.6 % of Russian and Polish women, and 11.6 % of Italians. These attitudes continued to the their next generations. The average percent of the second generation German, Irish, and Scandinavian women in domestic service was 37.7 %, but corresponding percentage of Russian, Italian, Hungarian, and Polish was only 16.6 %.[2]

A branching line was imposed on the influences of immigration on the domestic services by the legislation of immigration law, enacted in 1921. Before that time, the United States' policy had been one of virtually unrestricted immigration. However, the era of mass immigration was effectively terminated by the legislation, which established an immigration quota system, whose effect was with certain exceptions to limit the overall number of immigrants of any nationality admitted each year, based on the percentage of

[2] For more details, see the Table 2-10 on p. 71 of Katzman (1978)..

foreign-born persons of that national origin residing in the United States as of a base census year. A revised law, enacted in 1924, reduced the quota from 3.0 % in 1921 based on the 1910 census to 2.0 %, and substituted the 1880 census as the base year, thus systematically curtailing the inflows of ethnic groups from the later immigrant sources of Southern and Eastern Europe. This fundamental reversal of American immigration policy was due to a combination of influences, including intensified opposition by organized labor to a resumption of large scale immigration, wide spread ethnic and religious prejudices against the newer immigrant group, and the near hysteria concerning the danger of imported Bolshevism or anarchism (Lescohier, 1935). The 1924 Act was to continue as the basic statutory framework of U.S. immigration policy for a period of more than decades.

Following enactment of the 1924 law, female immigration fell to a rate about 137,000 per year in the period 1925-1929, and it remained well below 33,000 per year during the depression decade of the 1930s and the World War II period.

In 1952, special preference within quota limits was provided for individuals with specialized skills or abilities. The combined effects of the 1924 law, and this constraint sharply curtailed the volume of immigration and significantly changed the composition of the later immigrant group. Except the illegal immigrants, actually no more low educated or unskilled immigrants as a potential supply source for domestics were available since the mid-1950s. This explains largely why the percentage of immigrants who are working in domestic services among total female immigrants has been continuously decreasing since the mid-1950s.

Another fact to note is the influences of illegal immigrants. Due to the continued restrictions imposed on the unskilled and less educated immigrants, large number of illegal immigrants are believed to be in the U.S. Numbers have been growing since the end of the Bracero program in 1965. There is not much reliable information about that, however, some studies reported that a large part of them are working in some simple labor-intensive sectors, such as agriculture (Torok and Huffman, 1986). Domestic service is one of them. For more information about the U.S. immigrants and their influences on the U.S.labor market consequences and references, see Greenwood and McDowell (1986).

B. The Number of Domestic Service Workers

From the occupational data of the U.S. decennial censuses, and the Current Population Survey, a series on the number of domestic service workers can be constructed starting in 1900. The following discussion is based on the decennial censuses and the Current Population Survey starting in 1900. For convenience, the whole time period is divided into several subperiods. See Table 2-1 and Figure 2-2.

1. The Civil War to the World War I

The period between the end of the Civil War (1861-1865) and the World War I (1914-1918) was one of very rapid industrialization and concomitant urbanization. From 1870 to 1910, the number of domestic workers increased steadily -- nearly doubling --. The growth was undoubtedly increased by high immigration rates of low skilled women. Domestic work was the only type of job available to many of the newly arrived women during this period. They often replaced other household workers, particularly native-born white women, who were leaving their jobs for a variety of reasons, such as marriage, childbirth, or work in other occupations. At the end of the Civil War, freed slaves and industrialization in the North contributed to large migration of blacks from the South to northern cities (Crew, 1987).

During 1910 - 1920, the U.S. labor force was reshaped. The number of immigrants dropped sharply, a wider range of jobs became available to women, and child labor was reduced significantly. The number of domestic servants in 1920 declined by 23 % compared to 1910.[3]

By World War I, selected manufacturing occupations -- clothing, textile, cigar and tobacco industries --,

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[3] Many observers have doubted the accuracy of the number of domestics in this period. In general, it is agreed that even some portion of the sharp decline (about 25 %) between 1910 and 1920 have been attributed to the 1910 Census overcount of women working and the 1920 undercount. For further information, see Stigler (1946, Appendix A).

Table 2-1. Sexual Composition of Domestic Service Workers, U.S., 1870-1980a

	1870	1900	1910	1920	1930
(1) Total Labor Force (1000)	12,506	29,073	38,167	41,614	48,830
(1)' Female (%)	14.7	18.3	21.2	20.5	22.0
(2) Total Domestics (1000)	853	1,579	1,851	1,417	1,998
(2)' Female (%)	.	96.6	96.4	96.4	95.5
(3) = (2)/(1) (%)	6.8	5.4	4.8	3.4	4.1
(4) Female Domestics / Female Labor Force (%)	52.3	28.7	24.0	15.7	17.8

[a]Sources: U.S. Decennial Censuses.

1940	1950	1960	1970	1980
53,011	59,643	69,643	82,897	97,639
24.3	27.8	32.1	37.2	42.1
2,412	1,539	1,825	1,217	589
94.4	94.8	96.4	96.8	95.6
4.5	2.6	2.6	1.5	0.6
18.1	8.9	7.9	3.8	1.4

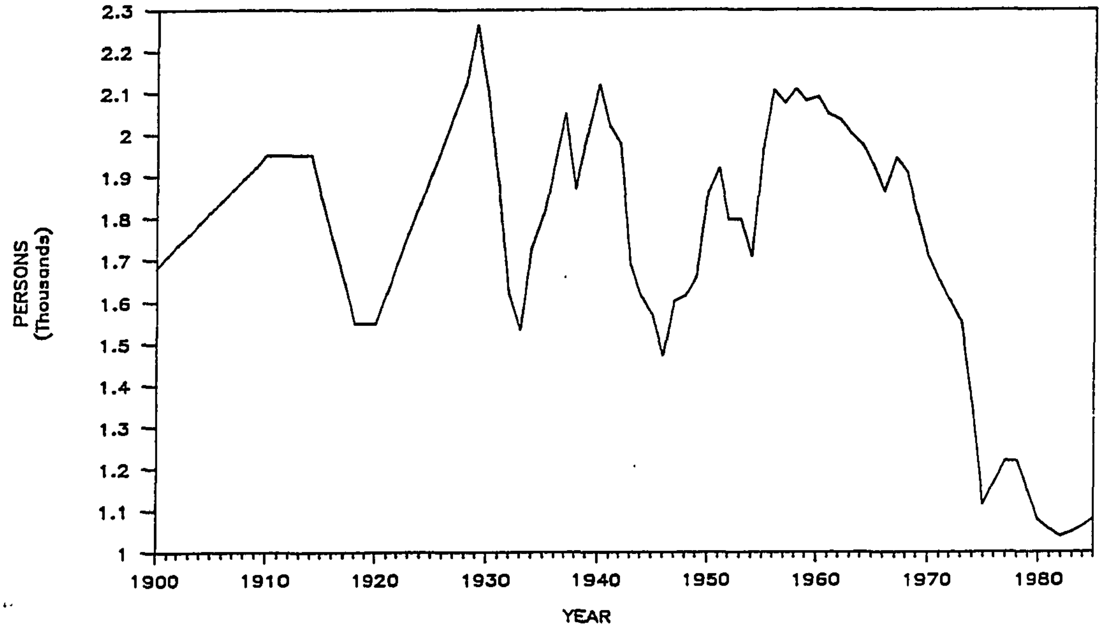

Figure 2-2. Number of Domestics

professional (e.g., school teacher), trade, and clerical occupations were available to women. Between 1910 and 1920, the largest increase in number of women workers occurred in the professional service, trade, and clerical occupations.

The number of girls (younger than sixteen) who were gainfully employed continued to decline at least after 1880. Young girls were an important source of domestic service workers in the nineteen century. Young girls ages 10 to 15 composed 9.9 % of household workers in 1880, and 9.4 % in 1900. Thereafter, as the State compulsory education laws spread, the proportion of young girls in domestic service dropped to 5.8 % in 1910, and 3.0 % in 1920.

For the demand side, after the Civil War, the rapid industrialization and accompanying urbanization of the country resulted in growing number of middle and upper income families who wanted and could afford household help. However, the family sizes decreased. The average number of private household workers per household was steadily decreased until 1920.

2. From World War I to 1960

During the four decades 1920-1960, the trend in the number of domestics shows some sharp changes. Between 1919 and the Great Depression, the number of domestic servants increased by 2.5 million. The number rebounded nearly 2.5 million. As World War I ended, men took over positions that were temporarily available to women during the War. Thus, females had to seek alternative lower-level occupations, e.g., domestic service or leave the labor market. Also, the rapid economic growth of the 1920s and low unemployment rate contributed to an increased demand for domestics.

During the Great Depression, the number of household workers decreased sharply. The number declined from 2.4 million in 1929 to 1.7 million in 1933 (about a 30 % decrease). During the post depression recovery, the number of domestics increased. The start of World War II reversed this upward trend.

During World War II, the female labor force participation rate steadily increased from 27.9 % in 1940 to 36.3 % in 1944. Women in the civilian labor force replaced males who were serving the military service. The increased female labor force participation during World War II is associated with a large increase in the number of domestics and rise in their wage rates. (See the big jump in wage rates during this period in Figure 2-3.)

At the close of World War II, the U.S. economy grew slowly. For the low-skilled women, wage and employment opportunities deteriorated. Also, the number of female immigrants jumped (up in 1946), mainly due to the special nonquota provisions for war brides, and certain refugee groups.

3. From 1960 to the present

The two decades since 1960 were characterized by rapid U.S. employment growth. The increase in the female labor force participation rate is notable during this period. On the other hand, the number of domestics has steadily decreased since 1960. The number of domestics for the early 1980s was about one-half of the 1959 number. Several factors contributes to these trends.

Since the 1960s, employment opportunities for women have expanded and schooling completion levels of women, especially of black female, have increased. The average years of school completed for black female increased from 8.8 years in 1960 to 12.0 years in 1980 (a 40.0 % increase). For white women, the average years of school completed increased only 1.3 years from 11.2 years in 1960 to 12.5 years in 1980 (an 11.6 % increase). Women with higher schooling levels have been employed primarily in occupations that pay higher wages than for domestic workers. The percentage of private household workers among all employed women have been decreased steadily from 8.9 % in 1960 to 2.5 % in 1980. These two factors have contributed to a decreased share of women being employed as household workers.

During this period public assistance programs became available. This raised the opportunity cost of many women and the availability of public assistance programs for poor families, such as OASDHI, AFDC, and job (skill) training programs since the mid-1960s has undoubtly reduced the supply of labor to low skilled jobs (Tacker, 1970; Duvall et al., 1982).

C. The Characteristics of Domestic Service Workers

Today, domestic service is overall viewed as a more and more low-skill, low-status occupation. Young women, particularly black women are shying away from it. Black domestic female workers, who tend to be older cleaners or servants, and white domestic workers, who tend to be young baby-sitters, often receive less than the minimum wage. Some characteristics of domestic workers are reviewed.

1. Sexual distribution

A century ago, private household work was the predominant occupation of all gainfully employed women and girls 10 years old and over. In 1870 domestic work accounted for more than half of all female wage earners. More details about the sexual composition over time are given in Table 2-1.

There are two facts that must be noted. First, the proportion of domestics who are females is relatively stable over time, around 95 %. This implies that domestic service is largely a female occupation. Secondly, as more and more women were employed in professional (school teacher, nurse, etc.), clerical, manufacturing, and sales jobs, private household workers accounted for a declining share of the female in the labor force (see Table 2-1). Since World War II baby boom ended, the proportion of employed women who are employed as domestics has fallen rapidly.

2. Racial and ethnic composition [4]

Through the whole period, the low social status, the absence of vocational or educational requirements, and the discrimination against women in many lines of employment may explain the racial and ethnic compositions of domestic service workers. Historical summary statistics are given in Table 2-2.

The trends in the proportion of foreign-born whites and of blacks employed as domestics given in Table 2-2 reflect the well known trends in immigration and the northward migration. Before 1950, the immigrants from the European countries held relatively high proportion of the domestics. This trend was discontinued due to the stricter restrictions on immigration. Since the immigration law enacted in 1954, the potential supply of immigrants for domestics was terminated, so that the percentage of foreign-born whites decreased thereafter.

The proportion of domestics who are black has increased since 1900. This may be explained by the fact that the generally depressed economic conditions in the labor markets

[4] Since domestic service is predominantly female, this section actually focuses on the female domestics.

Table 2-2. Nativity and Race of Female Domestics, U.S., 1900-1980[a]

	1900	1910	1920	1930
			Percentage	
Native-born Whites	42.8	37.4	36.8	37.7
Foreign-born Whites	23.0	21.4	17.4	14.7
Blacks	34.0	41.0	45.6	47.4
Others	0.2	0.2	0.2	0.2
Total	100.0	100.0	100.0	100.0
	% of females of each nativity			
Native-born Whites	22.3	15.0	9.6	10.4
Foreign-born Whites	42.5	34.0	23.8	26.8
Blacks	41.9	39.5	44.4	54.9
Others	24.8	22.9	22.9	19.4
Total	28.1	24.0	15.7	17.8

[a]Sources: U.S. Decennial Censuses.

1940	1950	1960	1970	1980
Distribution				
52.6	41.6	45.9	45.5	55.2
47.1	58.0	54.1	53.1	42.7
0.3	0.4		0.4	2.1
100.0	100.0	100.0	100.0	100.0
in Labor force who were Domestics				
11.0	4.0	4.1	2.1	0.8
56.4	41.3	34.3	15.9	5.0
16.7	12.0			
18.1	8.9	7.9	3.8	1.4

discouraged the Northward migration and increased the competition by white women for jobs as household workers. In 1910, about 90 % of black workers were still in the South and nearly three-fourths were confined to the two traditional black occupations, farming and menial service activities. The black' migration increased largely with industrialization after World War I (Crew, 1987). In general, throughout the whole period, the blacks' percentage remained relatively stable. After a peak in the 1950s, the blacks' portion has been decreased. As we have observed in the first section of this chapter, the steady decrease of domestics since 1960 was explained by both a slackened demand and a diminished supply. The exodus from this occupation was relatively more pronounced among blacks than among whites. Along with the advent of smaller families, continued improvements in household technology eliminated a lot of time-consuming household chores that had primarily been done by black domestics. The only type of domestic services that needed the outside help might be child-care, but this was largely taken over by young white females. At the same time, along with the large expansion of employment opportunities, increased educational attainment, and higher availability of public assistance may have sped up the departure of black women from this field. Consequently, black domestics were likely to be older cleaners or servants, white domestics, young baby-sitters.

The effects of social attitudes and occupational requirements are documented by a comparison of ratios of domestics to all women in the labor force, given in the low half of Table 2-2. In 1900, this ratio was almost twice as high for immigrants and blacks as for native-born white females, and it is three times as high for blacks as for whites in 1980. The fact that during the period of mass immigration, the ratio for foreign-born whites was high can be matched with the fact that the immigrants were a major resource of domestics.

D. Real Wage Rates of Domestic Service Workers

A detailed study of the movements of domestic workers' wages and hours working would be of great interest. However, it is difficult to find reliable information, because domestic service is the one very large occupation whose wages have never been significantly affected either by employee or employer combinations or social legislation, and the market is not highly organized. Such circumstances severely restrict us in evaluating the economic status of the workers and in investigating the market behaviors. The historical trend is given in Figure 2-3.

In the early decades of this century, earnings in domestic work were competitive with earnings in the other female unskilled and semiskilled occupations, but were below wages in professional, clerical, and skilled work. The

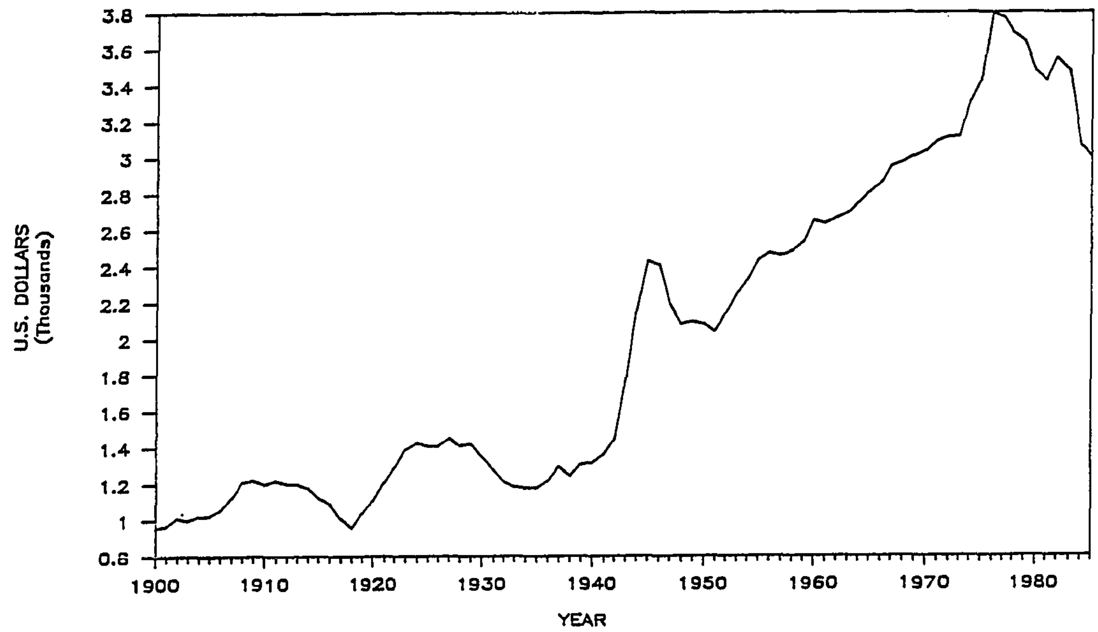

Figure 2-3. Real Wage Rate of Domestics

earnings gap between domestics and others has been getting bigger since the late 1940s. This trend accelerated after the 1960s, because labor productivity in other occupations was growing relatively fast, and domestic service a job least preferred, opened to workers with little schooling and skill.

The pattern and extent of the geographical differentials in domestic servants' earnings existed until the mass immigration and the northward migration of the 1950s. According to the 1940 census, the mean earnings of domestics in the North is more than two times higher than in the South, in the West it is about two times higher than in the South, and in the North Central it is 1.5 times higher. Also within regions, the community size and ethnity seem to explain some of the differences. In larger cities, earnings are larger than in smaller cities; and earnings decrease as the percentage of domestics who are non-white increases. In the case of domestics, differences in costs of living are not important consideration for geographical mobility because large portion of domestics receive food and lodging from their employers. Also, the receipt of room and board as a means of partial payment for domestic services helps to explain why wages paid are so low.

Although domestic services may seem like a homogenous occupation, some jobs require more skill than others, and the greater the skill or specialization involved in work, e.g., cooks, the higher is the wage. Many of these skills have become obsolete as new goods have become available in the market and new technology has been employed in household production, e.g., labor saving large appliances.

Since 1960s, the educational attainment of black female has been increasing faster than white females. Higher schooling levels are associated with an expansion of job opportunities and high wage rates. Individuals who continue to work as domestic servants continue to be individuals who have few other employment prospects.

E. Average Family Size and Female Labor Participation

The trends of family size and the number of children per household and female labor force participation are important phenomena for understanding the primary interest of this study.

The size of family has been decreasing steadily since the beginning of this century (from 4.8 members in 1900 to 2.8 in 1985). The rapid industrialization, the increasing female labor force participation, and the migration from the rural area (Agriculture) to the urban area (Industry and Service sectors) changed the traditional large family structures. Also the increasing single families might have sped up the trend.

The number of children per household has more dramatically decreased than the family size except the post

War baby boom period (from 0.6 children ages 0 to 5 per household in 1900 to 0.2 in 1983). The influences and associations of the number of children per household with other variables, such as the demand for domestics and female labor force participation are much stronger than those of the family size. The rearing of children is a very labor intensive activity in the household production. Some time-saving products for rearing baby might have reduced the labor intensivity. However, since modern couples are concerned about the quality of children rather than the quantity, the rearing of children still remains as a highly time-intensive activity, and plays a key factor that explains the behavior of the demand for domestic services and labor force participation for married women.

The FLFPR (Female Labor Force Participation Rate) stayed at a relatively stable level until the 1930s. During World War II, it arrived at a peak level (36.3 % in 1944), as the female labor force filled the shortage of the male labor force. The FLFPR dropped temporarily during the baby boom period, but it has increased continuously. Today more than half of the women labor force are working for the labor income. The increasing trend for the married women with children is more remarkable. In the late 1940s, the labor force participation rate for women with children ages 0 to 6 was only around one third of the total FLFPR. Today there is very little difference between the two rates. These phenomena may be caused by some typical factors, such as the decreasing family size and the number of children per household, improvements of technology in household production, the increasing female schooling, etc. The historical trends are given in Figures 2-4, 2-5.

F. Patenting Activity and Household Durable Goods Prices

It is generally believed that the technological progress in producing the labor-saving household durable goods has been growing steadily since the 1930s. Along with the mass production to meet the increasing demands for the household durable goods, such technological progress contributed to decreasing their prices. With lower costs, the increased stock of time-saving household appliances resulted in a large productivity gains in the household production. It is not easy to trace such technical changes which achieved through incorporating advanced technology in the industry in the household sector. One way is to focus on the patenting activity, and the trends of the prices of household durable goods.

About 5 million United States patents have been issued since the first was granted on July 31, 1790. The Patent and Trademark Office has assembled them to facilitate such huge collection of technology literature. Patents have been "classified" (categorized) into about 400 broad technological

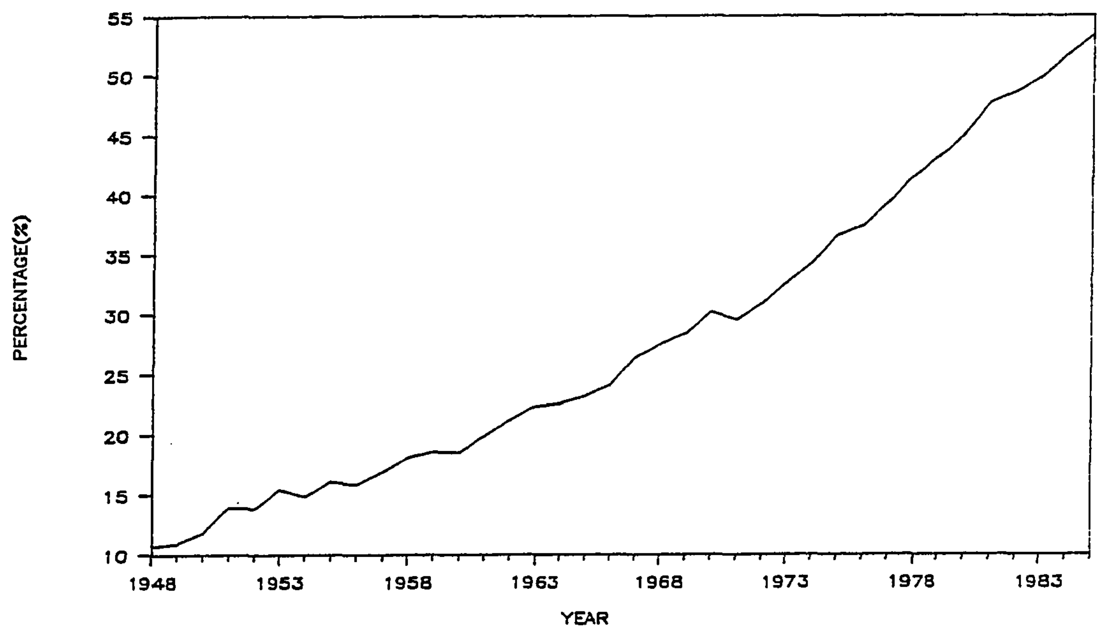

Figure 2-4. Female Labor Force Participation Rate

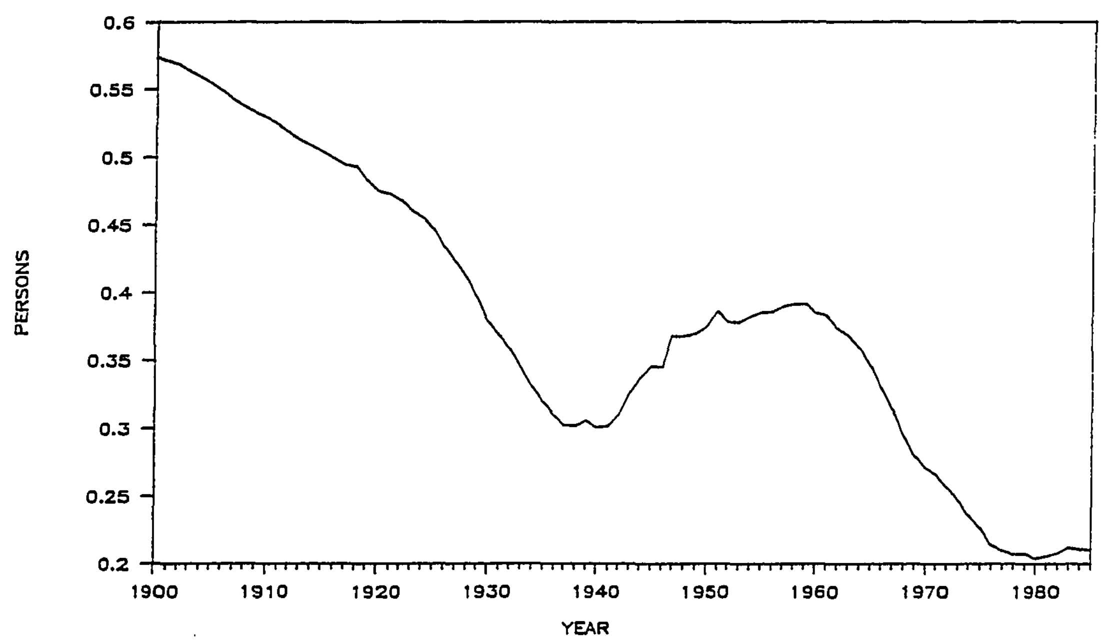

Figure 2-5. Number of Children per Household

grouping (called Classes) and over 100,000 specific technological categories (called Subclass). Together, these Classes and Subclasses form the structure of the patent system. Due to the increasing foreign inventions patented in the United States, U.S. patent activity is representative not only of U.S. technological effort but, to a large extent, of foreign technological effort as well.

Technology is the social pool of useful knowledge. The pool grows as more new technology (invention) is developed. Thus, the pool of knowledge may be represented by cumulating the patents granted. However, a large part of knowledge becomes obsolete over time as more advanced knowledge is introduced, so it needs to take account of decreasing weights over time for cumulating the patent activities.

Much inventive activity is mainly concentrated on patents for food preparation, heating and lighting, and clothes and laundry. The historical trends of patent activities is given in Figure 2-6. During the wars and reconstruction periods, the patenting are not relatively active. The trend of total number of patents curves highly upward after the World War I, and the period from the late 1950s to the early 1970s. After temporarily decreasing in the mid-1970s, it is increasing again. The patents for the consumer goods shows a little different trend. Except war periods where it showed more sharp decreases, overall it shows relatively stable cycles over time. The unweighted cumulative patent activities over all support the public's perception that there was relatively high technological progress during the decades after the World War I, and in the 1960s.

The investigation of the price of household durable goods has a couple of important meanings. That allows us to make: i) distinction between substitution and technical changes in the household production, and ii) inference of the households' demand behavior for domestic services and other related inputs for household production. The changes of relative inputs price ratio result in the changes in inputs ratio, that is the substitution between the household durable goods services and human time. The price also explains how the decision between employing domestics and purchasing the durable goods is made. The historical trend is given in Figure 2-7.

Except the two wars (World Wars I and II) and reconstruction periods, the price level was relatively stable before 1940. Some studies argued that a large part of household durable goods which are using in the modern households were introduced into the households and were in widespread use by 1940 (Lebergott, 1964: pp. 524, 528; Wilson, 1978). But since the price level was relatively higher than the cost of human time, it seem that not much substitution of the durable goods for human time has occurred. Due to the continued technological progress and the mass production to meet the increasing demand for the goods mainly caused by the increasing female labor force participation since the late

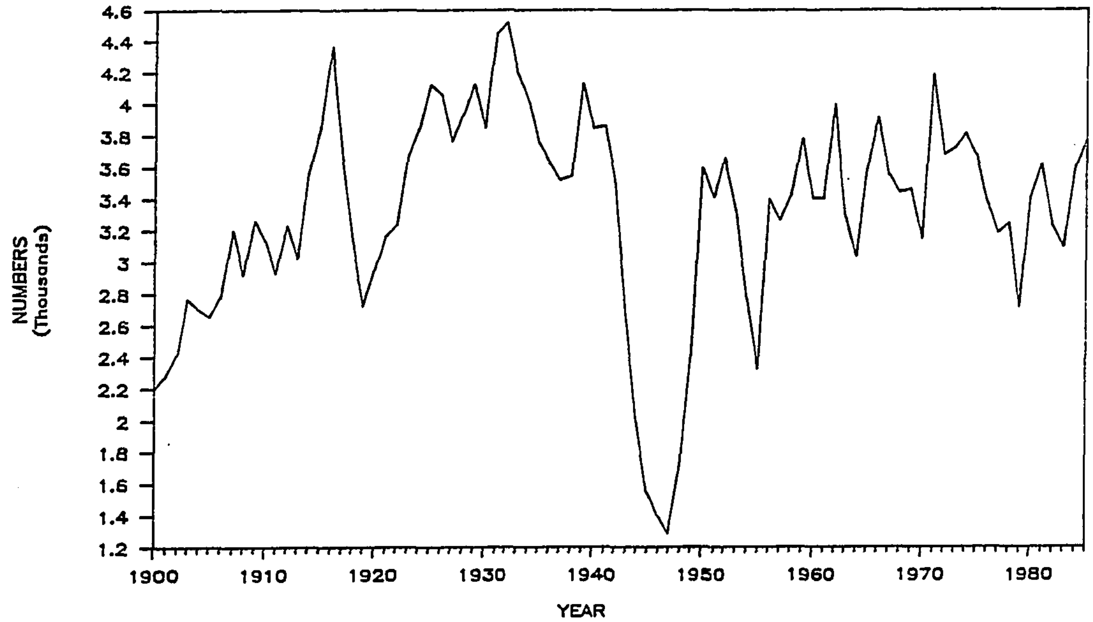

Figure 2-6. Patenting Activities for consumer Goods

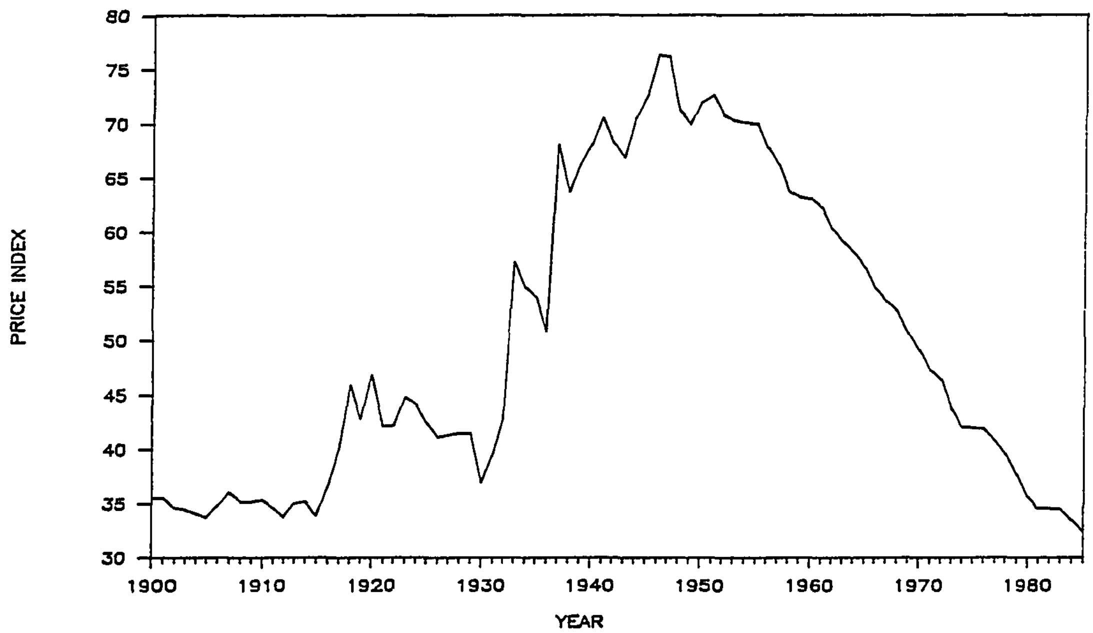

Figure 2-7. Real Price of Household Durables

1950s, the price level has decreased steadily over time. The net stock of the durable goods, such as kitchen and household appliances per household has increased nearly three times from 1950 to 1985. A large substitution of the durable goods services for female labor in the household sector has occurred in the last three decades. Such phenomenon is closely related with the dramatic increases in the labor force participation of women with children and the decreasing demand for domestics since the post war baby boom.

III. THEORETICAL FRAMEWORK

A model of household production and labor supply decisions is derived. Microdecisions are aggregated to obtain market demand functions for inputs used by the household and a market supply function for domestic service. Each household is assumed to make consumption decisions based upon utility maximization constrained by technology of household production, household income received, and endowments of adult human time.

In the first section, the model of household production is reviewed. In the succeeding section, the effects of changes in the price of services of household durable goods and technical change in the household on the demand for domestic service and nonhuman capital services are considered. In the third section, the qualitative effects of different economic forces on supply and demand for services of domestics and on the demand for goods and services that are substitutes for and complements to domestic services in household production are examined. In the last section, market demand and supply curves are obtained by aggregating of domestic services by aggregating over individual household decisions.

A. Household Production Model

After the early work by Margaret G. Reid (1934), the role of the household as a productive decision-making unit, was neglected until early 1960s. During the interim, labor economists modeled household decisions in the pure consumption model (i.e., leisure-labor model for labor supply), but they have not been concerned about the role of "human time" for household production.

In the mid-1960s, however, a number of economists began to apply methodological tools developed for the theory of the firm to the long neglected area of non-market productive activities of the household sector and to reexamine the economics of the household sector (Mincer, 1962, 1963; Becker, 1965; Lancaster, 1966; Muth, 1966). The major new insights provided by the so-called "new home economics" or "household production model" are that household activities are productive in nature and that they involve the use of "human time" as an important input of production. The result has been systematic incorporation of the cost human time into a number of non-work (or non-market) activities. With insights gained from the household production model, the scope of research to explain the various behaviors of households has been extended to decisions on fertility, health, education of children, recreation, and others.

Since the formal treatments by Mincer and Becker, the household production model has been widely used in microeconomics, especially in consumer demand theory, and in labor economics where it has experienced extensions and modifications (Gronau, 1977; Pollak, 1985).[5] Advancements in the econometric techniques have helped to overcome some problems for empirical studies done during the early stage of development of the model.[6]

B. Invention in Consumer Durable Goods Industry

Inventions in the household durable goods industry cause two effects in household production: i) a fall in the prices of durable goods and the prices of services of durable goods, and ii) changes in technology of household production.

A fall in input prices causes substitution effects among goods and services in household production and income effect (output effect), holding household's preferences and technology of production constant. Some of the new consumer durable goods also cause the production map to change. Here the attention focuses on the effects of this type of change on

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[5] Two issues of the Journal of Political Economy (81(2), part II (1973), and 82(2), part II (1974)) are entirely devoted to this topics as part of another issue (84(4), 1976). They contain excellent bibliographies as well.

[6] Statistical advancements here denote largely the development of estimation techniques using limited-dependent and qualitative variables, and solving selection bias problems. For more details, see the books, Maddala (1983), and Amemiya (1985).

demand for services of domestics, of consumer durables, and on related household inputs.

For firms, the rate of technical change is generally identified with the proportionate shift in the production function. This approach which has been taken over by the neoclassical economists was clearly developed by Hicks (1963). More development and modifications can be found in Solow (1957), Kendrick (1961), and Denison (1962). This approach requires explicit knowledge of the production function and quantities of inputs and outputs.

Graphically this approach is illustrated in Figure 3-1. If 1 and 2 are representative isoquants (for simplicity, constant returns to scale is assumed) for an aggregate production in successive time periods, the rate of technical change is measured as a/(a+b) (Stigler, 1961). Empirically, the measure is unambiguous only if the capital-labor ratio does not change. Otherwise, it is necessary to determine how much of the change is due to substitution along the known production frontier and how much to technical change. This requires knowledge of the production function. For example, as shown in Figure 3-1, a movement from points A to B represents different amounts of technical change depending on whether the production function is represented by isoquants 1 and 2 or 1' and 2'.

The Divisia index of technical change can make the distinction between substitution and technical change (Solow, 1957; Gollop and Jorgenson, 1980). It nets out any change that is due to movements along the isoquant by weighting these changes by their marginal products, which are approximated by factor prices in competitive markets. This is illustrated in the Figure 3-2. If the isoquants are represented by 1 and 2, the movement from A to B can be decomposed into the movement from A to C (substitution) and the movement from C to B (technical change). Empirically, this is measured by approximating the isoquant by its tangent at the initial point, which should equal the relative input price ratio. Technical change is thus measurable as c/(c+d). However, it should be noted that this measure is not valid if the production function is not differentiable, and the approximation will be reasonably good as long as the capital-labor ratio has not changed substantially between periods.

In practice, the traditional measure of technical change can not be employed for household production, because data are missing on output quantities. The lack of such information makes it difficult to summarize the type (e.g., Hicks neutral) or extent of technical change in household production. It is very probable that a significant share of technical change in household production is "embodied". The embodied technical change appears in new "consumer" (durable) goods that households purchase and later used in production. Thus, a large part of embodied technical change can be observed through changes in demand for goods and services. The

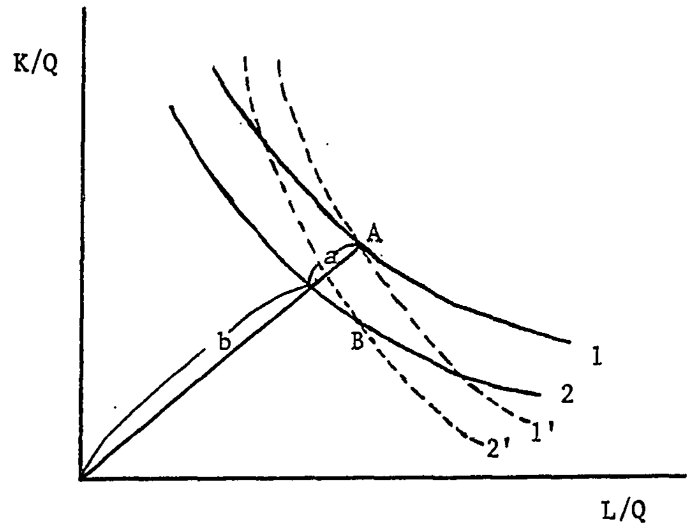

Figure 3-1. Technical Change without Substitution

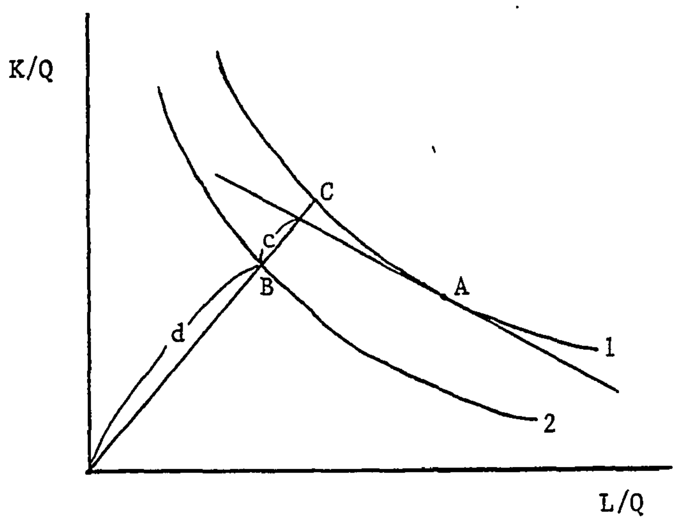

Figure 3-2. Technical Change with Substitution

"disembodied" technical change in household production can be approximated using a proxy variable which represents the general growth of inventive activity associated with consumer goods. Human capital development by households can change input-output relationships. This species of technical changes in household production may not be very significant, because household production technology is controlled largely by the "rules that are part of the shared knowledge of the culture", not by household specific knowledge.

In his seminal work, Schmookler (1966) criticized the conventional measure of productivity and attempted to demonstrate the importance of demand as a determinant of inventive activity which is a major source of technological progress. It is interesting to note his insights. A large part of the following paragraph comes from his book (1966, pp. 1-17).

Technology is the "social pool of knowledge" of the industrial arts. Any piece of technological knowledge available to someone anywhere is included in the pool. The portion of existing technology a people commands is called the nation's technological capacity. The rate of growth of a nation's technological capacity depends jointly on the rate at which it provides new technology and the rate at which it disseminates the old. We call the rate at which new technology is produced in any period the rate of technological progress, and the rate, at which technology in existence is disseminated, is called the rate of replication. Hence as defined here, an element of technology affects the rate of technological progress only once and only at one point on the globe, but it may enter the rate of replication at an indefinitely large number of places and over an indefinitely long period.

The economic return to any investment in either technological progress or replication comes only when the resulting knowledge is used. Technological knowledge may be used to produce either more knowledge or ordinary goods and services. A method of producing a given good, services or knowledge is a technique. When a household produces a good or service or uses a method or input that is new to it, it makes a technical change. Therefore, the next problem is how to define and measure the social pool of knowledge for the household sector.

Using the patent statistics, we might generate a proxy for the social pool of knowledge and "disembodied" technical change in household production. Patenting activities are regarded as an indicator of technological progress, and a cumulative summation appropriately weighted is a proxy for replication. Together these two factors form the technological capacity for the household production.

C. Household Decisions on Allocation of Resource

Using the household production model suggested by Gronau (1977), a static model is developed for analyzing the determinants of the demand for female labor in household production, for services of domestic servants and durable goods, and for related inputs, and for the supply of labor by adults (mainly by wife).[7]

Consider a single-person household. (The typical two adults or multiperson cases would be easily extended.) To explain household decisions on resource allocation, the household is assumed to behave as if maximizes utility subject to constraints on human time, income, and household production technology. The household utility function is assumed to be a monotone twice-continuously differentiable, strictly concave function:

$$U = U\ (Z,\ T_L) \qquad (3\text{-}1)$$

[7] The choice of household production function between Becker's model and Gronau's model seems not to be crucial. However, the distinction between leisure and work at home which is a major difference between the two approaches becomes important when nonmarket (nonincome related) time is the focus of analysis. Another reason for adopting Gronau's model is that it focuses more on production than Becker's model. Becker's model does not really deal with household production in the common sense of the term. It deals with consumption technology, but has little to say about home production. Theoretically, Gronau's model is relatively free from the assumptions about utility or production function, such as weak separability of household utility (or production), and constant returns to scale of household production function. These assumptions are frequently criticized in Becker's model.

where $Z = (Z_M + Z_H)$ is goods and services that are purchased in the market (Z_M) or produced at home (Z_H). Z_M and Z_H are assumed to be perfect substitutes. T_H represents leisure time. Household production requires inputs of own time (T_H), or/and employed household workers time (T_D) and nonhuman capital services. Because of human capital differences (e.g., schooling), productivity differences between T_W (skilled labor) and T_D (unskilled labor) are assumed to exist. So they are indexed separately.

An individual's time endowment is assumed to be allocated to three uses:

$$T = T_L + T_W + T_H \qquad (3\text{-}2)$$

where T_W is wagework time (others are already defined). The technology of the household production is represented by the twice-continuously differentiable, strictly concave asymmetric transformation function:

$$Z_H = f(T_H, T_D, K; \delta) \qquad (3\text{-}3)$$

where Z_H is household production, K is capital input, and δ is a vector of exogenous shift variables, such as age, schooling, and number (stock) of children at home and technology index. The income (budget) constraint is given by:

$$W_f T_W + V = P_{Z_M} Z_M + W_D T_D + P_K K \quad (3\text{-}4)$$

where V is nonwage income, P_{Z_M}, P_K are prices of Z_M and K, respectively. If $T_W > 0$, then equations (3-2) and (3-4) can be combined into a full-income (F) constraint:

$$F = W_f T + V = W_f(T_H + T_L) + P_{Z_M} Z_M + W_D T_D + P_K K \quad (3\text{-}5)$$

The Lagrangean equation for maximization of household utility (3-1), subject to the household production function (3-3), and full-income (3-5) is:

$$L = U\{Z_M + f(T_H, T_D, K; \delta), T_L\} + \lambda\{W_f T + V - W_f(T_H + T_L) - P_{Z_M} Z_M - W_D T_D - P_K K\}. \quad (3\text{-}6)$$

The necessary conditions for interior solutions are:

$$\partial L/\partial T_L = \partial U/\partial T_L - \lambda W_f = 0 \quad (3\text{-}7)$$

$$\partial L/\partial T_H = [\partial U/\partial Z][\partial Z/\partial Z_H][\partial Z_H/\partial T_H] - \lambda W_f = 0 \quad (3\text{-}8)$$

$$\partial L/\partial T_D = [\partial U/\partial Z][\partial Z/\partial Z_H][\partial Z_H/\partial T_D] - \lambda W_D = 0 \quad (3\text{-}9)$$

$$\partial L/\partial Z_M = [\partial U/\partial Z][\partial Z/\partial Z_M] - \lambda P_{Z_M} = 0 \quad (3\text{-}10)$$

$$\partial L/\partial K = [\partial U/\partial Z][\partial Z/\partial Z_H][\partial Z_H/\partial K] - \lambda P_K = 0 \qquad (3\text{-}11)$$

$$\partial L/\partial\lambda = W_f T + V - W_f(T_H + T_L) - P_{Z_M} Z_Z - W_D T_D - P_K K = 0. \qquad (3\text{-}12)$$

Assuming that elements of δ are not current household choice variables, equations (3-7) - (3-12) give a set of structural equations that can be solved (locally) for household rules, the derived demand for household inputs and supply of labor equations:

$$X = X(W_f,\ W_D,\ P_{Z_M},\ P_K,\ V,\ \delta), \qquad (3\text{-}13)$$

where $X = [T_L, T_H, T_D, K, Z_M]$. If some optimal choices are at corners rather than interior solutions, equation (3-13) as well as some equations (3-7) - (3-12) must be modified appropriately. This will occur, for example, when the wife (husband) has zero hours of wage work, or is retired.

Selected comparative static results and properties of this model are presented. First, the effects of a change in nonwage income, V is:

$$\partial T_H/\partial V = 0,$$

provided $T_W > 0$, $\partial T_L/\partial V > 0$, and $e_{T_L F} = [\partial T_L/\partial F][F/T_L] > 0$

i.e., leisure time is normal (Gronau, 1977). Also,

$$\partial T_W / \partial V = -\partial T_H / \partial V - \partial T_L / \partial V = -\partial T_L / \partial V < 0.$$

However, if $T_W = 0$, then $\partial T_H / \partial V$ may not be equal to zero. Graphically, these relationships are given in Figure 3-3.

Second, let there be an increase in the real wage rate (W_f / P_{Z_M}). If the person works in the market, a change in wages affects both the rate of substitution between leisure time, T_L, and goods, and "profitability" of household production. The increase in wages lowers the price of household produced inputs in terms of time, thereby, making household production using his (her) own time less profitable and inducing substitution of Zs for leisure time. This change will, therefore, unambiguously reduce housework time, T_H, while its effect on T_L is indeterminate. If the substitution effect (the movement from e to f in Figure 3-4) is smaller than the income effect (the movement from f to g in Figure 3-4), then $\partial T_L / \partial W_f > 0$. The household's labor supply to the market (T_W) depends on the extent of the decrease in T_H and on the changes in T_L, but probably $\partial T_W / \partial W_f > 0$, provided the income effect is not too strong. Also, the increase in wage rate causes substitution of purchased labor (T_D) and capital (K) for housework time through the decreases in their relative prices $(W_D / W_f, P_K / W_f)$. The effects are graphically presented in the Figure 3-4.

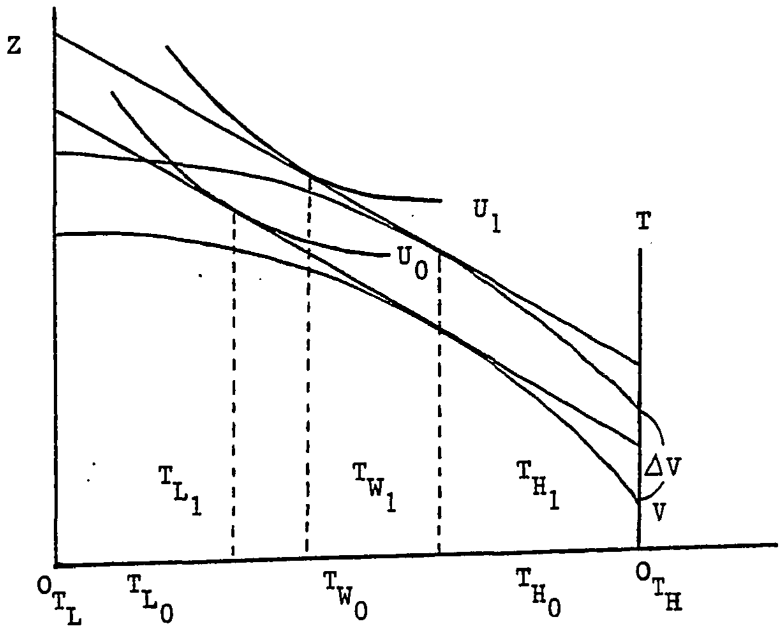

Figure 3-3. Effects of Increase in Asset Income, V

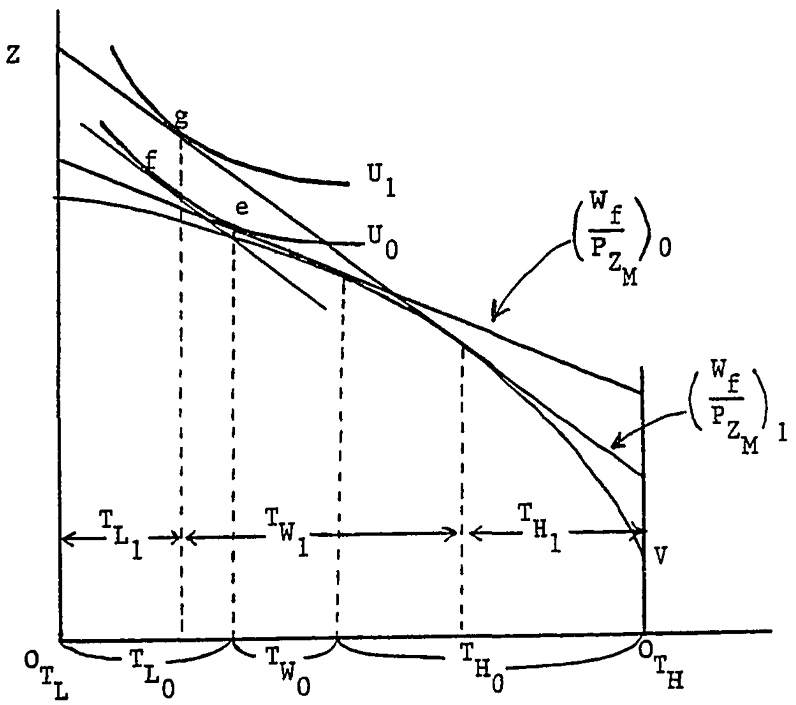

Figure 3-4. Effects of Increase in Female Wage, W_f

Third, a change in the household technology parameter δ may affect household behavior and household welfare. It is impossible to predict the implications of this change without specifying the exact consequences of the change in δ (i.e., changes in production function f(.)) and general consumption behavior. However, in the limited sense, we expect that an increase in individual's schooling to raise his (her) wage and to enhance the efficiency of household production. The gain in production efficiency from schooling seems unlikely to be neutral in its effect on the shape and location of the transformation curve and on resource saving. Furthermore, enhanced production efficiency implies increased real income and consumption of home commodities, holding resources constant. The increased consumption absorbs some or all of the saved resources. The net effect on the household time uses, and purchased inputs is *a priori* ambiguous.

Finally, the presence of children can be expected to change the marginal rate of substitution between pairs of some inputs (Gronau, 1977). When the model is extended to two-adults households, the presence of young children may raise the marginal rate of substitution between wife's and husband's housework time in producing home goods, and therefore, reducing wife's income-related labor and leisure. The human time intensity of children declines as they grow older, especially after entering school, and capital service may become more highly substitutable for parents' household labor.

D. The Market for Inputs Used in Household Production

In this section, aggregate demand functions are obtained for inputs used in household production -- wife's home time, domestic services, capital services, and related inputs and labor supply. These aggregate demand and supply functions are obtained by assuming that individual household behavior does not affect the prices that it pays for inputs or services for labor services and then aggregating over the optimal decisions of individual households.

Deriving the model for the market causes aggregation problems: i) aggregation of commodities, and ii) aggregation over individual households. The aggregation problems occur in many fields of economics, particularly in macroeconomic model analysis. The aggregation of commodities can be justified by the Leontief-Hicks composite commodity theorem (Leontief, 1936; Hicks, 1936). The aggregation over individual households is one of the oldest, but still one of most common assumptions in formulating aggregate economic forces directly from the microeconomic behavior. Some suggestions to justify the aggregation over individuals are given by some studies (e.g., Brown and Deaton (1972)), however, they are not complete.

Let us assume there are two types of households: (1) N households with females (wives) who have low schooling levels and supply domestic services and (2) N* household with females with high schooling levels and demand the services of domestic servants. Further, it is assumed that type (1) households do not simultaneously supply and demand domestic services.

For the household with low schooling levels, the aggregate demands for leisure, home time, capital services, other market purchased commodities and services, and labor supply are obtained by aggregating the individual household's optimal decisions (3-13):

Leisure time: $$T_L^D = \sum_{i=1}^{N} T_{Li}(W_D, P_{ZM}, P_K, V_i, \delta_i)$$

Home time: $$T_H^D = \sum_{i=1}^{N} T_{Hi}(W_D, P_{ZM}, P_K, V_i, \delta_i)$$

Domestic services: $$T_D^D = 0$$

Capital services: $$K^D = \sum_{i=1}^{N} K_i(W_D, P_{ZM}, P_K, V_i, \delta_i)$$

Market commodities: $$Z_M^D = \sum_{i=1}^{N} Z_{Mi}(W_D, P_{ZM}, P_K, V_i, \delta_i)$$

Labor supply: $$T_W^S = \sum_{i=1}^{N} (T - T_{Li}^D - T_{Hi}^D) = NT - T_L^D - T_H^D.$$

The aggregate decision functions for the households with high schooling levels can be similarly obtained:

Leisure time: $T_L^{D*} = \sum_{i=1}^{N^*} T_{Li}^*(W_f, W_D, P_{ZM}, P_K, V_i^*, \delta_i^*)$

Home time: $T_H^{D*} = \sum_{i=1}^{N^*} T_{Hi}^*(W_f, W_D, P_{ZM}, P_K, V_i^*, \delta_i^*)$

Domestic services: $T_D^{D*} = \sum_{i=1}^{N^*} T_{Di}^*(W_f, W_D, P_{ZM}, P_K, V_i^*, \delta_i^*)$

Capital services: $K^{D*} = \sum_{i=1}^{N^*} K_i^*(W_f, W_D, P_{ZM}, P_K, V_i^*, \delta_i^*)$

Market commodities: $Z_M^{D*} = \sum_{i=1}^{N^*} Z_{Mi}^*(W_f, W_D, P_{ZM}, P_K, V_i^*, \delta_i^*)$

Labor supply: $T_W^{S*} = \sum_{i=1}^{N^*} (T - T_{Li}^* - T_{Hi}^*) = N^* T - T_L^{D*} - T_H^{D*}$.

Assuming that market prices and skilled female wage rates are fixed, i.e., $P_K = \bar{P}_K$, $P_{ZM} = \bar{P}_{ZM}$, $W_f = \bar{W}_f$[8], then the aggregate market demands for Z_M and K, and aggregate supply of skilled female labor are obtained as follows:

$$Z_M^A = Z_M^D + Z_M^{D*}$$

[8] These assumptions can be justified by the facts that households demand only a small share of new durable goods produced, and labor services of women providing skilled labor services are less than 50 % of total skilled labor services supplied.

$$= \sum_{i=1}^{N} Z_{Mi}(W_D, \bar{P}_{ZM}, \bar{P}_K, V_i, \delta_i) + \sum_{i=1}^{N^*} Z_{Mi}^*(\bar{W}_f, W_D, \bar{P}_{ZM}, \bar{P}_K, V_i^*, \delta_i^*)$$

$$= Z_M^A (W_D, \bar{W}_f, \bar{P}_{ZM}, \bar{P}_K, V_i, \delta_i, V_i^*, \delta_i^*),$$

$$K^A = K^D + K^{D*}$$

$$= \sum_{i=1}^{N} K_i + \sum_{i=1}^{N^*} K_i^* = K^A(W_D, \bar{W}_f, \bar{P}_{ZM}, \bar{P}_K, V_i, \delta_i, V_i^*, \delta_i^*),$$

$$T^{S*} = N^* T - \sum_{i=1}^{N^*} T_{Hi}^* - \sum_{i=1}^{N^*} T_{Hi}^*$$

$$= S_T^*(\bar{W}_f, W_D, \bar{P}_{ZM}, \bar{P}_K, V_i^*, \delta_i^*).$$

Similarly, the market for domestic services is obtained as follows:

$$T_D^{D*} = T_D^S$$

$$= \sum_{i=1}^{N^*} T_{Di}^* (\bar{W}_f, W_D, \bar{P}_{ZM}, \bar{P}_K, V_i^*, \delta_i^*)$$

$$= NT - \sum_{i=1}^{N} T_{Li} (W_D, \bar{P}_{ZM}, \bar{P}_K, V_i, \delta_i)$$

$$- \sum_{i=1}^{N} T_{H_i} (W_D, \bar{P}_{Z_M}, \bar{P}_K, V_i, \delta_i).$$

For this last market, taking V_i and δ_i as fixed and exogenous to current decisions, and fixed N and N*, then we can determine the market wage and quantity of domestic services, i.e., we can find W_D.

The theoretical model developed here for the markets for household inputs and labor supply can be applied for the empirical analysis. Based on the aggregate decision functions a traditional structural equations system, other descriptive analytical frameworks such as vector autoregression analysis, or a complete demand system for household inputs can be specified.

IV. A VAR EXPLANATION: DOMESTIC SERVANTS, DURABLE GOODS, PATENTING ACTIVITY, AND RELATED VARIABLES

A. Introduction

This chapter examines the long-term relationships among the major economic forces associated with the issues in this study. To search for relationships among variables is to impose a rigid structure on the relationships that are of interest. The justification for such an approach is frequently weak.[9] An alternative approach is represented by the vector autoregressive modeling methodology.

Vector autoregression (VAR) is an econometric methodology for summarizing relationships among economic variables. It has been employed to study macroeconomic time series and to make projections. It has special appeal in those areas where macroeconomic dynamic theory is unable to identify statistically the underlying structural system (Sims, 1980, 1987; Sargent, 1979, 1984). If this econometric methodology is applied to our long historical aggregate time series data, it is possible that some useful economic interrelationships among variables can be uncovered and other possible relationships can be eliminated from consideration. The

[9] Preliminary estimates of a structural model for the market for domestic services are reported in the end of this dissertation. As a whole the results using long-run time series data were reasonable and largely consistent with previous studies.

results from this approach can also be useful for constructing a structural model.[10]

This chapter examines the relationships among six key variables by fitting and interpreting the results from a six-variable vector autoregression system. The variables included in the study are number of immigrants, price of household durable goods, the unemployment rate, average household income, total number of domestic service workers, and their wage rates. Annual data from the time period 1900 to 1985 are employed.

This chapter is organized as follows. First, the econometric framework is presented. Next the empirical results from estimation are reported and interpreted. The final section summarizes the findings.

B. An Econometric Framework: Vector Autoregression

The econometric methodology adopted in this chapter was suggested in the work of Sims (1980), and has been applied mainly in the analysis of macroeconometric time analysis. Sims argued that the traditional macroeconometric analysis

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[10] Sargent (1981) argues that in a well formulated equilibrium framework based on optimizing agents who form expectations in a manner consistent with the equilibrium model, restrictions on the parameters across the equations of the VAR will be implied. The underlying structural parameters in this context are those related to preference functions and technological constraints. Note structural econometric models are not structural in this sense.

style in which model builders construct claims for a connection between their models and reality -- the style in which "identification" is achieved for the models -- is not appropriate. According to him, the identification claimed for existing large-scale model is incredible. The dynamic elements of the models are not well specified, a weak distinction exists between endogenous and exogenous variables, and expectations formations are incompletely treated.[11] Instead, he proposed the alternative of estimating an unrestricted vector autoregressions (VAR). VAR can be interpreted as the reduced form relationships that arise from macroeconometric structural models. Sims also developed a method for describing or summarizing the content of the vector autoregression from which hypotheses could be formulated.

Suppose we have time series observations on economic variables. To make the above argument more precise, we assume a linear econometric model. The structural equations can be stated as:

$$A_0Y_t + A_1Y_{t-1} + \dots + A_mY_{t-m}$$
$$= B_0X_t + B_1X_{t-1} + \dots + B_nX_{t-n} + E_t \qquad (4\text{-}1)$$

[11] This argument was also developed in some detail by Lucas and Sargent (1979), who argued that dynamic economic theory gives rise to restrictions of a very different form than those that are currently implemented or even implementable in existing computer econometric procedures. The upshot is that no good reason exists from dynamic economic theory to believe that the restrictions on existing structural macroeconometric models are even approximately correct.

where Y_t is a (p x 1) vector of endogenous variables, X_t is a (k x 1) vector of exogenous variables and E_t is (p x 1) vector of random disturbances. The matrices, A_is are each (p x p), the B_js are (p x k).

As Sims proposed, the VAR techniques are not based on a particular economic theory. Instead, economic theory is used to narrow the set of variables over which one will search for relationships. The vector autoregression model has many free parameters to be estimated. Restrictions can be imposed on the VAR, but they are not motivated directly by economic theory. They are aimed simply at forecasting performance, i.e., delivering estimators with small mean squared errors. Therefore, constructing a specific structural model like (4-1) is not very meaningful. Thus, the VAR technique permits an examination of a full range of possible interrelationship among economic variables, and the distinction between endogenous and exogenous variables is not important.[12]

If all variables are endogenous, the structural equations (4-1) can be written as a gth order VAR for Z_t [13] (for

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[12] In general, (unconstrained) VAR imposes no prior restrictions on the interactions among variables. Litterman (1981), however, suggested the use of Bayesian priors, which filter the useful signal from the accompanying noise and produces biased but mean squared error superior forecasts. The Bayesian procedure is a compromise between the extremes of standard structural specification (with highly objectionable priors) and unconstrained VARs.

[13] The lag length of the VAR is initially unspecified, but it may be determined with the aid of statistical tests, e.g., asymptotic chi-square test.

simplicity the deterministic terms, like constant, trend were omitted):

$$A(L)Z_t = U_t \qquad (4\text{-}2)$$

where $Z_t = [Y_t, X_t]'$ is an n x 1 (n = p + k) vector, A(L) is an (n x n) matrix of polynomials in the backward-shift operator, L, i.e., $A(L) = A_{.0} - A_{.1}L - A_{.2}L^2 - \ldots - A_{.g}L^g$, and U_t is an (n x 1) vector of random disturbances, each of which is independent and identically distributed with zero mean and finite variance.[14] A(L) is normalized so that the first entry of each polynomial in As diagonal is unity.

Under the assumptions about the error term U_t and equal length lag structure across the model, the ordinary-least-squares estimator (OLS) for each equation turns out to be identical with the joint conditional maximum likelihood estimator. This conclusion holds even when variance-covariance matrices Σ_U is unrestricted (Litterman, 1979). The vector autoregression system (4-2) has [n (n g + d)] free coefficients to be estimated, where g is the lag length, d is the number of deterministic components. For even moderate sizes of n and g, OLS estimation either is simply not possible

[14] Sims (1980) assumed that each of U is serially uncorrelated, with zero mean and finite variance. However, this assumption is too weak to apply the central limit theorem for normalty for large samples. For more information, see Fuller et al. (1981).

due to exhaustion of degrees of freedom or estimates have large sampling errors because the number of degrees of freedom is small. Therefore, restrictions on the number of variables and lag length for each of them must be imposed so that a reasonable number of degrees of freedom exists.

Once the As in (4-2) are estimated, we can express Z_t as a linear combination of current and past disturbances (Us) or as a distributed lag on U_t. By drawing upon the Wold moving average representations (MAR) for an autoregressive model,

$$Z_t = \sum_{s=0}^{\infty} B_s U_{t-s} \tag{4-3}$$

where B_s is an (n x n) matrix of parameters.[15]

A useful way of describing the performance of the VAR model is to examine the system's response to random shocks. This methodology was suggested and implemented by Sims (1980). Except for scaling, this is equivalent to tracing out the system's moving average representation (MAR) by matrix polynomial long division. To see that we can write the MAR as

$$Z_t = [A(L)]^{-1} U_t, \tag{4-4}$$

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[15]A finite stationary autoregressive (moving average) time series which has all roots of the auxiliary (or characteristic) equation are less than one in absolute value can be inverted to an infinite moving average (autoregressive) time series. For the inversion from a finite autoregressive representation (ARR) to an infinite moving average representation (MAR), see statistical time series analysis books, e.g., Fuller (1976).

recognize that

$$\sum_{s=0}^{\infty} B_s L^s = [A(L)]^{-1} \qquad (4\text{-}5)$$

exists, i.e., finding the B_s is equivalent to inverting the estimated coefficients of the matrix polynomial. Here we can regard the i,j-th component of B_s, $b_{ij}(s)$ as the "average" response, s period ahead, of the i-th variable, to an initial shock in the j-th variable. If the system is stable, the impulse responses will dampen out as time wares on.

The interpretation of these impulse responses critically depend upon the extent to which the random shocks that generate the responses are distinct. In the interpretations we choose to give for the impulse responses, the contemporaneous cross-equation correlation of shocks is assumed to be small, i.e., we assume the variance-covariance matrix of the residuals is diagonal. However, the contemporaneous correlation among the residuals for the different equations in the system is an epidemic phenomenon in the empirical analysis. Because it is not possible to partition the variance of Z into pieces accounted for by each <u>innovation</u>[16], it is appealing to apply an orthogonalization transformation to U', or $e_t = TU_t$ where T is a matrix chosen

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[16] Sims (1980) called the residuals "innovations" because the residuals are "new" in the sense of not being predicted from past values of variables in the system.

to make the variance-covariance matrix of e_t the identity matrix. There is, however, no uniquely best ways to choose T. One way is to choose T's so that they have a triangular form. The connection between elements of e and Z are such that, if T is lower triangular, e_{jt} is the normalized error in forecasting $Z_{i,t}$ for i < j (Choleski Factorization). We can write (4-3) as

$$Z_t = \sum_{s=0}^{\infty} B_s T^{-1} e_{t-s}. \tag{4-6}$$

Now the interpretation for the components of MAR can be applied to the components of the matrix function $B_s T^{t-1}$ since the elements of e are uncorrelated.

This type of orthogonalization is equivalent to restricting the system such that it is recursive or a "shock" in Z_1 has a contemporaneous effect on all remaining n-1 variables, Z_2 has contemporaneous effects on all n-2 variables (excludes Z_1, and Z_2), ..., and Z_n only on itself. Hence, each triangularization imposes a particular <u>block recursive</u> system on the contemporaneous relation among the variables. Thus, it is important to test this procedure by changing the ordering of the variables to see whether there are important changes in the results.

Once the As in the VAR have been estimated, the matrix $B_s T^{-1}$ for s = 0, 1, 2, ..., k, ... can be computed. Let the i,j-th component, $\tilde{b}_{ij}(s)$, of $B_s T^{-1}$, be the response of Z_i to an innovation or exogenous shock of one standard deviation in Z_j, then

$$w^2_{ij}(k) = \sum_{s=0}^{k} \tilde{b}^2_{ij}(s) / \sum_{j=1}^{p} \sum_{s=0}^{k} \tilde{b}^2_{ij}(s) \qquad (4\text{-}7)$$

is the proportion of the forecast error variance in Z_i, k period ahead, produced by an innovation in Z_j. The vector $w^2_{.j}(k)$ for large k is called the <u>variance decomposition</u> of the variable Z_i. Under the condition that variance-covariance matrix is time invariant, stationarity of the VAR is equivalent to the condition that

$$\lim_{s \to \infty} b_{ij}(s) = 0, \text{ for all i and j} \qquad (4\text{-}8)$$

i.e., shocks dampen out over time. Under that condition, $w^2_{ij}(k) \longrightarrow w^2_{ij}$ as $k \to \infty$, and w^2_{ij} is the overall variance proportion of Z_i due to a one standard deviation shock in Z_j.

The techniques described above are still being refined by researchers, and some parts of them are still being debated (for the latest development, see Sims (1987)). Although the techniques were developed partly in response to criticisms of standard simultaneous equations macroeconometric models, they are not intended to remedy all the defects in the standard models pointed out by critique like Lucas (1976). Furthermore, the VAR may be complementary to traditional structural analysis in the sense that it permits an analysis of error structures or the causal relationships among variables.

C. Estimation [17]

The choice of variables to include in the analysis is based largely on the theoretical model of the market for the domestic services developed in Chapter 3 and the general summary of long-term trends presented in Chapter 2.[18] The choice is, however, constrained by the fact that there are only 86 observations. Thus, only a maximum of 6 - 8 variables could be included and results be significant.

The system consists of six aggregate variables for the U.S. economy for the time period 1900 to 1985: IMMT (total number of U.S. immigrants), DPRICE (U.S. real price of household durable goods), UNEM (U.S. unemployment rate), INCOME (average U.S. real household income), WAGE (annual real earnings of U.S. domestic household workers), and DMST (number of U.S. domestic household workers). Also, deterministic

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[17]The empirical work reported in this chapter was performed with the RATS computer package, Version 2.00, written by Doan and Litterman (1986).

[18]Although the VAR techniques are not based on a particular equation specification of economic theory, economic theory is useful as a guide to the set of variables that might be related. We, however, can not say anything about the underlying economic system by looking meanly at the magnitude of the coefficients of the As in the VAR system (4-2).

components are added for intercept, time trend, and its square.

The first task in the empirical analysis is to determine the lag length or the order of the polynomials operator A(L) in (4-2). This is accomplished by application of statistical tests on the coefficients in (4-2). According to Sims (1980), the conventional likelihood ratio test for determining lag length is too conservative in favor of acceptance of the null hypothesis. As an alternative, he suggests a modified test statistic of

$$(N - k)[\log /\Sigma_R/ - /\log /\Sigma_U/] \sim X^2_{df} \qquad (4\text{-}9)$$

where N is the number of observations, k is the number of explanatory variables in each equation, $/\Sigma_R/$, $/\Sigma_U/$ are determinants of variance-covariance matrices of restricted, and unrestricted model, respectively, and df is the degrees of freedom (number of linear restrictions).

A statistical test was performed to determine the lag length of the VAR system. Four lags specification was tested as a restriction model on five lags specification using the Sims' modified likelihood ratio test. The chi-square, X^2(df = 36) = 47.12 with 36 restrictions, so the four-lags specification can not be rejected at 5 % level. Thus, the VARs were estimated with a lag length of four.

Table 4-1 presents the estimated parameters of the six

Table 4-1. Estimated Parameters of the VAR System, 1900-1985

Regressor	lag	Dependent Variables: IMMT	DPRICE	UNEM	INCOME	WAGE	DMST
Const.		-0.341***	-0.789	-7.942	5.045	0.164	0.369
Trend		0.003	0.003	-0.130	-0.088	-0.007	0.028**
Trend^2		$959*10^{-8}$	$372*10^{-7}$	$552*10^{-6}$	$340*10^{-6}$	$-171*10^{-7}$	$-372*10^{-7}$
IMMT	1	1.507*	-0.018	3.862	-0.691	-0.643***	0.021
	2	-0.374***	-0.272	-11.433**	-2.580	0.320	0.296
	3	-0.074	0.387	11.600**	12.185	1.055	-0.045
	4	-0.086	0.135	-2.813	-4.761	-0.836**	-0.172
DPRICE	1	0.006	1.236*	0.607	0.720	0.144	-0.100
	2	-0.039	-0.401***	0.094	-0.089	-0.046	-0.158
	3	0.013	0.070	-1.520***	0.739	-0.129	-0.202
	4	-0.005	-0.164	1.025***	-0.560	-0.049	0.241
UNEM	1	0.012***	0.068**	0.863*	0.204	-0.015	-0.002
	2	-0.022*	-0.098**	-0.473*	-0.518**	-0.045***	0.016
	3	-0.025*	0.039	0.371**	0.224	0.008	0.062
	4	-0.009	-0.020	-0.463*	-0.312	0.012	0.019
INCOME	1	0.015***	0.038	-0.143	0.857*	0.040***	-0.025
	2	-0.008	-0.028	-0.004	-0.542**	-0.002	0.053
	3	-0.003	-0.022	0.063	0.341	0.003	-0.037
	4	-0.001	0.028	0.162	-0.051	0.006	0.009
WAGE	1	0.004	-0.108	-2.014**	-1.406	1.179*	0.340
	2	-0.026	0.124	1.124	4.187***	-0.270	-0.370
	3	0.008	-0.012	1.455	-3.096	-0.312	0.216
	4	0.024	0.020	-2.178**	-0.509	-0.073	0.136
DMST	1	0.050	-0.254	0.744	-0.755	0.071	1.077*
	2	-0.046	-0.086	-1.412	-0.204	-0.012	-0.188
	3	-0.003	0.198	1.408***	1.395	0.150	-0.291
	4	-0.042	-0.064	0.202	0.785	-0.091	-0.107
R^2		0.998	0.998	0.944	0.934	0.995	0.998
Sig. Level		0.486	0.371	0.719	0.108	0.875	$229*10^{-5}$

*, **, *** indicate that the coefficients are significantly different from zero at 1%, 5%, 10% levels, respectively.

equation system where each equation was fitted using OLS equation-by-equation. Note that the autoregressive coefficients are difficult to interpret because many of the variables are highly correlated. Statistical tests for individual coefficients are not very useful because of near multicollinearity in each equation. Equivalent, but more comprehensible, information is contained in the MAR coefficients. They will be discussed in the following section.

Granger tests of statistical causality (Granger, 1969) can also be performed on the variables in a VAR model. They boil down to tests of the hypotheses that all coefficients of a particular variable are jointly zero. There are a number of different ways of implementing these tests. Some tests are reported in table 4-2. According to the table, the causal relationships between variables in the VAR system are not quite straightforward. Some relationships are noted as follows. Immigration causes unemployment, and unemployment causes immigration and household income. Price of household durables and unemployment rate weakly cause domestics, but not significant. This tests results may represent the real causal relationships in a very limited context because of the misleading possibility of the OLS estimates as pointed out previously. Rather than using this F test, more substantial causal relationships can be explored using the impulse responses or error decompositions. We discuss about that in

Table 4-2. F Statistic for Hypothesis that Coefficients on Designated Lagged Variable are Jointly Zero

Designated Variable	Dependent Variables					
	IMMT	DPRICE	UNEM	INCOME	WAGE	DMST
IMMF	757.18*	1.43	3.77*	1.70	1.76	0.39
DPRICE	0.61	30.28*	1.25	0.67	1.36	1.90
UNEM	2.91**	1.97	8.94*	2.06***	1.17	1.76
INCOME	1.11	0.67	1.14	3.98*	1.35	0.29
WAGE	0.23	0.10	1.85	1.47	31.61*	0.50
DMST	1.77	1.17	1.26	1.38	0.81	8.76*

*, **, *** indicate that the null hypotheses are rejected at the 1%, 5%, and 10% level, respectively.

detail in the following section.

D. Description and Interpretations: Impulse Responses and Error Decompositions

Autoregressive systems are difficult to describe succinctly. It is especially difficult to make sense of them by examining the coefficients in the regression equations themselves. The estimated coefficients on successive lags of a given variable tend to oscillate in sign because this is a requirement for a stable difference equation system, and there are complicated cross-equation feedbacks. Therefore, the common econometric practice of summarizing distributed lag relations in terms of their implied long-run equilibrium behavior may be quite misleading.

The best descriptive device is analysis of the system's response (reaction) to typical random shocks. This procedure was formularized in (4-5) in the previous section. The "typical shocks" are positive residuals of one standard deviation unit in each equation of the system. The ordering of the variables is based on the primary interests of this study. The block recursive ordering of variables adopted here is: IMMT -DPRICE - UNEM - INCOME - WAGE - DMST. The orthogonalization method is Choleski (see p. 12-24 of Doan and Litterman (1986)).

Impulse responses in the triangularized system are presented in the four sets of Figures 4-1a-f, 4-1a'-f', 4-2a-f, and 4-2a'-f' given in the end of this chapter. The first two sets show the responses of the six variables to one standard deviation shock in a particular variable, and the second two sets depict the responses of a particular variable to shocks in itself and all other variables in the system simultaneously. We discuss specific response patterns and interrelationships between variables after first establishing several general features of the responses.[19]

The first characteristic to note is the overall stability of the system. Responses to shocks in time period 1 tend to dampen a little slowly, but they convergence to zero (i.e., to mean values) within a 50 to 60 year period. The second notable feature is the relatively long cycle of the responses, which supports the evidence of relatively long persistency of the variables in the system.

Throughout the figures, the responses to exogenous shocks exhibit quite interesting patterns in which we find some common patterns which are consistent with the hypothetical

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[19]The discussions in this section are largely focused on the response patterns of domestics and their wage rates. In the structural model context, these two variables are classified as endogenous and others are as exogenous. Even though the VAR does not require such explicit treatment or a specific structural model, it is reasonable to interpret the VAR results implicitly in terms of structural sense. Note that the impulse responses describe the interrelationships or causal relations through identifying the affects of exogenous shocks. One of the purposes of this study is to draw some synthetics from the VAR and the traditional structural modelling.

interrelationships between variables in the structural model sense. UNEM and DMST react in a same fashion to exogenous shocks in the variables in the system as does IMMT. WAGE reacts in an opposite fashion to shocks as do UNEM and DMST. Also it is notable that the variables, INCOME, DPRICE, and WAGE react in an opposite fashion to shocks as does DMST. These common response patterns to shocks throughout the system can be interpreted in terms of market structure for domestics service workers as hypothesized by the structural model given in Chapter 3. The patterns also can be interpreted along with the historical trends of the variables given in Chapter 2 where we found that the fluctuations in the domestics and their wage rates sensitively responded to the general economic cycle. In a recession, an increase (a positive innovation) in IMMT or in UNEM increase DMST, and decrease INCOME and WAGE. Note that in a recession, domestic work might be the only available job for (female) workers who have low-skill and low-schooling. The influx of such workers into the domestic service sector might plausibly resulted in the decrease in WAGE and increase in DMST. The decrease in INCOME would be expected to reduce the demand for household durable goods, but a reduction of DPRICE would be expected to increase the demand for household durable goods. The decrease in demand for domestics due to a decrease in INCOME is a straightforward relationship expected. The actual quantity of domestic services, however, demanded by households would be decreased, i.e., in recession the number of domestics in labor force which includes the unemployed domestics is increased but the quantity of domestic services demanded is decreased. Discussions about the reverse relationships are quite obvious for the booming period.

The magnitudes of the responses are interesting. In general the innovations in the four exogenous (in the sense of structural model) variables (IMMT, DPRICE, UNEM, and INCOME) have substantial effects on each other and the endogenous variables (DMST and WAGE). Among them the persistent real effects of DPRICE innovations in particular on WAGE and DMST are economically significant.

All effects on the WAGE (of domestic servants) from shocks in other variables become insignificant after 30 years. Also the magnitude of the WAGE responses over the whole period is small. This inactive responsiveness may explain the failure of structural models of the market for domestic service workers. However, the response patterns of DMST is different. As seen in Figures 4-2f and 4-2f', there is persistence of effects, lasting around 15 years. These patterns are largely consistent with the periodical fluctuations in the number of domestics, and their low rate of turn over. (See the trend of domestics in Figure 2-2 in Chapter 2.)

Now let us turn to the more specific patterns for each variables. Discussions are mainly focused on the response patterns of DMST and WAGE to shocks in the first four variables (IMMT, DPRICE, UNEM, and INCOME). Some important findings are summarized in the following.

i) The responses of the UNEM, INCOME, and WAGE to a shock in IMMT are remarkable in the first 30 years (Figures 4-1a and 4-1a'). This indicates that IMMT innovations have very persistent effects on the U.S. economy as a whole and on wage rates of lower-occupations such as wage rates of domestics. However, their effects on other variables, DPRICE and DMST are not significant. These response patterns imply that IMMT innovations affect domestics indirectly through the effects on unemployment rate and household income or their wage rates.

ii) Figures 4-1b and 4-1b' depict the responses to a innovation in DPRICE. Overall the responses are active during the first 40 years. The responses of INCOME and UNEM are notable. UNEM and IMMT respond in a similar fashion, but the magnitude of IMMT's response is relatively small. DMST responds in an opposite direction to a shock in DPRICE as do INCOME and DPRICE, but DMST responds in a same fashion to a shock in DPRICE as does IMMT.

iii) There exist a few years lag between responses of DMST and of other variables (IMMT, UNEM). The lags between DMST, and IMMT and UNEM suggest that it takes time for such variables to affect the supply side of domestic service workers through the market mechanism.

iv) In Figures 4-1c and 4-1c', and 4-1d and 4-1d', IMMT reacts less actively to exogenous shocks in UNEM and INCOME. Recall the very active responses of UNEM and INCOME to shocks in IMMT in Figure 4-1a. We may interpret that these response patterns represent the causal relationships, i.e., IMMT causes in Granger sense UNEM and INCOME.

v) Figures 4-1c (4-1c') through 4-1f (4-1f') reinforce the response patterns mentioned above. The DMST and the WAGE move in the opposite direction for the first 30 years thereafter the WAGE responses converge to the mean value. The response patterns of the variables, INCOME, DPRICE, and DMST are easily identifiable. DMST reacts in a quite opposite direction to shocks in the variables in the system as do DPRICE and INCOME. These patterns imply that the demand side could be more easily identifiable than the supply side of the market for domestic service workers in the structural sense.

The decomposition of the variance of the variable is a useful way to show the main channels of influence in the model. This issue is pursued with the aid of information presented in the Table 4-3. The numbers in the table were derived using equation (4-7) which represents the allocation of the variance of forecast error.[20]

A variable which is strictly exogenous would, if no sampling error existed in the estimated system, have entries

[20] Different orderings may yield quite different apportionment of variances. In this study, several different orderings are used to check whether they yield significant differences. No significant differences were observed.

Table 4-3. Decomposition of Variance: Proportions of Forecast Error Variance k Years Ahead Produced by Each Innovation (w_{ij})

			Triangularized Innovations in (j)					
Forecast Error in(i)	k	S.E.	IMMT	DPRICE	UNEM	INCOME	WAGE	DMST
IMMT	1	0.0102	1.00	0.00	0.00	0.00	0.00	0.00
	3	0.0273	0.93	0.00	0.04	0.01	0.00	0.02
	5	0.0433	0.90	0.03	0.05	0.01	0.00	0.01
	10	0.0802	0.82	0.12	0.04	0.01	0.00	0.00
	30	0.1227	0.56	0.18	0.08	0.03	0.07	0.08
	50	0.1292	0.52	0.19	0.09	0.03	0.08	0.09
DPRICE	1	0.0506	0.00	1.00	0.00	0.00	0.00	0.00
	3	0.1305	0.01	0.77	0.02	0.13	0.04	0.04
	5	0.1893	0.01	0.65	0.02	0.13	0.08	0.11
	10	0.2527	0.01	0.53	0.15	0.14	0.07	0.09
	30	0.2864	0.03	0.52	0.15	0.12	0.08	0.08
	50	0.2994	0.04	0.52	0.16	0.12	0.08	0.09
UNEM	1	0.2105	0.02	0.01	0.97	0.00	0.00	0.00
	3	0.3298	0.01	0.01	0.73	0.17	0.07	0.01
	5	0.3866	0.05	0.14	0.55	0.18	0.06	0.01
	10	0.5060	0.20	0.25	0.35	0.11	0.05	0.03
	30	0.6297	0.24	0.21	0.30	0.10	0.08	0.07
	50	0.6402	0.24	0.21	0.29	0.10	0.09	0.07
INCOME	1	0.3227	0.00	0.03	0.04	0.93	0.00	0.00
	3	0.5061	0.03	0.10	0.06	0.77	0.01	0.02
	5	0.6067	0.06	0.24	0.08	0.58	0.01	0.03
	10	0.7021	0.09	0.25	0.18	0.44	0.01	0.03
	30	0.8030	0.09	0.26	0.18	0.36	0.05	0.06
	50	0.8120	0.09	0.27	0.18	0.35	0.05	0.06
WAGE	1	0.0313	0.00	0.06	0.02	0.03	0.88	0.00
	3	0.0747	0.05	0.20	0.00	0.17	0.57	0.00
	5	0.0980	0.09	0.24	0.01	0.26	0.39	0.00
	10	0.1129	0.14	0.23	0.06	0.26	0.30	0.02
	30	0.1358	0.16	0.21	0.08	0.24	0.25	0.06
	50	0.1364	0.17	0.21	0.08	0.24	0.25	0.06
DMST	1	0.0645	0.00	0.10	0.01	0.47	0.08	0.34
	3	0.1247	0.00	0.15	0.01	0.40	0.15	0.29
	5	0.1608	0.01	0.30	0.05	0.27	0.15	0.22
	10	0.1963	0.01	0.34	0.16	0.19	0.13	0.17
	30	0.2181	0.02	0.36	0.16	0.17	0.13	0.16
	50	0.2226	0.02	0.36	0.16	0.16	0.13	0.16

of 1.00 on its diagonal cell in the table and zeroes in all other cells in the table. Strict exogeneity is equivalent to the condition that a variable's own innovations account for all of its variance. Some important findings are summarized.

i) IMMT and DPRICE have more than half of their variances accounted for by own-innovations at all time horizons shown. No other variable has so much variance accounted for by its own-innovations. Thus, interactions among the remaining four variables are strong, and the remaining variables have some feedback effects from IMMT and DPRICE.

ii) IMMT does not have any sources of strong feedback, but it feeds into the other variables, such as UNEM, and WAGE.

iii) DPRICE also does not have any source of strong feedback. However, INCOME innovations of a moderate size feed into DPRICE which suggests the demand-pull effects. Over the whole horizon, DPRICE innovations are the main sources of variation in the other four variables, UNEM, INCOME, WAGE, and DMST. Among these variables, the feedback effects for DMST and WAGE are remarkable. These findings suggest that the effects of DPRICE are closely related to the effects of other variables in the system, and DPRICE plays an important role in the market for domestic services.

iv) The main sources of feedback to UNEM are IMMT and DPRICE innovations. UNEM also has sizable effects on the variance of INCOME and DMST.

v) The variations in the WAGE are largely explained by

IMMT, DPRICE, and INCOME, but not by the variations in DMST.

vi) For DMST a large portion of its variation is explained by the feedback effects of other variables except IMMT. At the initial step, only 34 % of the variance is explained by its own innovations, and the percentage declines as time after the shock passes. During the early phase, the dominant effects come from the INCOME, but after 5 steps, DPRICE is the dominant explanatory factor. Also, interesting to note that DMST has a moderate amount of feedback from WAGE, but not vice versa.

The findings based on the Table 4-4, suggest that the U.S. market for domestic services is largely explained by the variables in this VAR system. Among the variables, the variations in DPRICE which were caused by the technological progress in the industry sector and change in input prices have strong feedback effects on DMST and WAGE. Also the feedback effects of the variations in INCOME on DMST and WAGE are significant. The direct interaction between the domestics and their wage rates is not bidirectional. As pointed out above, the number of domestics receives some feedback effects from the wage rate, but the wage rate does not receive feedback from the number of domestic service workers. The wage rate has been largely determined by the exogenous environmental factors rather than by the number of domestics itself.[21]

The second column in Table 4-4 displays the standard error of forecasts over various forecasting horizons for the model when sampling error in the estimated coefficients is ignored.[22] Actual forecast errors will of course be substantially larger, even if the model's parameters do not change, because the statistical estimates are imperfect. Pretending that the estimated trend coefficients are known exactly, we see that the size of the forecast error increases steadily as the forecasting horizon lengthens to 30 years. For a stationary process, forecast standard errors tend to converge on some upper bound as the horizon increases. This system seems to converge very slowly, but overall the standard error of forecast indicates that the system is slowly dampened.

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[21]This may suggest that the wage rates for domestic service workers are determined by U.S. wage rates in general and not by the number of one type of labor. Thus, to verify this statement, the VAR system including the wage rate in the manufacturing sector was estimated again. However, the results reveal that the feedback of the wage rate of domestic service workers from the manufacturing wage rate was not significant.

[22]The standard errors of forecasts are computed from the same MAR's used in computing table 4-4. They use the formula for the t-step ahead expected squared forecast error in variable i:

$$s^2(i,t) = \sum_{i=1}^{p} \sum_{v=0}^{t-1} a_{ij}(v)^2 s_j^2,$$

where there are p variables in the system, $s_j^2 = s^2(j,1)$ is the variance of the j-th innovation, and $a_{ij}(v)$ is the coefficient on the v-th lag of the j-th innovation in the MAR equation for variable i (Sims, 1980).

E. Concluding Remarks

In this study, we adopted a descriptive analysis framework, so called VAR techniques. This approach could be effectively used for the analysis of macroeconomic behaviors in which the traditional structural modeling with highly objectionable maintained hypotheses is not appropriate. The results from this study support the approach.

In general the interactions and causal relations among variables in the system are significant and quite straightforward. The fluctuations in the number of domestics and their wage rates have been largely determined by variations in other variables. They are the total number of immigrants, real price of household durable goods, unemployment rate, and average real household income. These variables could be classified as the exogenous variables in the structural modeling for the market for domestic service workers. Especially, the effects of variations in household durable goods prices which were caused by the technological progress proxied by the patenting activity on other variables in the system are remarkable. We also found that there is only one directional interaction between the number of domestics and their wage rates from wage rates to domestics. Relatively wage rates did not respond significantly to the shocks in other variables in the system. This findings suggest that more studies are needed to identify the determination of the wage rate of domestic service workers.

Our experience in this study suggests that the VAR analytic can be effectively used for the analyses of simplified economic behaviors represented by small number of variables that have presumed strong interactions or causalities. However, the VAR may be not appropriate for the well specified economic behaviors with large number of variables. Some minor unsatisfactory results of this study may be explained in this context, because the VAR system is based on the behavioral model for the market for services of domestics. For the market behavior, we need to incorporate quite different characteristics to identify the demand and supply, respectively. The identification results in extending the system, but such a step throws a doubt whether the VAR could handle such a big system efficiently. In practice extremely long time series rarely are available, and the OLS estimation for the many AR coefficients involves some statistical problems.

Finally, it should be noted that VAR techniques have many unsolved technical problems, such as some testing procedures, orderings and orthogonalizations. Still these procedures seem quite robust. The results from different procedures could be different. So it may need a few more experiments to give more credits to the current results.

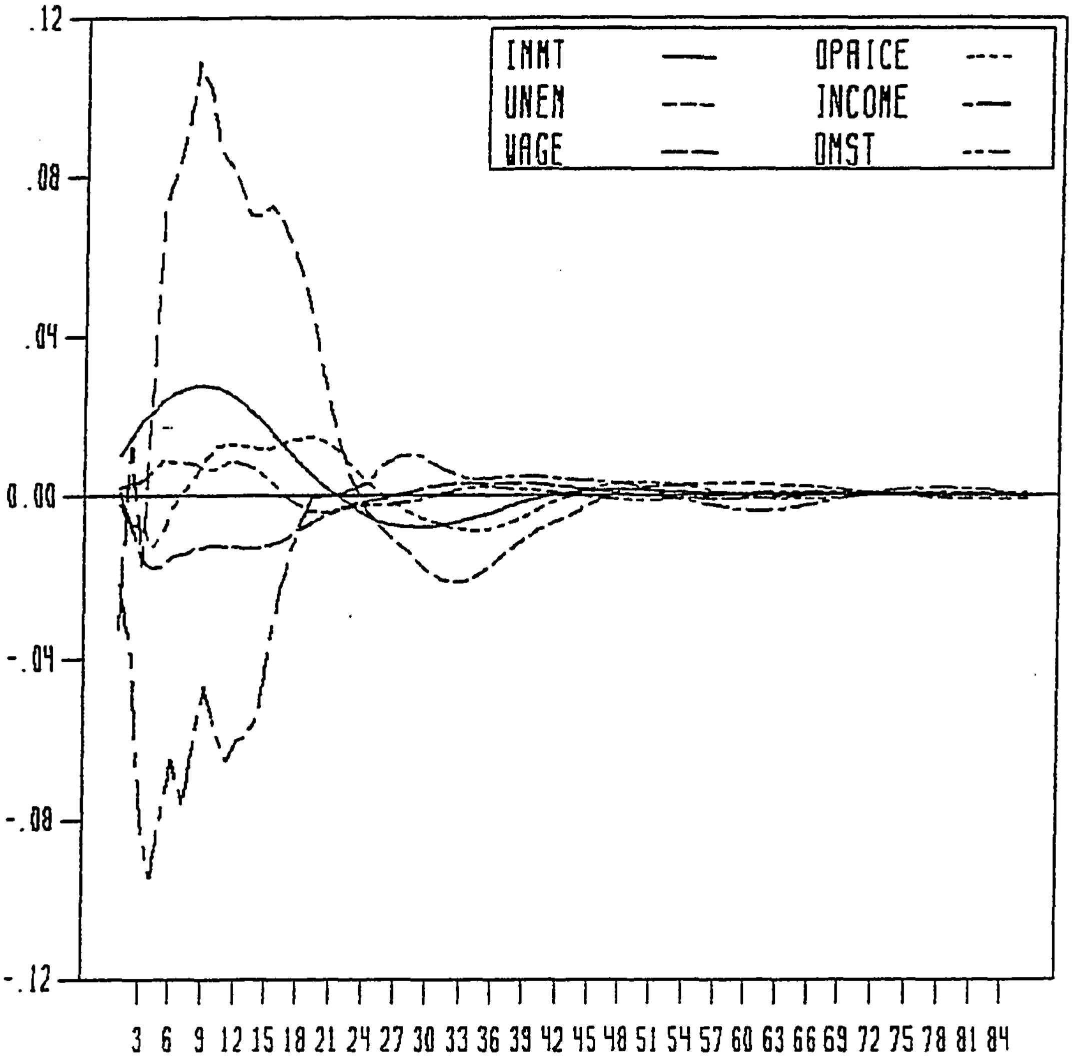

Figure 4-1a. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in IMMT

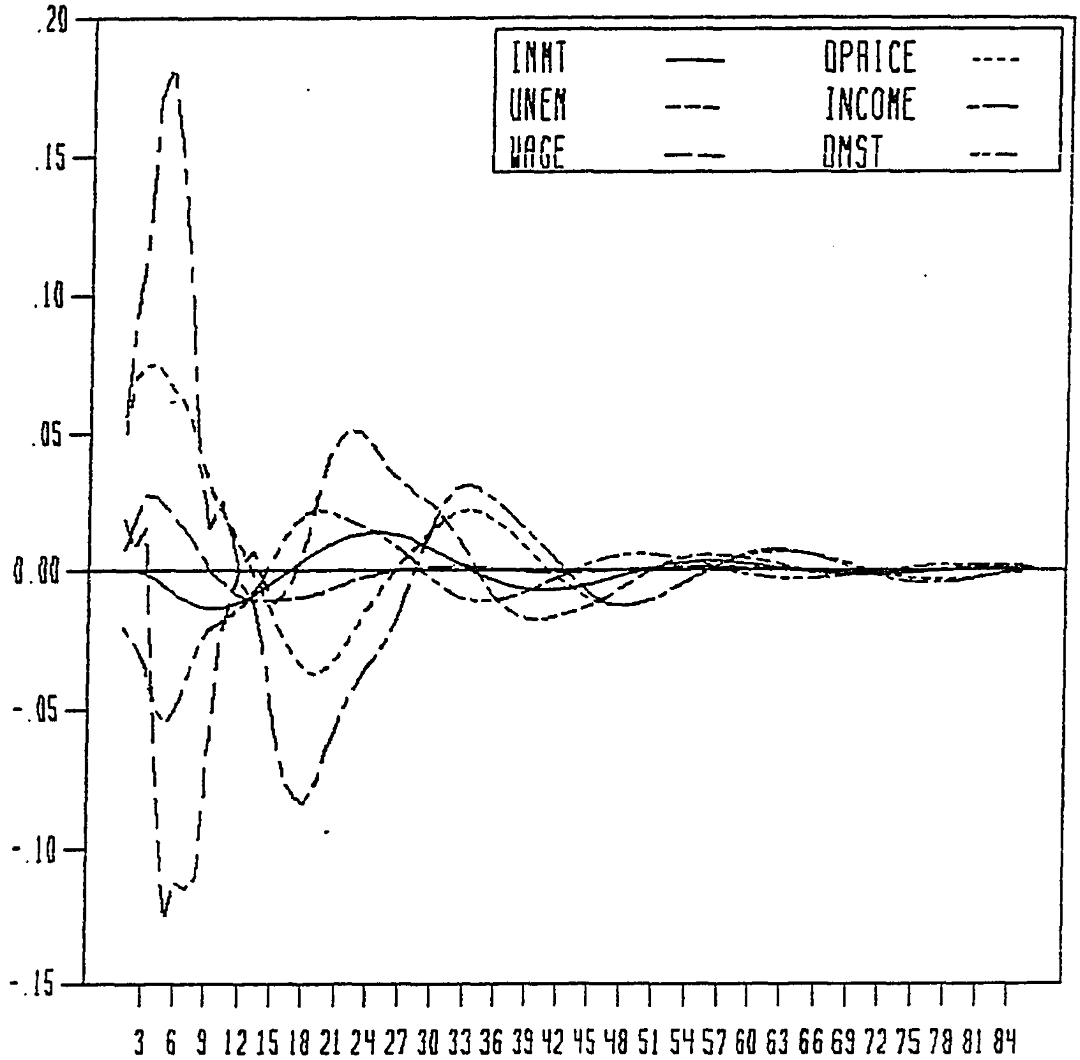

Figure 4-1b. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in DPRICE

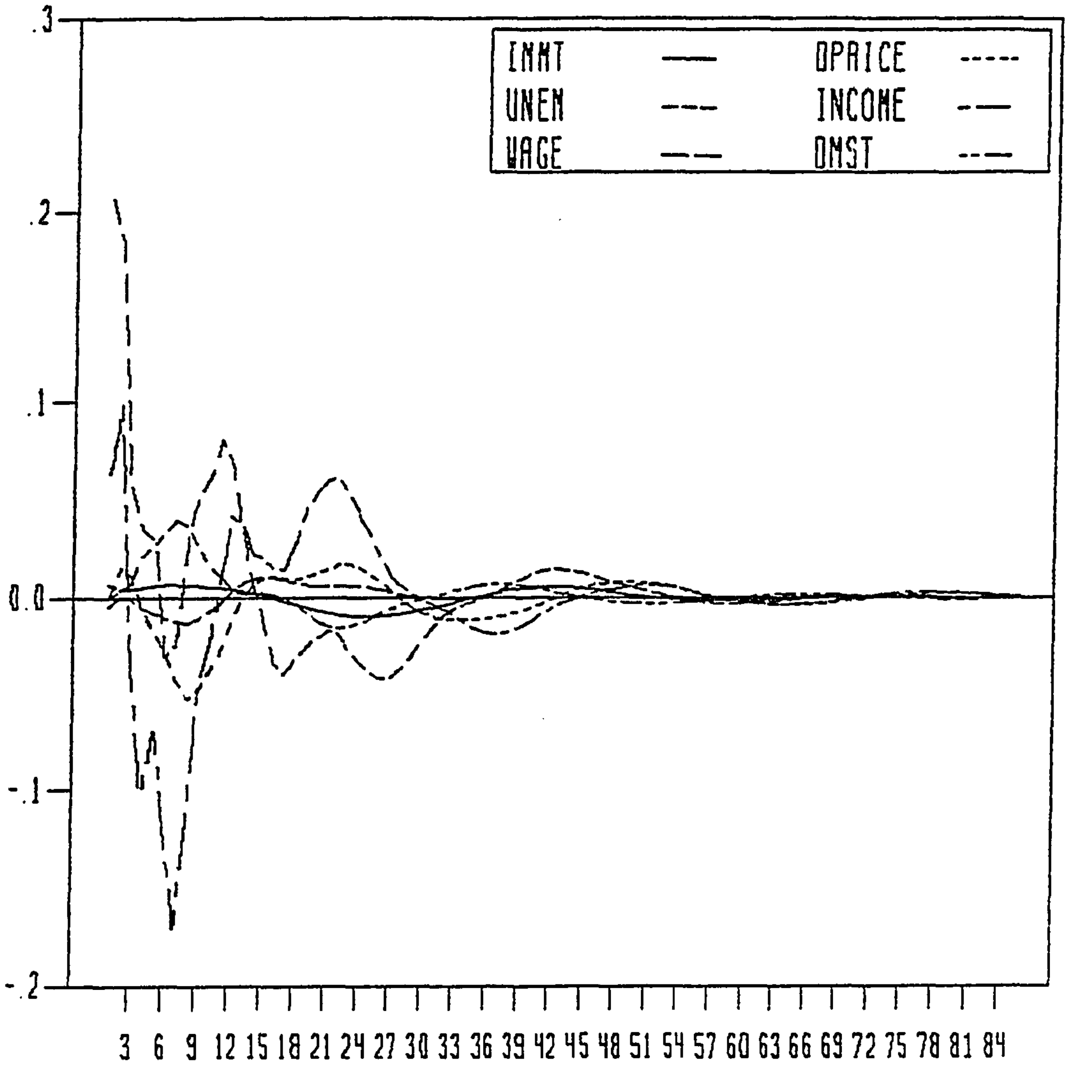

Figure 4-1c. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in UNEM

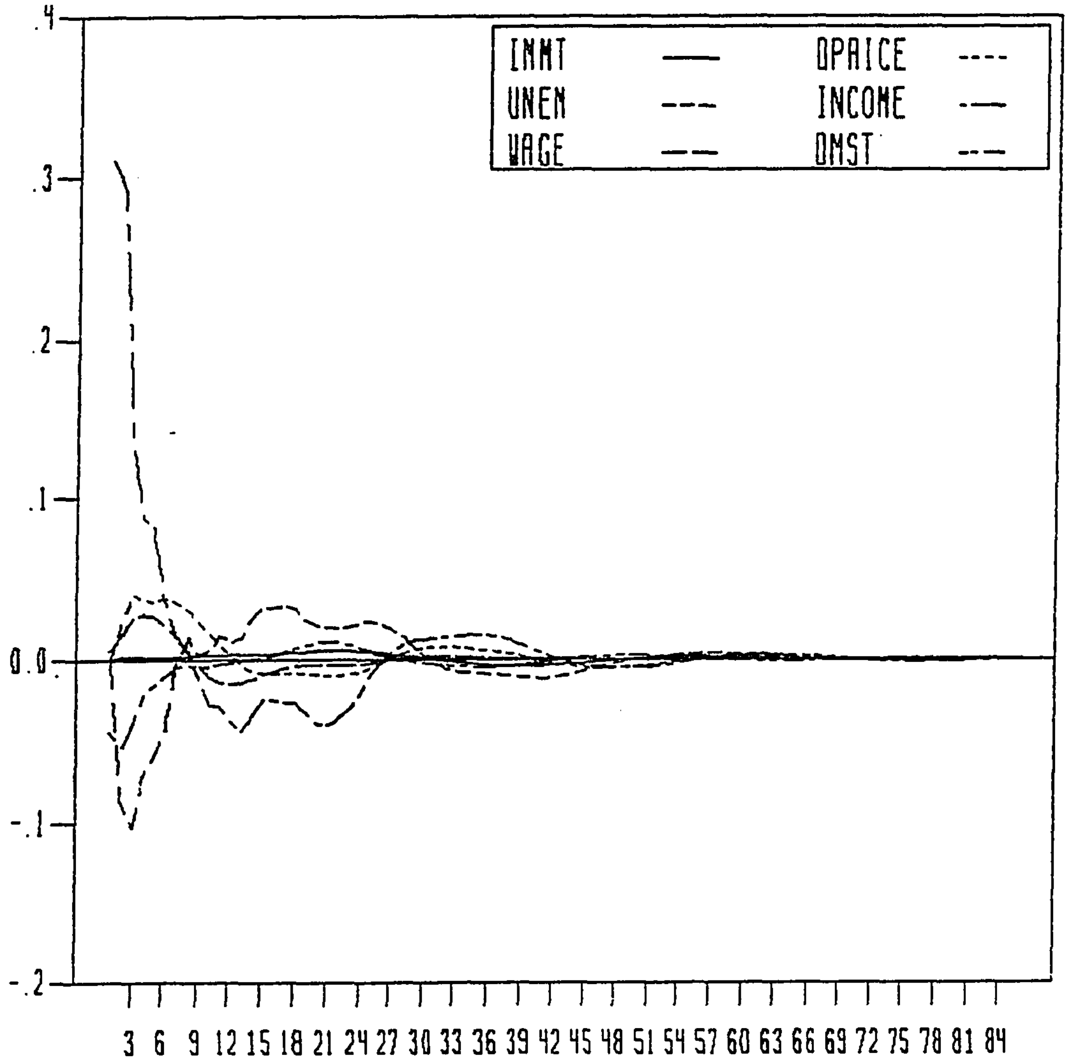

Figure 4-1d. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in INCOME

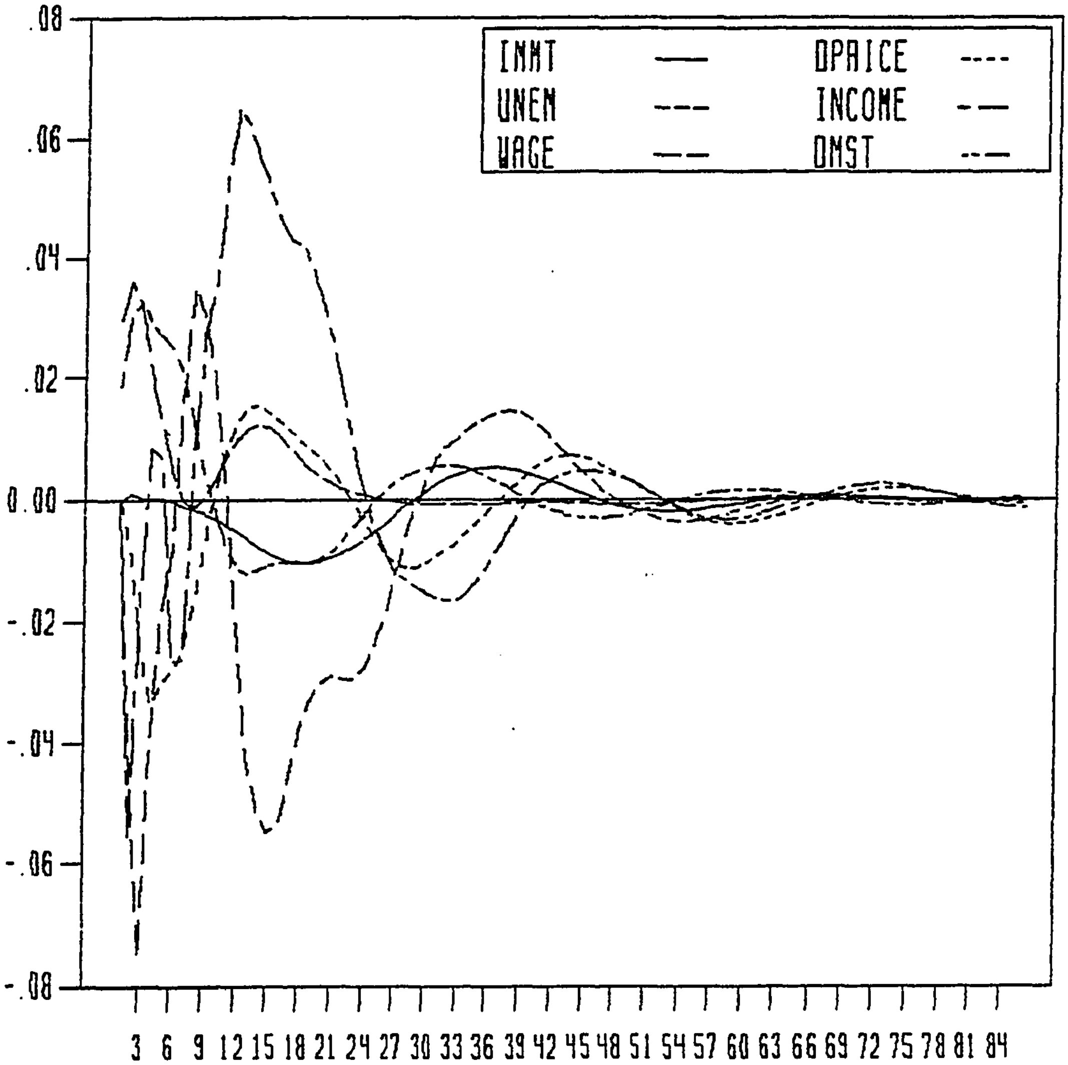

Figure 4-1e. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in WAGE

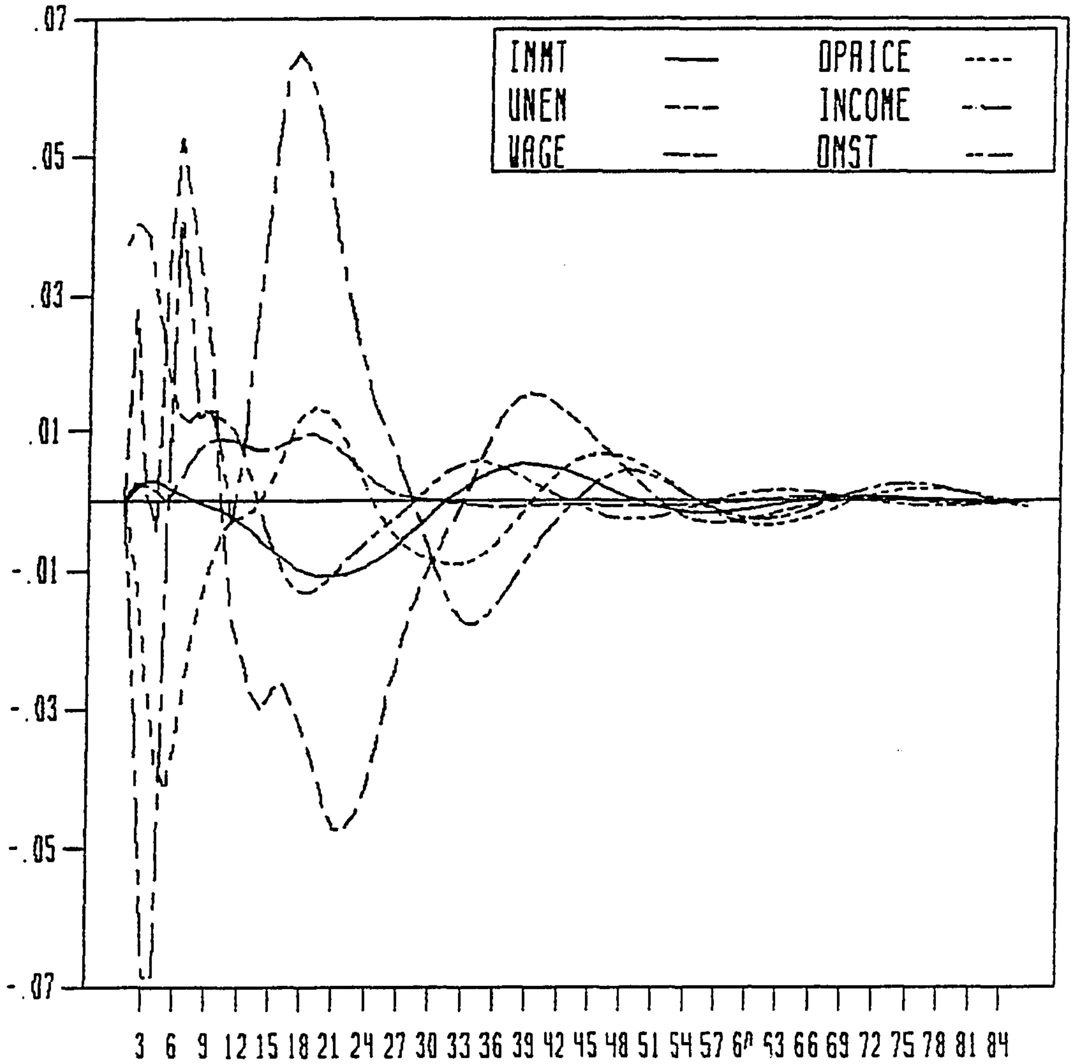

Figure 4-1f. Responses of IMMT, DPRICE, UNEM, INCOME,
WAGE, and DMST to a Shock in DMST

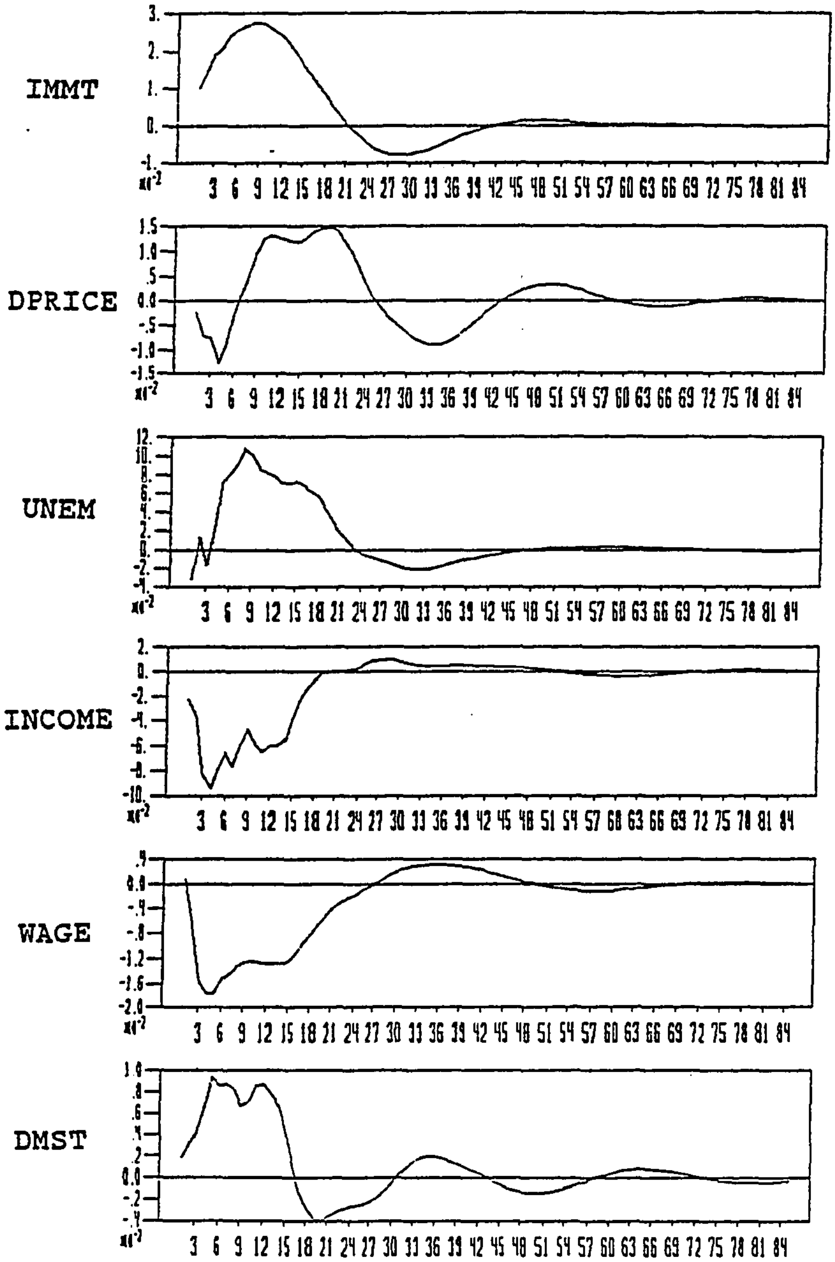

Figure 4-1a'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in IMMT

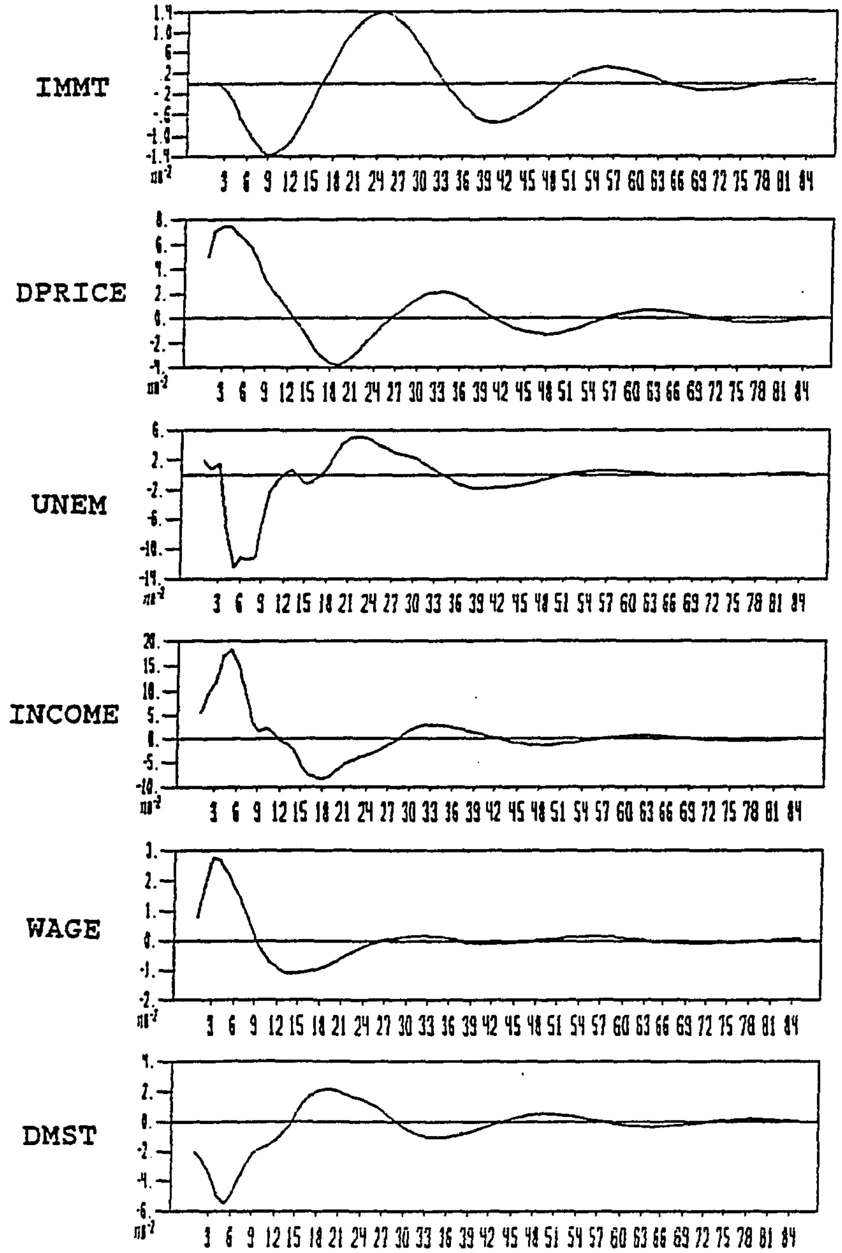

Figure 4-1b'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to s Shock in DPRICE

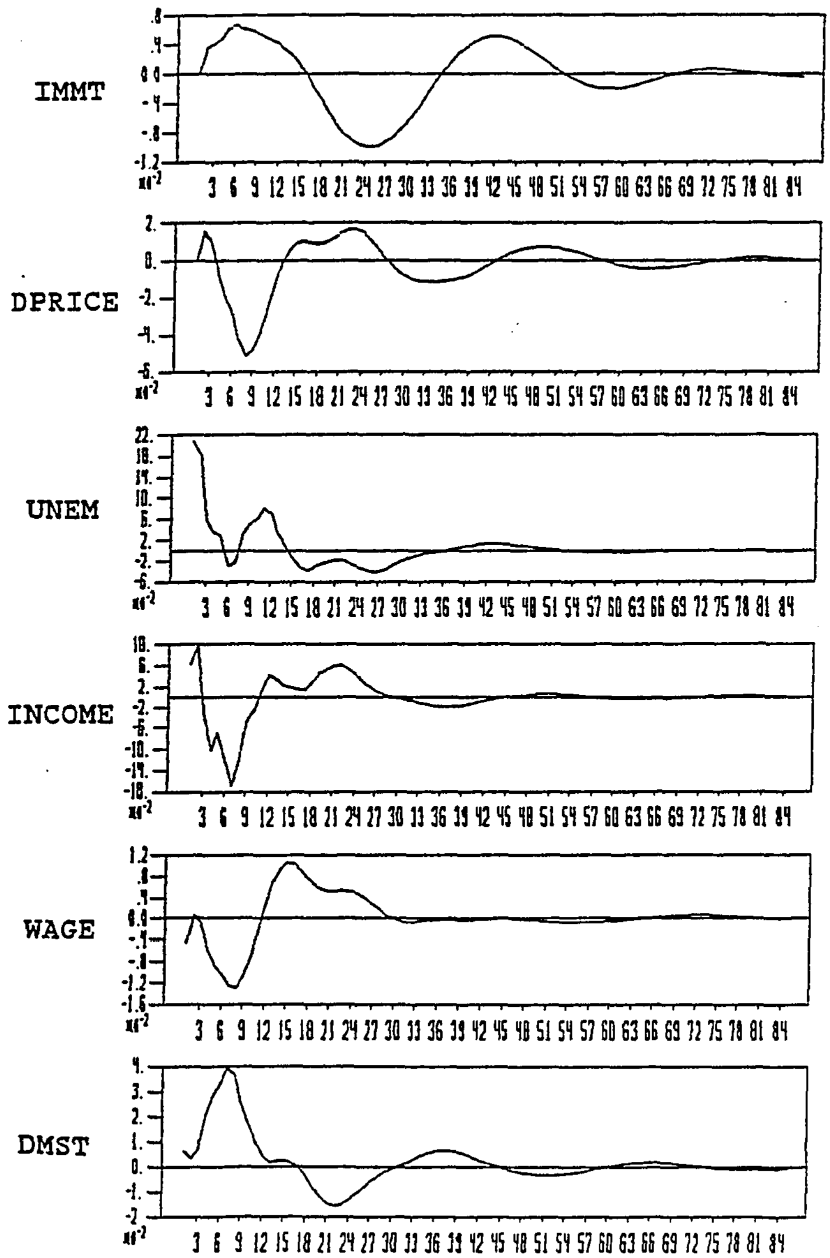

Figure 4-1c'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in UNEM

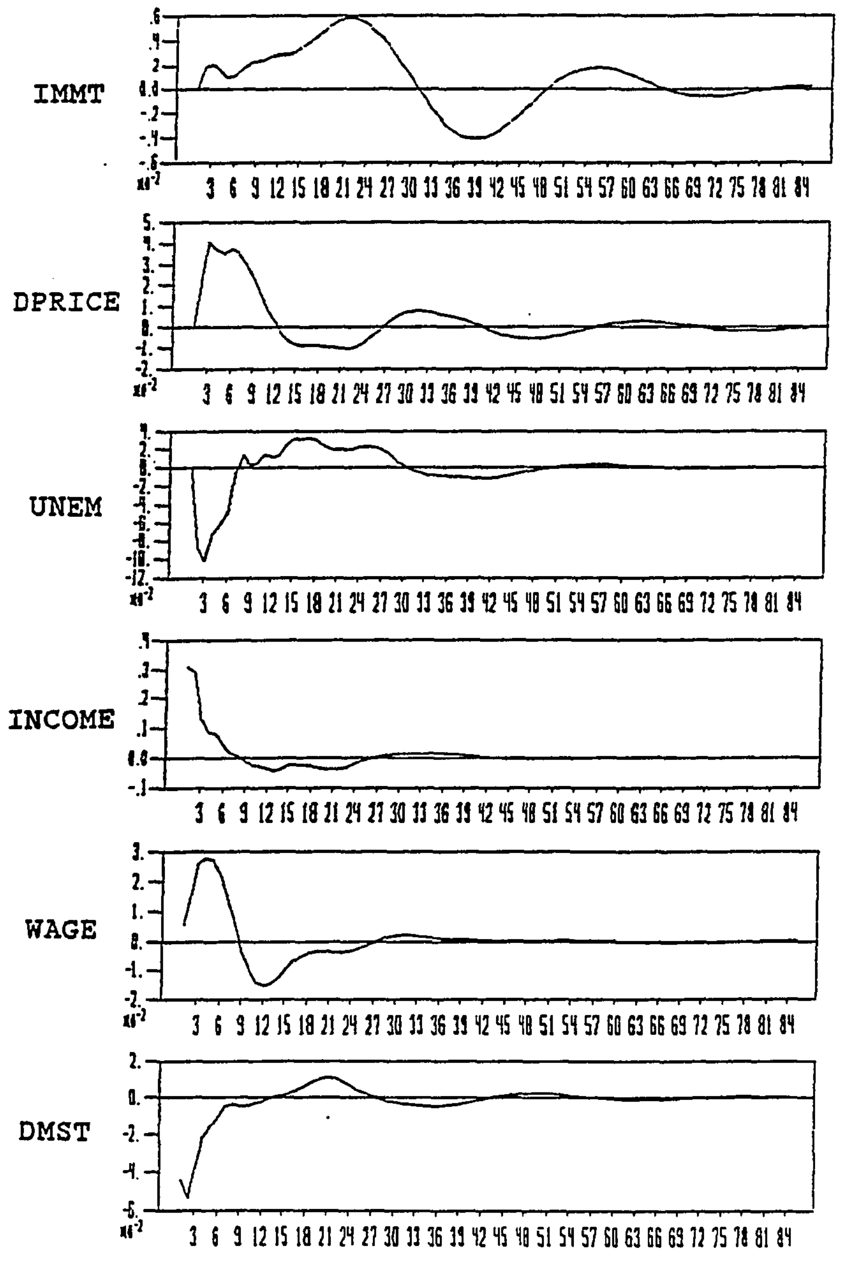

Figure 4-1d'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in INCOME

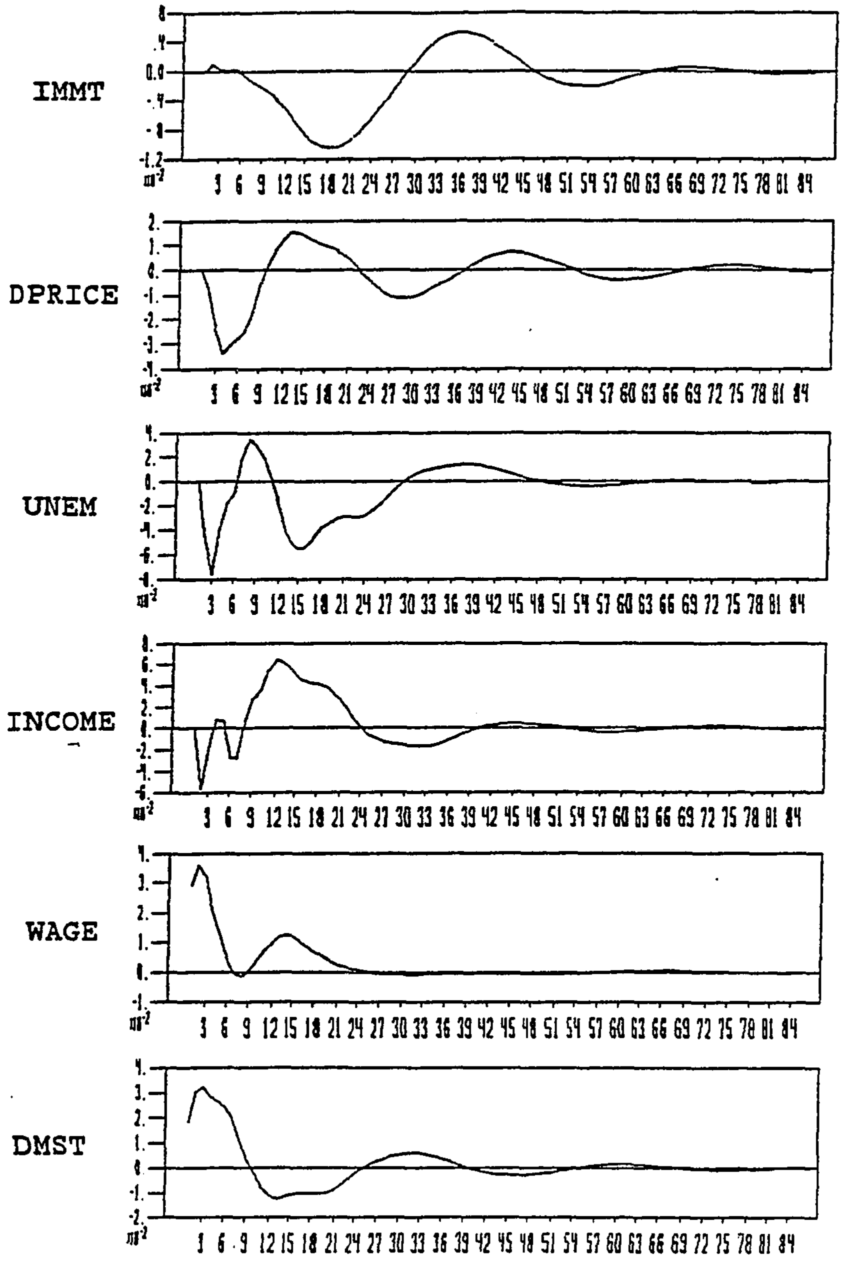

Figure 4-1e'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in WAGE

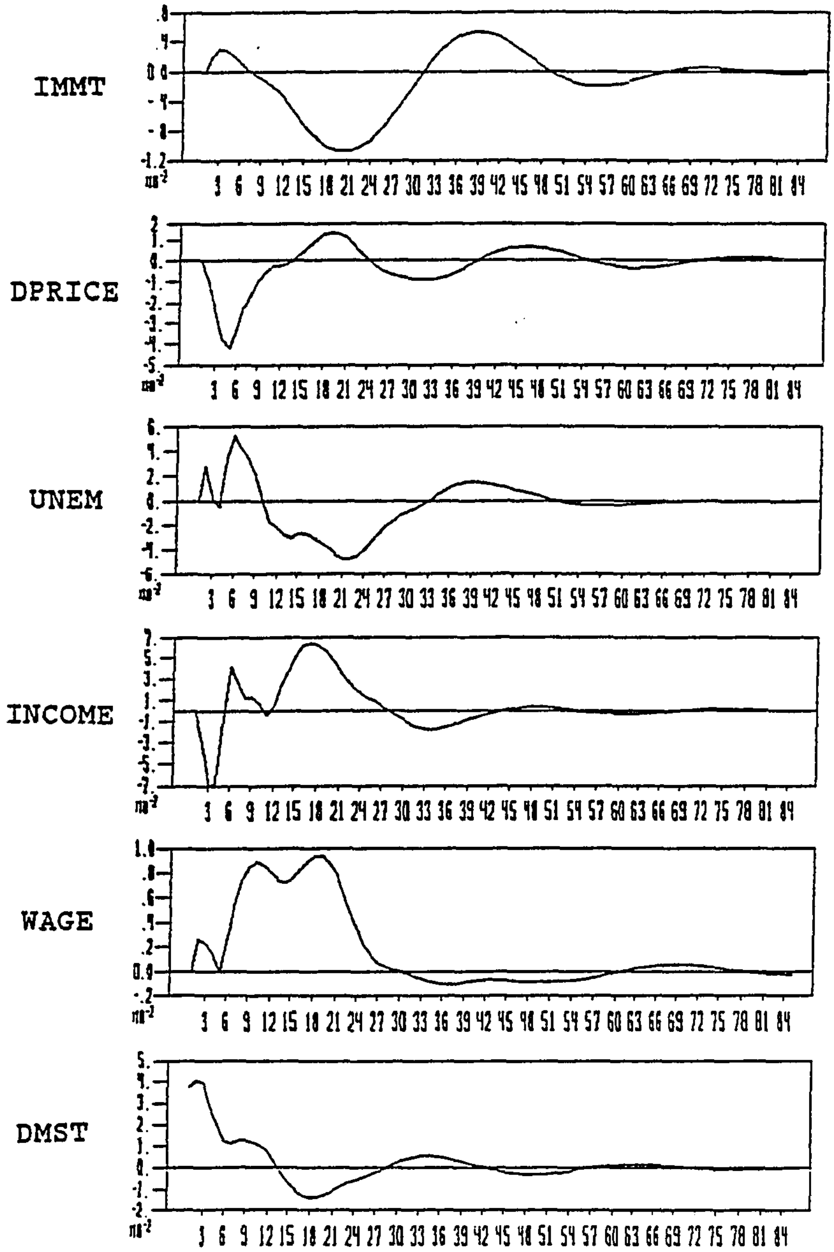

Figure 4-1f'. Responses of IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST to a Shock in DMST

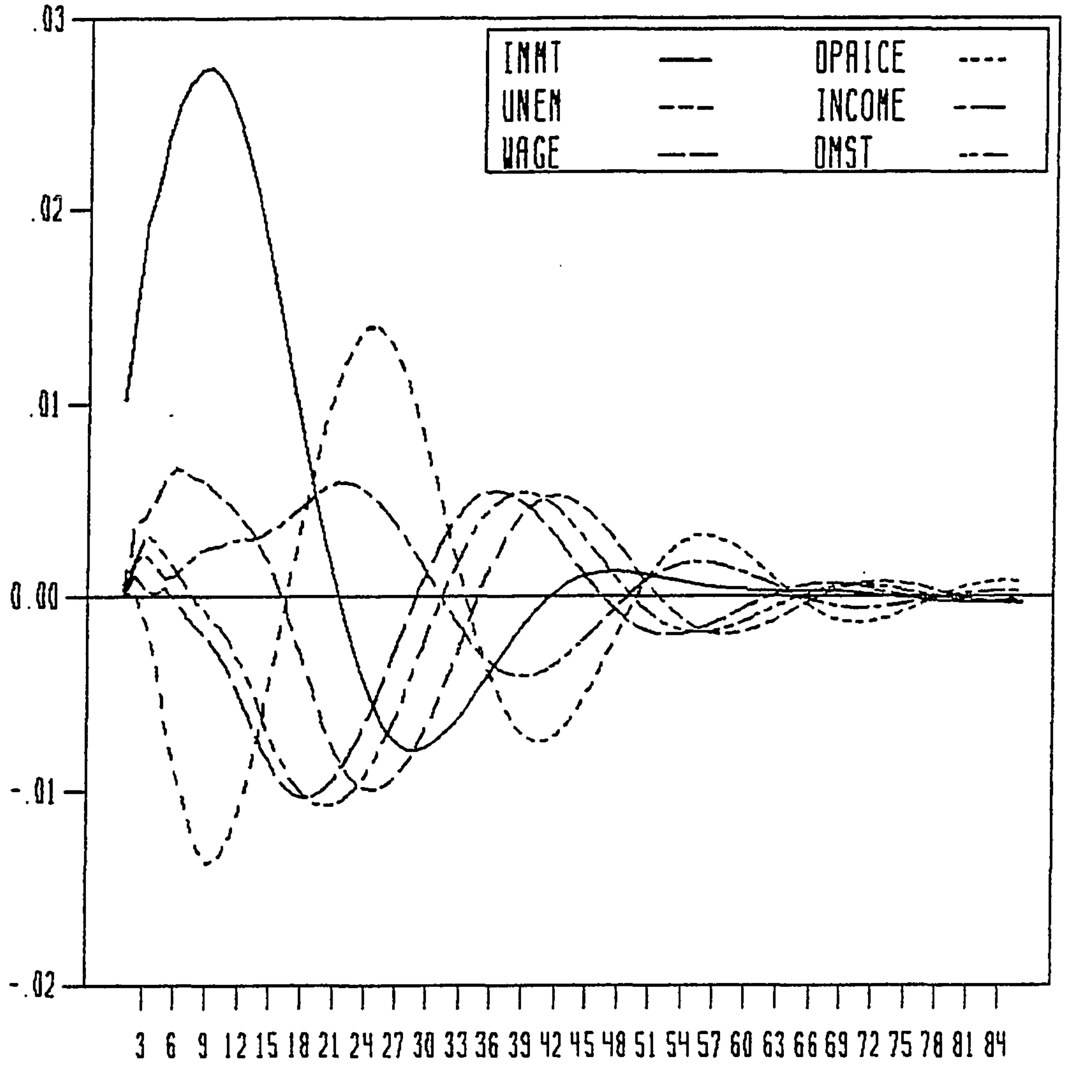

Figure 4-2a. Responses of IMMT to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

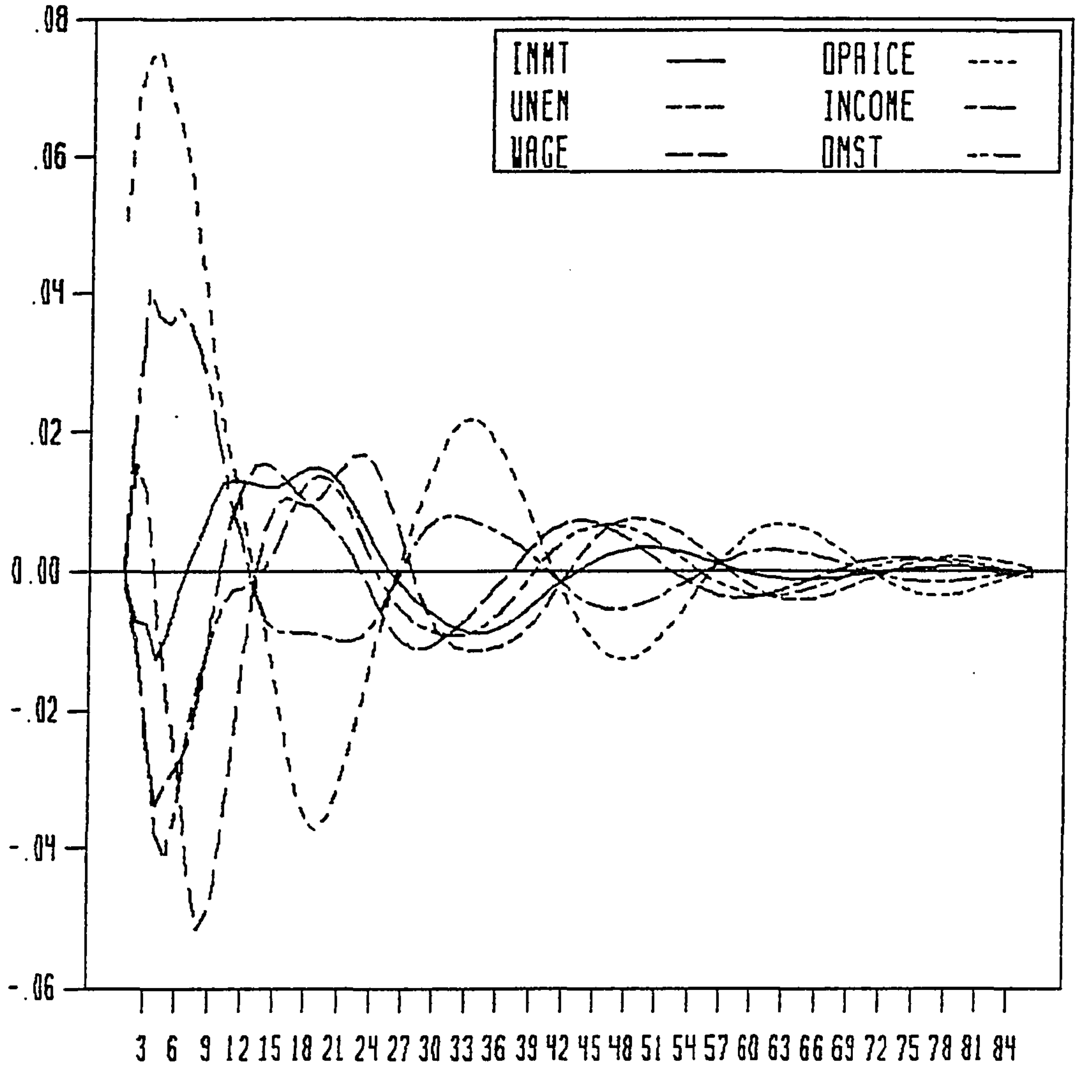

Figure 4-2b. Responses of DPRICE to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

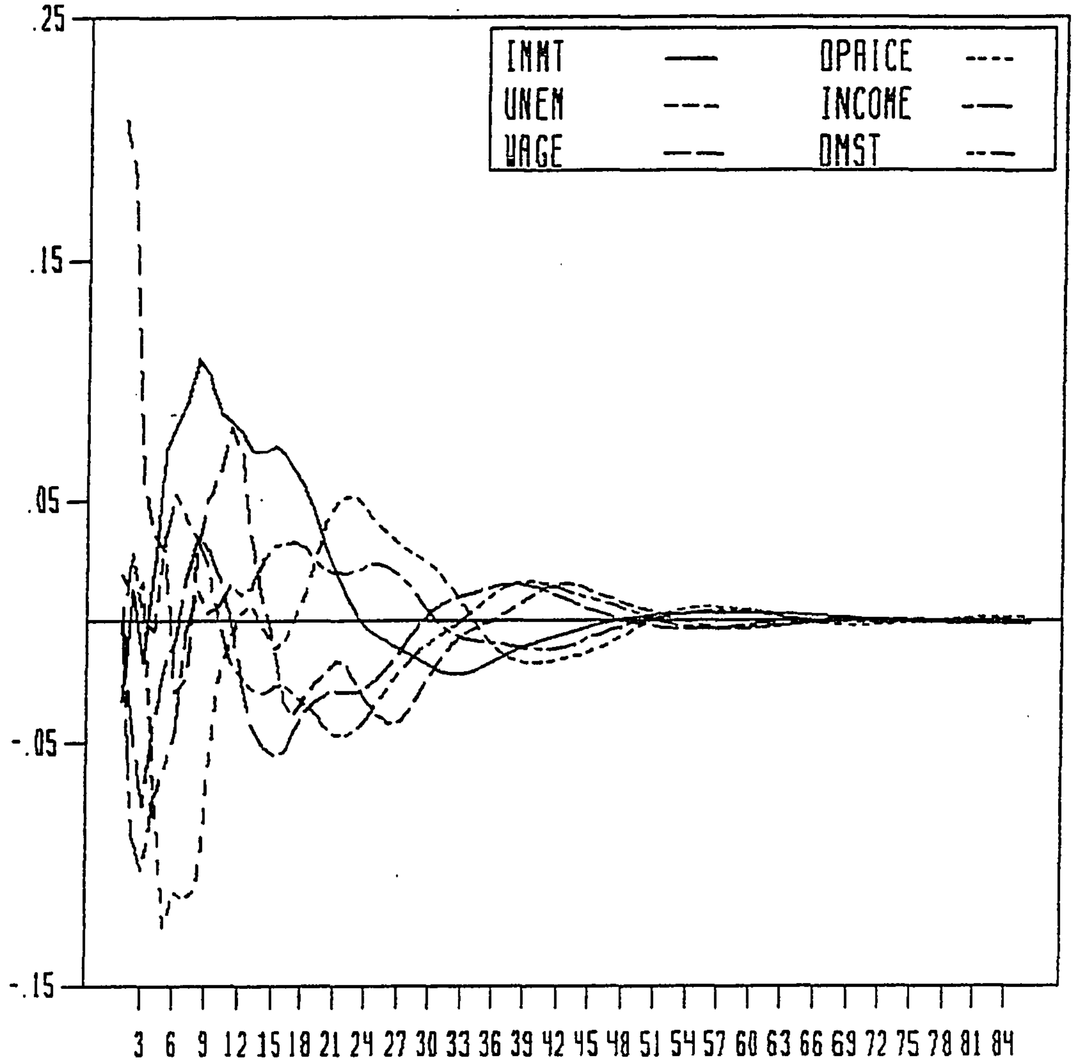

Figure 4-2c. Responses of UNEM to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

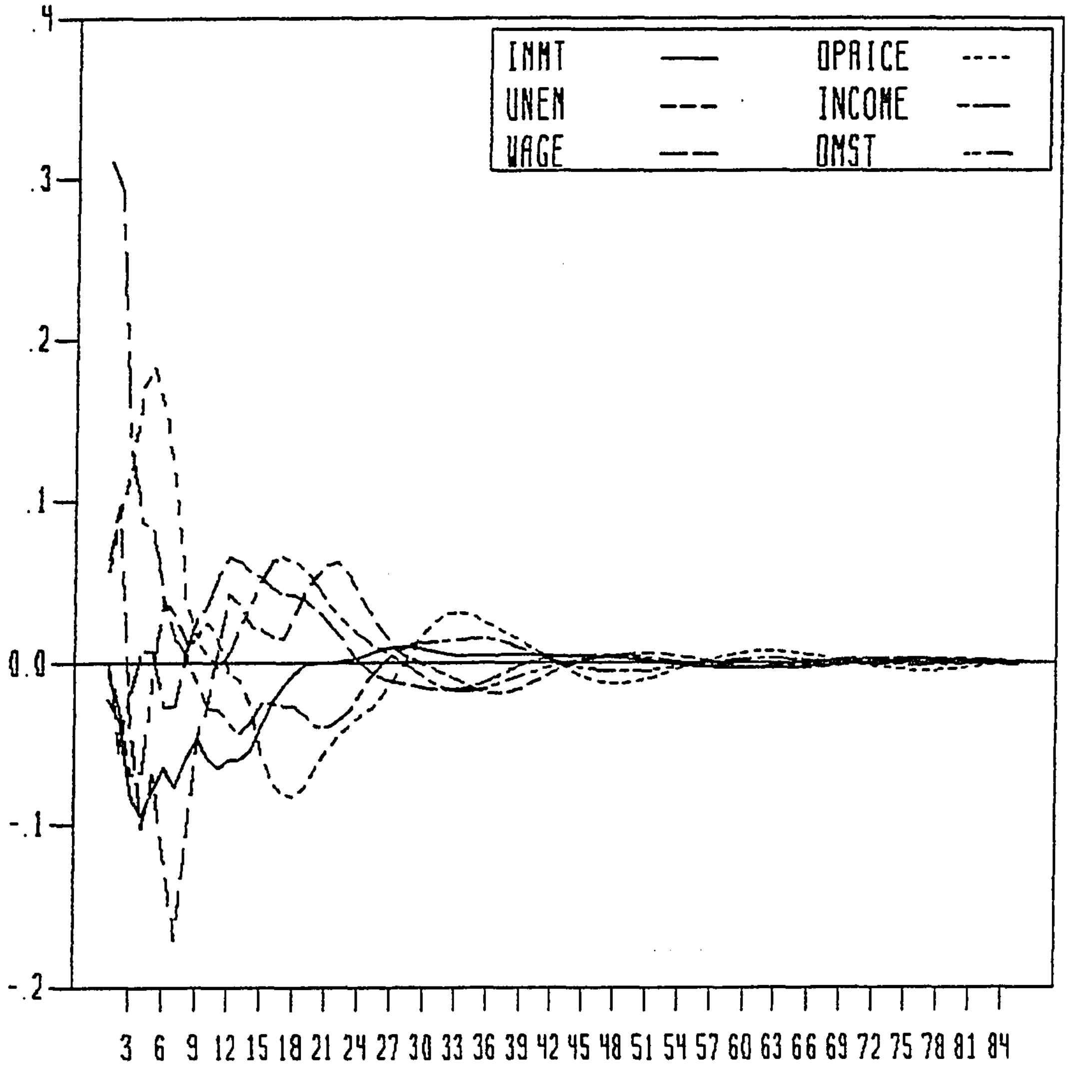

Figure 4-2d. Responses of INCOME to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

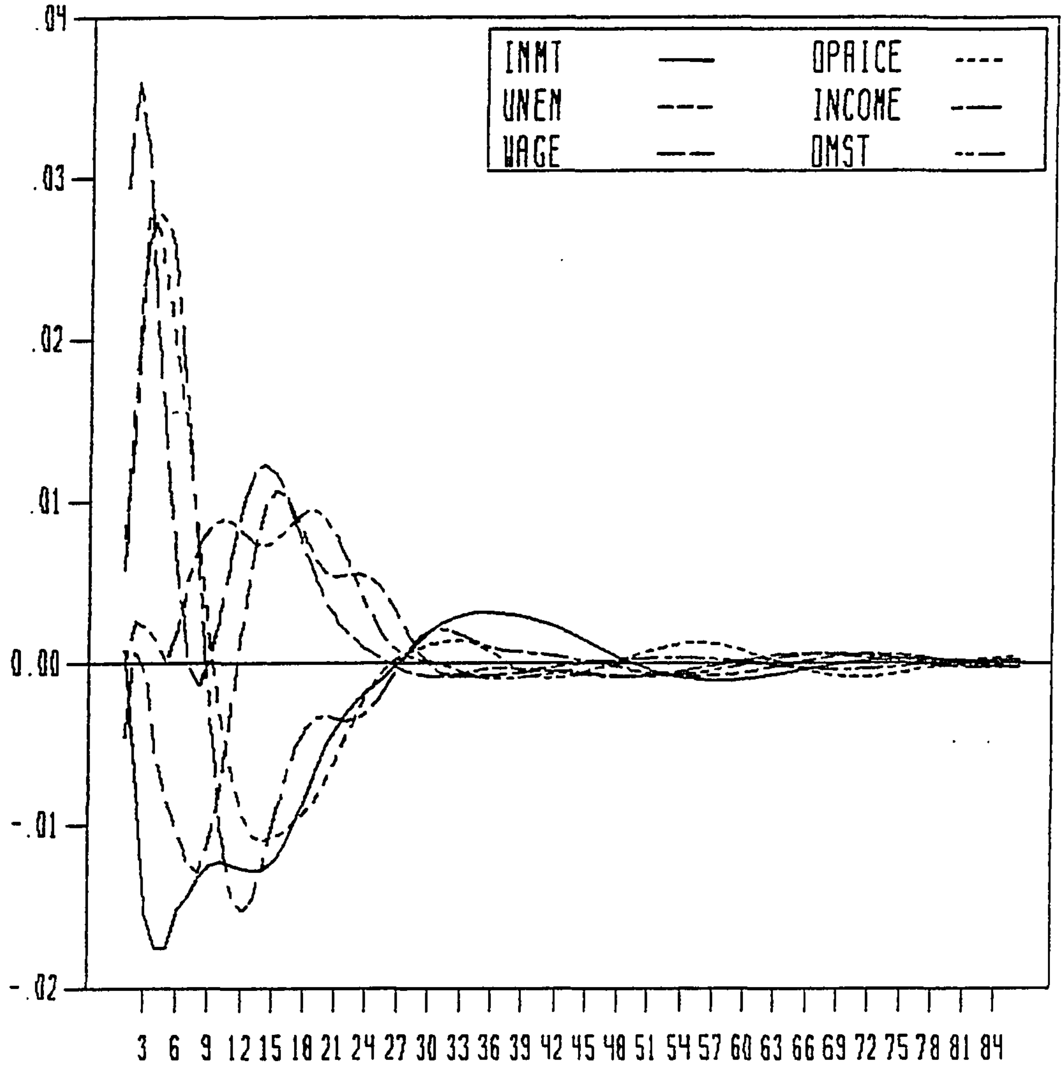

Figure 4-2e. Responses of WAGE to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

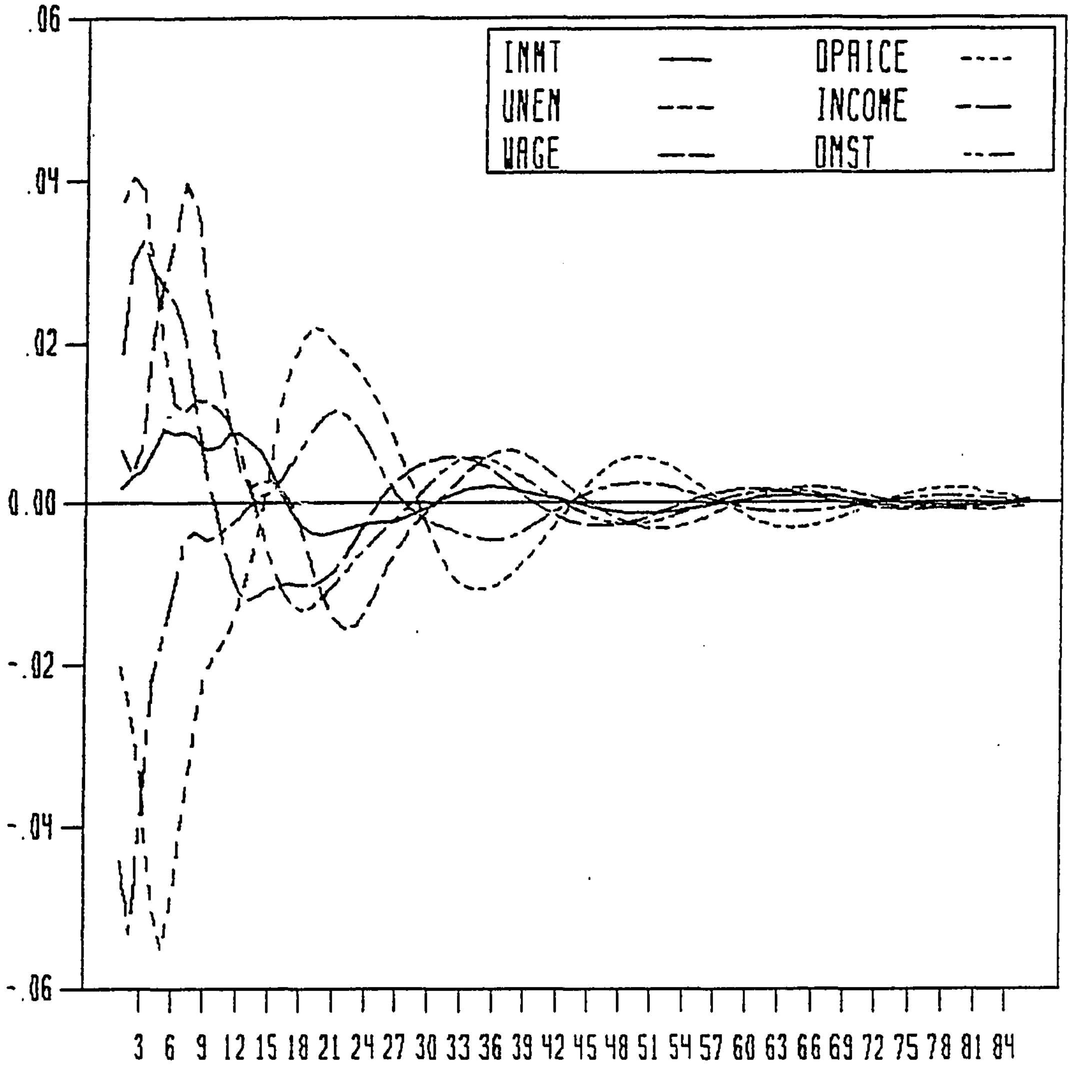

Figure 4-2f. Responses of DMST to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

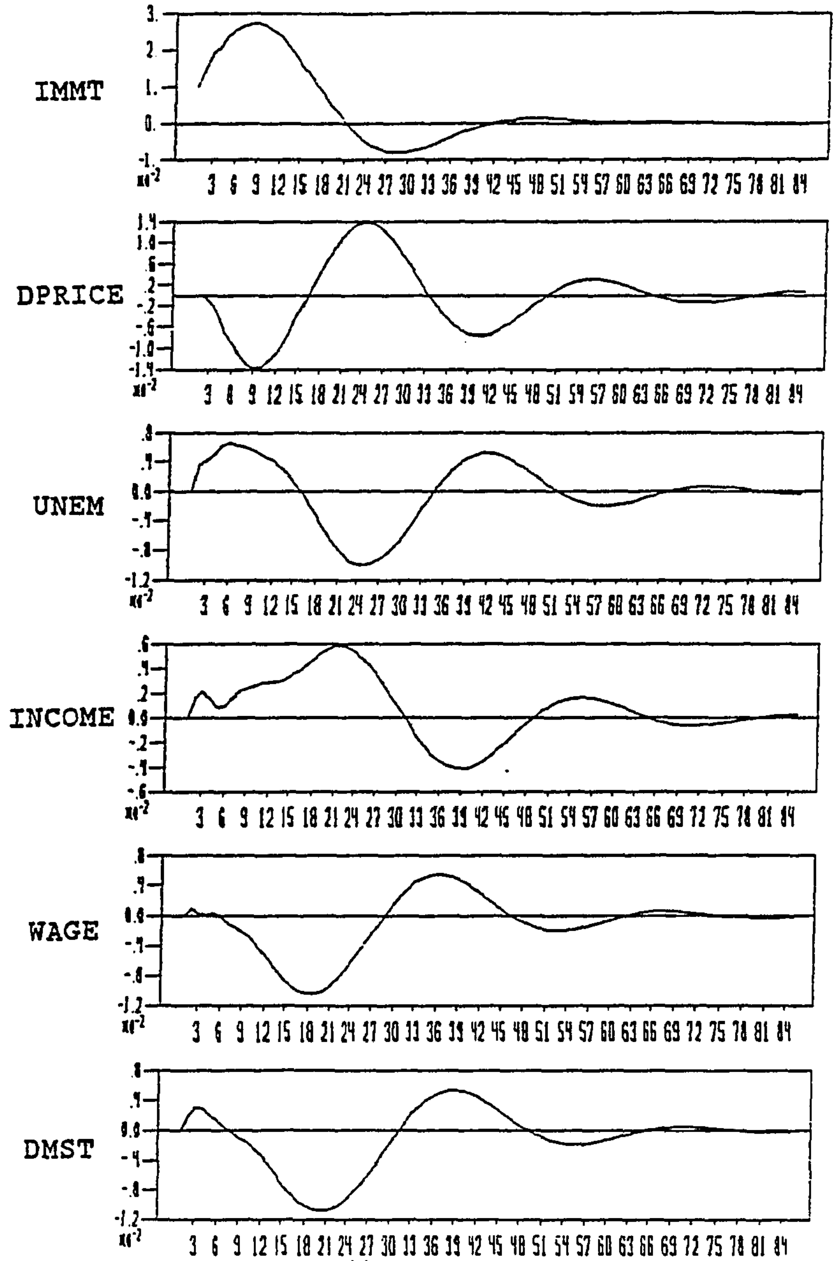

Figure 4-2a'. Responses of IMMT to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

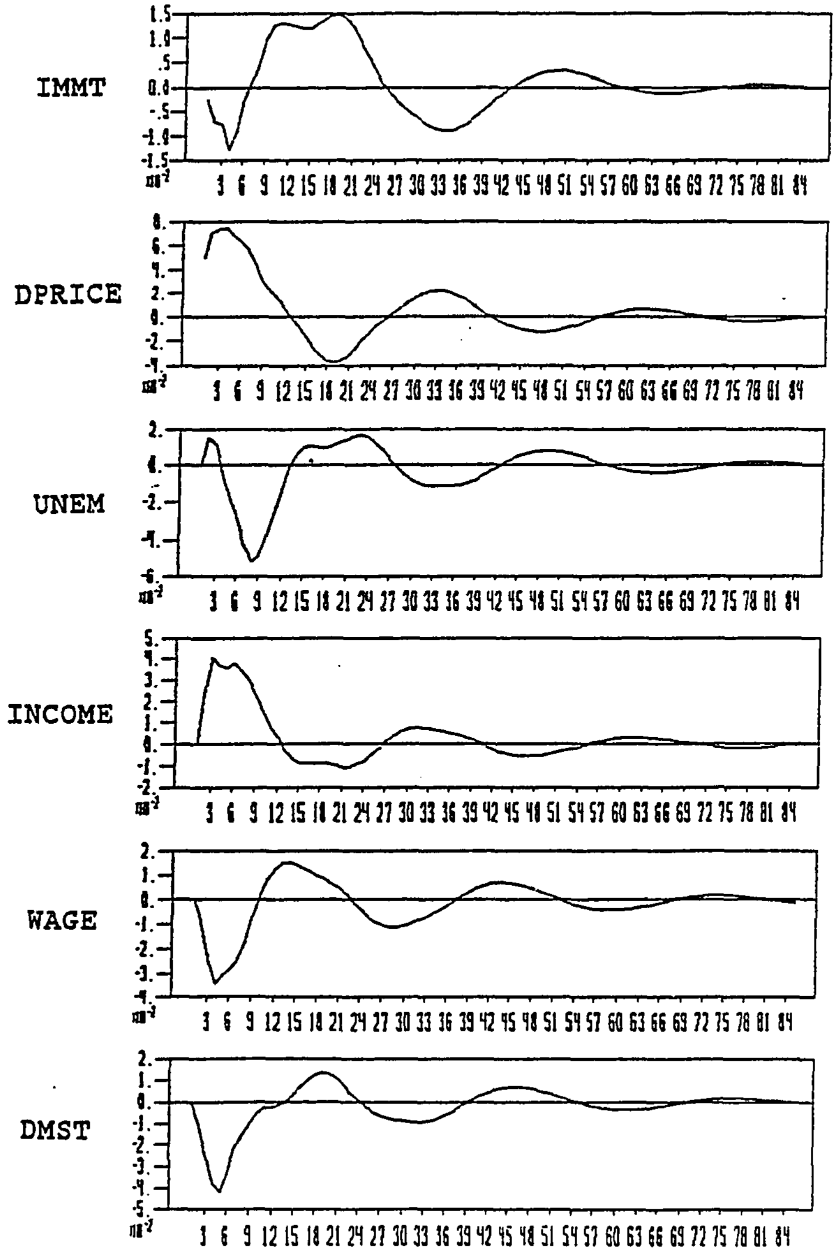

Figure 4-2b'. Responses of DPRICE to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

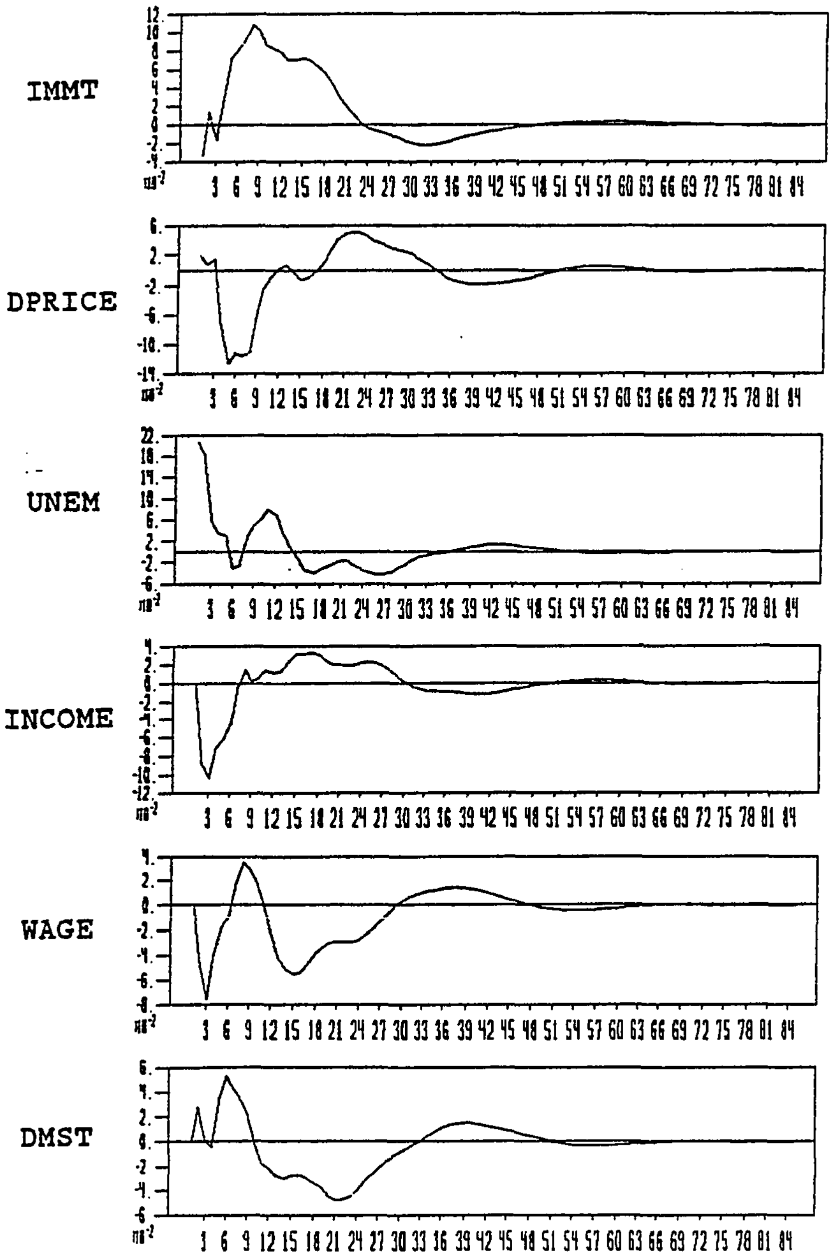

Figure 4-2c'. Responses of UNEM to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

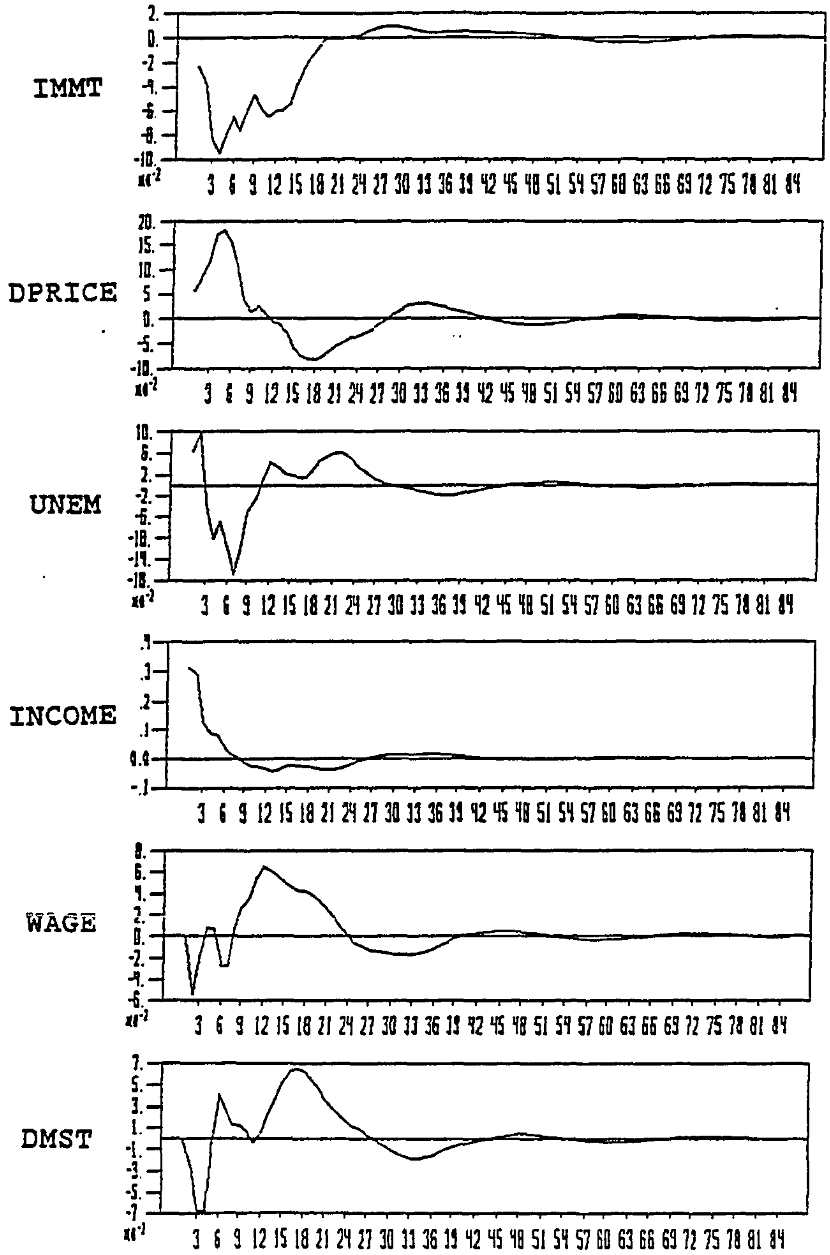

Figure 4-2d'. Responses of INCOME to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

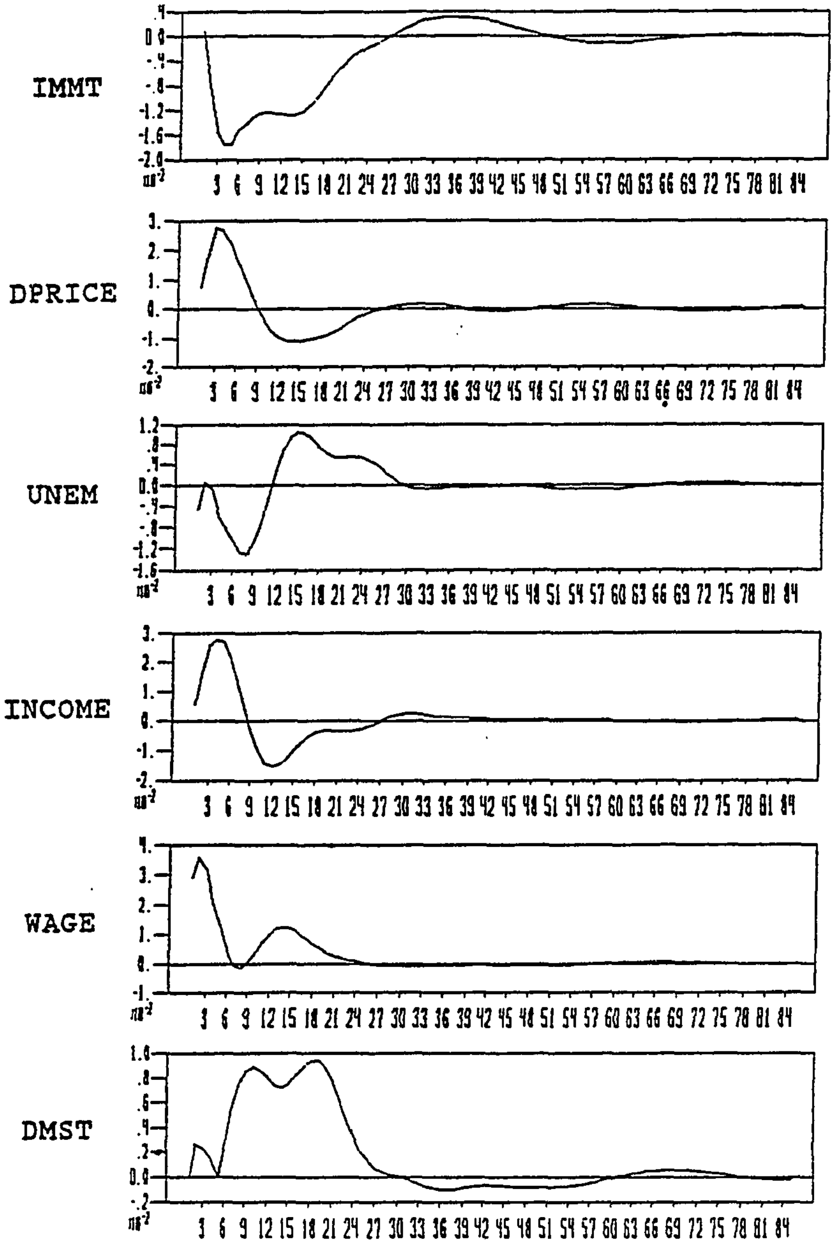

Figure 4-2e'. Responses of WAGE to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

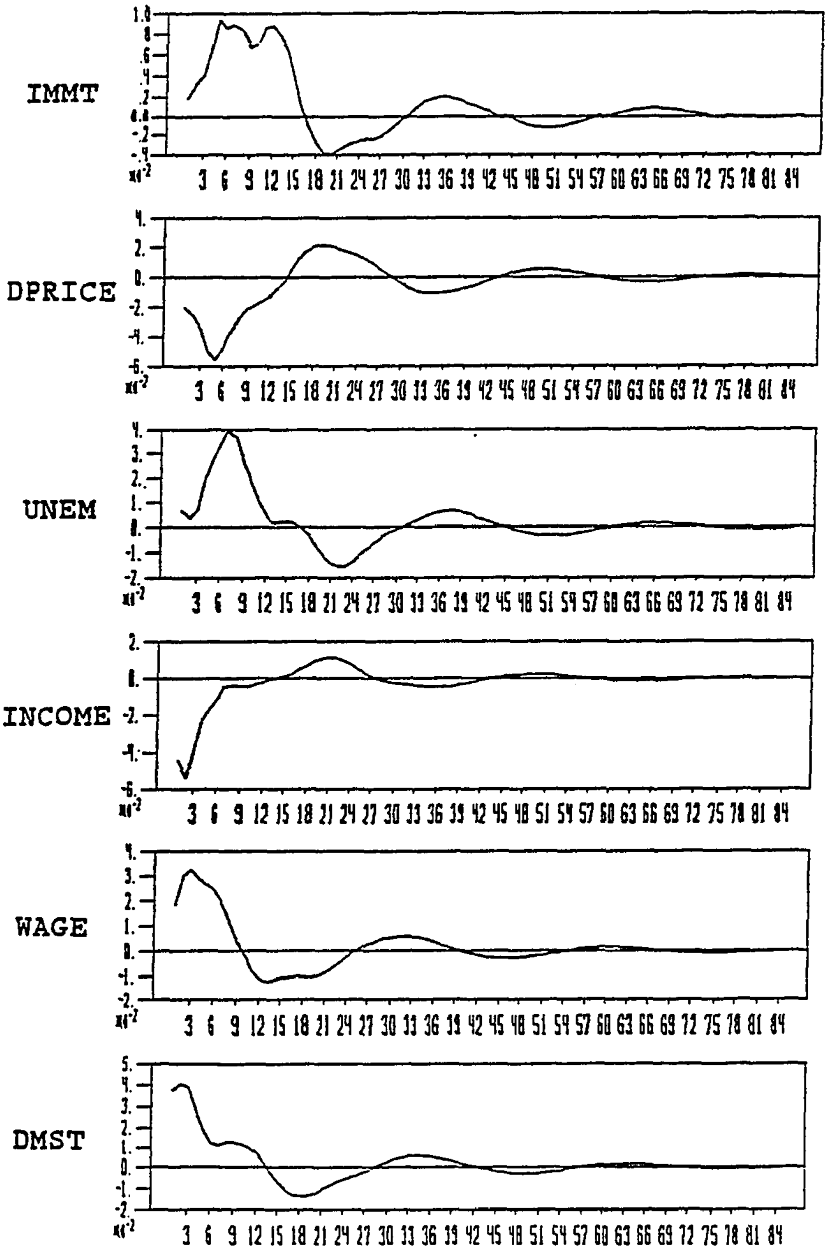

Figure 4-2f'. Responses of DMST to Shocks in IMMT, DPRICE, UNEM, INCOME, WAGE, and DMST

V. DEMAND FOR INPUTS FOR HOUSEHOLD PRODUCTION

A. Introduction

This chapter examines the structure of household demand for a set of inputs used in household production. The set of inputs considered here is "derived" from maximization of a hybrid household-utility function. As shown in Chapter 3, the hybrid utility function results from substituting a household production function into a standard ordinal household utility function (Pollak and Wachter, 1975).

The set of inputs consists of domestic services, services of household durable goods, commercial laundry and cleaning services, food away from home, wife's home time, and residual category. There has been a marked change of expenditure shares of these inputs since 1945 in the United States. Among them, the decreasing trends of shares for domestic services and wife's home time are remarkable. The share of domestic services (wife's home time) in household consumption expenditures has decreased from 1.2 % (19.7 %) in 1947 to 0.34 % (10.1 %) in 1985. The share for services of household durable goods has also decreased after the late 1950s.

For the empirical analysis, an almost-ideal-demand system (AIDS) is developed and estimated. In the specified demand system for inputs, each of the expenditure share equations is a function of the prices of the above inputs, household income (expenditure), and a variable for technical change. The demand system is fitted to U.S. aggregate data for 1948-1985.

Expenditures on the services of household durable goods, rather than on new durable goods, are the correct measure of durables to consider in a household input demand system. In this study, the data on expenditures on the services were obtained and used. The change in concept is shown to be important empirically. The elasticities are much different for expenditures on services than for expenditures on new durable goods.

The chapter is organized as follows. The second section presents the econometric model of household expenditure. The third section details the stochastic specification of the model and estimation procedure. The fourth section contains a discussion of the empirical findings and implications. The final section presents the conclusion.

B. Specification of an Econometric Model

Ever since Richard Stone (1954) first estimated a system of demand equations derived explicitly from consumer demand theory, there has been a continuing search for alternative specifications and functional forms. Many models have been used, but perhaps the most important in current use, apart from the original linear expenditure system, are the Rotterdam model (Theil, 1965, 1976; Barten, 1969) and the translog model

(Christensen, Jorgenson, and Lau, 1975; Jorgenson and Lau, 1975). For more details about surveys and comprehensive treatments of demand systems, see Brown and Deaton (1972), Barten (1977), and Deaton and Muellbauer (1980b). Recently another demand system, so-called Almost Ideal Demand System (AIDS) was proposed by Deaton and Muellbauer (1980a) as a solution to many of shortcomings of the other demand systems. Because of theoretical and empirical advantages, the AIDS has been perceived as a very useful tool in demand analysis (Ray, 1980; Goddard, 1983; Blanciforti and Green, 1983; Barewal and Goddard, 1985; Blanciforti, Green, and King, 1986). In this study, the specification of the household input demand system (3-13) is assumed to be the almost-ideal-demand system.

1. Almost ideal demand system (AIDS)[23]

Along with the theorems of Muellbauer (1975, 1976) which allow the exact aggregation over individual households, AIDS is derived from the necessary and sufficient conditions for the existence of a representative budget level. Thus market

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[23]The name of the system stems from the properties associated with it. Deaton and Muellbauer (1980a, p.312) list the following advantages of the system: 1) it gives an arbitrary first-order approximation to any demand system; 2) it satisfies the axioms of choice exactly; 3) it aggregates perfectly over consumers without invoking parallel linear Engel curves; 4) it has a functional form which is consistent with known household-budget data; 5) it is simple to estimate, largely avoiding the need for non-linear estimation; and 6) it can be used to test the restrictions of homogeneity and symmetry through linear restrictions on fixed parameters.

input demand functions can be represented as if they were the outcome of rational decisions by a representative household. These preferences, known as the PIGLOG (price independent generalized logarithm) class, are represented via the cost or expenditure function which defines the minimum expenditure necessary to attain a specific utility level at given prices. We denote this function c(u,p) for utility u and price vector p, and define the PIGLOG class as

$$\log c(u,p) = (1-u)\log\{a(p)\} + u \log\{b(p)\} \qquad (5\text{-}1)$$

where u lies between 0 (subsistence) and 1 (bliss) so that the positive linearly homogenous functions a(p) and b(p) can be regarded as the costs of subsistence and bliss, respectively. (About this point, see the Appendix of Deaton and Muellbauer (1980a).) Deaton and Muellbauer proposed the following specific functional forms for log a(p) and log b(p),

$$\log a(p) = \alpha_0 + \sum_k \alpha_k \log p_k + \tfrac{1}{2} \sum_k \sum_j r^*_{kj} \log p_k \log p_j \qquad (5\text{-}2)$$

$$\log b(p) = \log a(p) + \beta_0 \prod_k p_k^{\beta_k} \qquad (5\text{-}3)$$

so that the AIDS cost function is written

$$\log c(u,p) = \alpha_0 + \sum_k \alpha_k \log p_k + \tfrac{1}{2} \sum_k \sum_j r^*_{kj} \log p_k \log p_j$$

$$+ u \beta_0 \Pi p_k^{\beta_k}. \tag{5-4}$$

Here α_i, β_i, and r^*_{kj} are parameters. It can easily be checked that c(u,p) is linearly homogenous in p, provided $\sum_i \alpha_i = 1$, $\sum_j r^*_{kj} = \sum_k r^*_{kj} = \sum_j \beta_j = 0$.

The demand functions can be derived from equation (5-4). A fundamental property of the cost function (Shephard, 1953, 1970; Diewert, 1974) is that its price derivatives are the demand functions: $\partial c(u,p)/\partial p_i = q_i$. Multiplying both sides by $p_i/c(u,p)$ we obtain

$$\partial \log c(u,p)/\partial \log p_i = p_i q_i / c(u,p) = w_i \tag{5-5}$$

where w_i is the budget share of input i. Hence, logarithmic differentiation of (5-4) gives the budget shares as a function of prices and utility:

$$w_i = \alpha_i + \sum_j r_{ij} \log p_j + \beta_i u \beta_0 \Pi p_k^{\beta_k} \tag{5-6}$$

where

$$r_{ij} = ½ \, (r^*_{ij} + r^*_{ji}). \tag{5-7}$$

For a utility-maximizing household, total expenditure E is equal to c(u,p), and when c(u,p) is a single valued function, this equality can be solved for u as a function of p and E, the indirect utility function. If we do this for (5-4) and substitute the result into (5-6) we have the budget shares as a function of p and E; these are the AIDS demand functions in the budget share form:

$$w_i = \alpha_i + \sum_j r_{ij} \log p_j + \beta_i \log(E/P) \qquad (5\text{-}8)$$

where P is a price index defined by

$$\log P = \alpha_0 + \sum_k \alpha_k \log p_k + \tfrac{1}{2} \sum_j \sum_k r^*_{kj} \log p_k \log p_j. \qquad (5\text{-}9)$$

The restrictions on the parameters of (5-4) plus equation (5-7) imply restrictions on the parameters of the AIDS equation (5-8). The three sets of conditions are:

$$\sum_i \alpha_i = 1, \; \sum_i r_{ij} = 0, \; \sum_i \beta_i = 0, \qquad (5\text{-}10)$$

$$\sum_j r_{ij} = 0, \qquad (5\text{-}11)$$

$$r_{ij} = r_{ji}. \qquad (5\text{-}12)$$

Provided (5-10), (5-11), and (5-12) hold, equation (5-8) represents a system of demand functions which add up to total expenditure ($\Sigma w_i = 1$), are homogenous of degree zero in prices and total expenditure taken together, and which satisfies the Slutsky symmetry conditions.

C. Estimation

1. Specification of an econometric model

In general, a function form that can be fitted to data can be obtained by substituting (5-9) into (5-8) to give

$$w_i = (\alpha_i - \beta_i\alpha_0) + \sum_j r_{ij}\log p_j + \beta_i\{\log E - \sum_k \alpha_k \log p_k - \tfrac{1}{2}\sum_k \sum_j r_{kj}\log p_k \log p_j\}. \tag{5-13}$$

Estimates of the parameters, i.e., αs, rs, βs, in this non-linear system of equations can be obtained by applying the maximum likelihood methods. (Note that since the data add up by construction, (5-10) is not testable.) As Deaton and Muellbauer (1980a) suggest, it is possible to exploit the collinearity of the prices to obtain a much simpler empirical equation. Note from (5-8) that if P were known, the model would be linear in the parameters α, β, and rs, and estimation (at least without cross-equation restrictions such as symmetry) can be done equation-by-equation by applying OLS. Given normally distributed errors, OLS is equivalent to maximum likelihood estimation for the system as a whole. The adding-up constraints (5-10) will be automatically satisfied by these estimates. In situations where prices are closely collinear, it may well be adequate to approximate P as proportional to some known, price index, say P^*. The obvious candidate in view of (5-8) and (5-9) is Stone's (1953) index,

$\log P^* = \sum_k w_k \log p_k$. If $P \approx \phi P^*$, then (5-8) can be written as

$$w_i = (\alpha_i - \beta_i \log\phi) + \sum_j r_{ij} \log p_j + \beta_i \log(E/P^*). \quad (5\text{-}14)$$

In equation (5-14) this framework, the α_i parameters are identified only up to a scalar multiple of β_i. If we write α_i^* $= (\alpha_i - \beta_i \log\phi)$, it is easily seen that $\sum_k \beta_k = 0$ implies $\sum_k \alpha_k = 1$.[24] The empirical work below is based on a linear approximation to (5-14).

In this study, a household expenditure system for household inputs is proposed that incorporates the technology of household production and female labor force participation behavior. However, these data are not recorded in the national accounts. To proceed, a proxy is derived. The implicit expenditure for women's home time (EXP_{hp}) is obtained from the following formula:

$$EXP_{hp} = (1 - FLFR)\, W_f \quad (5\text{-}15)$$

where FLFR is the (married) female labor participation rate, and W_f is the female earnings.

[24] Many studies, notably Ray (1980), Blanciforti and Green (1983), Blanciforti, Green, and King (1986), Goddard (1983), as well as Deaton and Muellbauer (1980a) have reported success using this linear approximation, especially in case of time series data analysis.

In the demand system, an "environmental variable" is additional which proxies the technical change in household production. In household production, a significant share of technical change is "embodied". The embodied technical change will appear in household durable inputs that households purchased. This effect is implicitly incorporated in the model through the prices of services of durable goods. "Disembodied" technical change represents an increase in real household income, although relative prices and real cash income (expenditures) are held constant. Disembodied technical change could be proxied by the patenting activity of consumer goods in the United States. With both technology and prices included in the demand system, we can attempt to identify their separate effects on household resource allocation.

The technology variable may also to solve some statistical problems encountered in empirical demand studies. Deaton and Muellbauer (1980a) found that imposing homogeneity restrictions introduced serial correlations in the disturbances of the demand equations, and lead to a rejection of homogeneity. They argued that such a phenomenon occurred due to the misspecification of the model caused by omitting some relevant variables, such as lagged dependent variables, or time trends. The hypothesis presented here is that the left-out variable is proxied by inventive activity.

Finally, the econometric model to be estimated is specified as follows:

$$w_i = \alpha_i^* + \sum_j r_{ij} \log p_j + \beta_i \log(E/P^*) + \delta_i \log T + e_i, \quad i = 1, 2, \ldots, 6, \qquad (5\text{-}16)$$

where i represent a particular household input group, and T stands for technology in household production.

2. Data

Annual data for the years 1948 to 1985 are used for the empirical work. Earlier data are excluded from the analysis because the Great Depression and World War II years present unusual circumstances.

All consumption expenditure series, except the value of services of household durable goods and the implicit expenditure for wife's home time, come from the National Income and Products Accounts (NIPAs) published by the U.S. Department of Commerce. The female earning data were taken from the Current Population Survey (CPS).

a. The value of services provided by the stock of household durable goods.[25] There are two general approaches to the measurement of the value of services of household

[25]The discussion in this part heavily depends upon Katz (1982, 1983) and Katz and Peskin (1980). I am thankful to Arnold Katz for providing the basic materials and giving valuable suggestions.

durable goods: (i) the opportunity cost measure, and (ii) the user-cost measure. In both measures, the value of services is estimated by summing the costs incurred by the owner of the durable goods.

In the opportunity cost measure, the rate of return, which reflects the productivity of capital, is applied to the average value of the net stock to derive a net return, and depreciation and operating costs (e.g., expenditures on repair and maintenance) are added. In terms of a single durable, this measure can be expressed in the following form:

$$C_{s,t} = r_t (P_{s,t} + P_{s+1,t+1})/2 + D_{s,t} + O_{s,t} \qquad (5\text{-}17)$$

where $C_{s,t}$ is the service value of an s year old durable in year t, r_t is the average rate of return in year t, $P_{s,t}$ is the purchase price of an s year old durable at the beginning of year t, $D_{s,t}$ is depreciation on an s year old durable in year t, and $O_{s,t}$ are operating costs associated with an s year old durable in year t.

The user-cost measure provides an estimate of the market rental price based on costs of owners. It is directly derived from the principle that the purchase price of a durable equals the discounted present value of its expected future benefits. This measure can be expressed in the following form:

$$C^e_{s,t} = r^e_t P_{s,t} + (P_{s,t} - P^e_{s+1,t+1}) \qquad (5\text{-}18)$$

where $C^e_{s,t}$ is the expected serve value of an s year old durable in year t, r^e_t is the expected rate of return in year t, and $P^e_{s+1,t+1}$ is the expected purchase price of this durable at the beginning of year t+1 when it is s+1 years old. Equation (5-18) states that in equilibrium the annual service value that a household expects to receive from owing a durable equals the costs that the household expects to bear from not selling it at the beginning of the year, i.e., foregone interest, plus the expected decline in the market value of the durable during the year. The expected decline in purchase price is usually partitioned into expected depreciation and expected capital losses, where the capital loss (gain) component represents the change in the price of asset due to changes in the price levels.

In this study, the user-cost measure is employed to estimate the service value of durable goods. User cost measure has advantages such as: i) the basic data are relatively easier to obtain with small measurement errors, and ii) it is possible to consider the price expectations into the household decisions for purchasing durable goods. The procedures are explained in detail in Katz (1982, 1983). As Katz reported, the series of service values are affected by using different assumptions about some procedures of estimations, such as the relative efficiency (the ratio of service value of an old durable to that of a new durable) and expected inflation. The series actually employed for the empirical analysis is obtained assuming that the relative efficiency of capital is decreasing geometrically, and the household's expectation of inflation is "adaptive".

The definitions and the items covered in the six household expenditure groups are summarized in Table 5-1.

The implicit price series are obtained by dividing current dollar expenditures for each input by the constant dollar magnitude. A proxy for technology in the household sector is the cumulative number of U.S. household-related patents, which were supplied by the U.S. Patent and Trade Mark Office.[26]

In the AIDS model, the dependent variables in the demand system are the expenditure weights of each input group. The Figure 5-1 presents the basic trends of the weights over the period 1948-1985. In the Figure, the expenditure shares for wife's home time, domestic services, and commercial cleaning and laundry services are decreasing over time. The share for services of durable goods is also decreasing after the late 1950s. No apparent trend exists for the expenditure share on food away from home.

[26]The number of patents used in this study are the ones granted by the U.S. Patent Office. Some of them are foreign patents. The share of foreign patents is not significant, but it is increasing steadily.

Table 5-1. Expenditure Groups and Definitions

Expenditure Group i	Classification in NIPA	Definitions
(1) Domestic Services	Domestic Service	Expenditures on purchasing household operation service by domestic (private) household workers, excluding child care workers.
(2) Durables Services		Services provided by the Stock of household durables, estimated by eq. (5-18).
	i) Kitchen and other household appliances ii) China, glassware tableware, and utensils	i) Includes refrigerators, freezers, cooking ranges, dish washers, laundry equipments, heater, air conditioners, sewing machines, vacuum cleaners, other electric appliances.
	iii) Other durable house furnishing	iii) Includes principal house furnishings such as floor covering, hand, power and garden tools.
(3) Cleaning and Laundry services	i) Cleaning, storage, and repair of clothing and shoes ii) Other clothing	Expenditures for cleaning, laundering, storage, repair, and miscellaneous personal services related to clothing.
(4) Food away from Home	Purchased meals and beverages	Expenditures for purchases of meals and beverages from retail, services, and hotel, school, institutions, and industrial lunchrooms, and also tips.
(5) Expenditure on Wife's Home Time		Implicitly obtained by the formula (5-15).
(6) Residual Consumption Expenditure		Total consumption expend. plus (2) minus expend. on durables, (1), (3), (4), and (5).
Total Consumption Expend. in this study		(1) + (2) + (3) + (4) + (5) + (6)

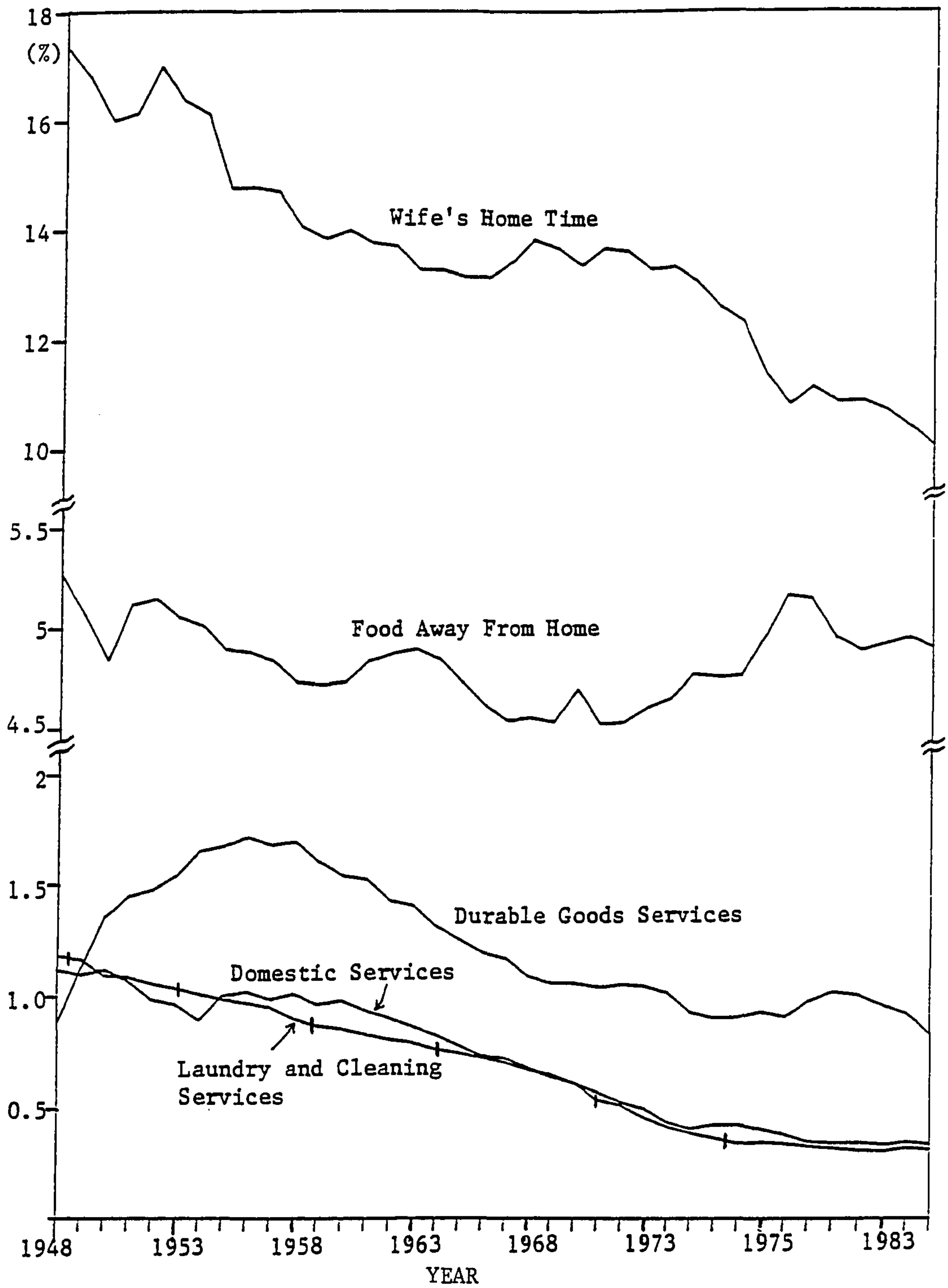

Figure 5-1. Trends of Household Expenditure Shares

D. Empirical Results and Implications[27]

In this section, we examine estimates of the household input demand system that is fitted to U.S. aggregate data. Table 5-2 reports the results from fitting equation (5-16) when constraints on the parameters are not imposed. In the column headed $\sum_j r_{ij}$, the row sums of the unconstrained r_{ij} matrix shows 10^2 times the absolute effect on each expenditure share of a 1 % increase in all prices and total expenditure. Under homogeneity, this number should be zero. For the durable goods services and food consumption away from home, homogeneity is rejected at 5 % significance level among the six equations. For the other input groups, the coefficients are each not significantly different from zero at 5 % level. The results imply that a proportional increase in prices and income or expenditure increases the demand for household durable goods services and food consumption away from home. This results support the notion that adding conditioning variables (T which represents technology in this study) contributes to the acceptance of the homogeneity hypothesis. Table 5-3 reports the parameter estimates when the homogeneity restrictions are imposed in the estimation process.

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[27]In this study, we also estimated the specified demand system (5-16) using the expenditure on the household durable goods. The results are reported and interpreted briefly in Appendix 5.2. Both results are largely consistent with each other except the equation of value of services provided by the household durable goods stock. For more details, see Appendix 5.2.

Table 5-2. Unconstrained Maximum Likelihood Estimates of the Household Expenditure System, U.S., 1948-1985

Input/ Equation i	Coefficients				
	α_i	r_{i1}	r_{i2}	r_{i3}	r_{i4}
(1) Domestic Service	0.02277 (0.39)[a]	-0.00137 (-0.52)	0.00194 (1.21)	0.00555 (1.58)	-0.00428 (-0.65)
(2) Durables Service	-0.03069 (-0.76)	-0.00303 (-1.69)	0.01102 (9.98)	-0.00932 (-3.86)	0.00273 (0.60)
(3) Cleaning, Laundry	0.08856 (3.72)	-0.00436 (-3.30)	-0.00015 (-0.23)	0.00595 (4.22)	-0.00963 (-3.63)
(4) Food away from Home	0.59567 (3.99)	-0.00648 (-0.99)	-0.00580 (-1.43)	0.00552 (0.63)	0.00797 (0.48)
(5) Wife's Home Time	1.38564 (2.01)	0.00744 (0.25)	-0.03433 (-1.84)	-0.04723 (1.16)	-0.02517 (-0.33)
(6) Residual Consum.	-1.06177 (-1.60)	0.00689 (0.24)	0.02733 (1.52)	0.03952 (1.00)	0.02839 (0.38)

[a]The t-ratios are in parentheses.

r_{i5}	r_{i6}	β_i	δ_i	$\sum_j r_{ij}$	R^2	D-W
-0.01071	0.00513	-0.00342	0.00265	-0.00006	0.98	2.00
(-1.27)	(1.27)	(-0.70)	(0.37)	(-1.38)		
0.01927	-0.01653	-0.01053	0.00986	0.00006	0.99	1.05
(3.30)	(-5.93)	(-3.12)	(1.98)	(2.11)		
0.00593	0.00065	0.00438	-0.01027	-0.00001	0.99	2.12
(1.74)	(0.40)	(2.22)	(-3.53)	(-0.67)		
0.03859	-0.01919	0.01529	-0.06481	-0.00031	0.99	1.67
(1.81)	(-1.88)	(1.24)	(-3.57)	(2.72)		
0.02049	0.05714	0.00330	-0.09577	-0.00032	0.99	1.92
(0.21)	(1.21)	(0.06)	(-1.14)	(-0.70)		
-0.07357	-0.02720	-0.00903	0.15834	0.00002	0.99	2.01
(-0.78)	(-0.60)	(-0.16)	(1.95)	(0.05)		

Table 5-3. Maximum Likelihood Estimates of the Household Expenditure System, Homogeneity Restrictions Imposed, U.S., 1948-1985

Input/ Equation i	Coefficients				
	α_i	r_{i1}	r_{i2}	r_{i3}	r_{i4}
(1) Domestic Service	0.07893 (1.79)[a]	-0.00193 (-0.74)	0.00276 (1.83)	0.00666 (1.93)	-0.00084 (-0.14)
(2) Durables Service	-0.09317 (-2.92)	-0.00240 (-1.27)	0.01010 (9.22)	-0.01055 (-4.21)	-0.00108 (-0.24)
(3) Cleaning, Laundry	0.09920 (5.72)	-0.00357 (-3.48)	0.00001 (0.01)	0.00616 (4.53)	-0.00898 (-3.68)
(4) Food away from Home	0.28520 (2.30)	-0.00333 (-0.45)	-0.01037 (-2.44)	-0.00061 (-0.06)	-0.01102 (-0.63)
(5) Wife's Home Time	1.71201 (3.41)	0.00413 (0.14)	-0.02953 (-1.72)	-0.04079 (-1.04)	-0.00521 (-0.07)
(6) Residual Consum.	-1.08217 (-2.25)	0.00710 (0.25)	0.02703 (1.64)	0.03912 (1.04)	0.02714 (0.40)

[a]The t-ratios are in parentheses.

r_{i5}	r_{i6}	β_i	δ_i	R^2	D-W
-0.00657	-0.00009	0.00022	-0.00646	0.99	2.02
(-0.82)	(-0.06)	(0.05)	(-2.03)		
0.01467	-0.01074	-0.01457	0.01997	0.99	1.30
(2.52)	(-9.20)	(-4.78)	(8.68)		
0.00672	-0.00034	0.00507	-0.01200	0.99	2.26
(2.12)	(-0.53)	(3.06)	(-9.59)		
0.01566	0.00966	-0.00484	-0.01444	0.99	1.41
(0.69)	(2.13)	(-0.41)	(-1.62)		
0.04460	0.02681	0.02447	-0.14871	0.99	1.92
(0.49)	(1.46)	(0.51)	(-4.11)		
-0.07508	-0.02530	-0.01035	0.16164	0.99	2.01
(-0.86)	(-1.44)	(-0.23)	(4.67)		

When symmetry of r_{ij} is imposed on the equation system, the expenditure equations must be estimated jointly and not equation-by-equation.[28] Because the dependent variables sum to unity across the equations, the variance-covariance matrix is singular for the m equations system. This means that one equation can be deleted from the system of equations, and estimates of the coefficients can be recovered from the coefficients of the other m-1 equations. When the coefficients of the m-1 equations are estimated by full-information maximum likelihood or iterative seemingly unrelated methods, the estimates are unaffected by the choice of the equation to delete (Barten, 1969; Kmenta and Gilbert, 1968).

The null hypothesis that all symmetry conditions hold jointly can not be rejected at the 5 % significance level.[29]

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[28] Deaton and Muellbauer (1980a) noted that it is a matter of choice to impose symmetry when homogeneity is rejected. Mizon (1977) criticized this procedure and suggested that optimal inference requires that further testing be abandoned as soon as a rejection is encountered. But this criticism would be correct if we were certain of the maintained hypothesis. Many economists would choose not to test homogeneity, treating absence of money illusion as a maintained hypothesis.

[29] The symmetry hypothesis can be tested using the chi-square (X^2) statistic

$$N\ (\ln /\Sigma_R/ - \ln /\Sigma_R/) \sim X^2\ (df),$$

where $/\Sigma_R/$ and $/\Sigma_U/$ are the determinants of the covariance matrices of restricted and unrestricted models, respectively, and N is the number of observations and df is the number of degrees of freedom which equals the number of restrictions imposed.

The sample value of chi-square (X^2) is 10.0 and the critical value with 10 degrees of freedom at the 5 % significance level is 18.3. Table 5-4 reports the results homogeneity and symmetry restrictions are imposed.

The interpretation of the parameters of the AIDS model are as follows; the estimated r_{ij}s represent 10^2 times the effect on the i-th expenditure (budget) share of a 1 % change in the price of the j-th input, holding "real" expenditure (E/P) constant. The estimates of the r_{ij}s are in general positive for substitutes and negative for complements, and the r_{ij}s are positive for price-inelastic inputs and negative for price-elastic inputs. Luxury inputs are identified by a positive β_i; necessities have negative β_is.

The price, expenditure, and technology elasticities for the AIDS model are defined in equations (5-20) - (5-23).

$$e_{ii} = -1 + r_{ii}/w_i - \beta_i \tag{5-20}$$

$$e_{ij} = (r_{ij} - \beta_i w_j)/w_i \tag{5-21}$$

$$e_{iE} = 1 + \beta_i/w_i \tag{5-22}$$

$$e_{iT} = \delta_i/w_i \tag{5-23}$$

where e_{ii}, e_{ij}, e_{iE}, and e_{iT} are the own-price, cross-price, expenditure, and technology elasticities, respectively. The NIPA implicit deflator, a Paasche Index, is used for P^*. (For derivations, see Appendix 5.1.)

The estimates of the price, expenditure, and technology elasticities for this data set are presented in Table 5-5. The coefficients were taken from Table 5-4, and sample mean values of the w_i's were employed. The estimates in the Tables 5-4 and 5-5 are reasonable. All own-price elasticities (regression coefficients) have the right signs and 17 (20) out of the 35 regression coefficients are statistically significant at 5 % (10 %) level. The technology variable -- the cumulative number of patents for household-related goods -- has regression coefficients that are generally significantly different from zero.

The estimates of β_i classify domestic services, cleaning and laundry services, and wife's home time as luxuries, but services of household durable goods, and food consumption away from home as necessities.[30] Within this six input expenditure system, the luxury-necessity classification is reasonable. As general economic growth occurs, productive activities are shifted from the household to the market sector and other outside activities, e.g., social activities, travelling.

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[30]This classification scheme applies only to the six commodity system, i.e., the weight summation of the expenditure elasticities for these six commodities sum to one. The luxury-necessity classification might be different if more commodities were included.

Table 5-4. Maximum Likelihood Estimates of the Household Expenditure System, Homogeneity and Symmetry Restrictions Imposed, U.S., 1948-1985

Input/ Equation i	Coefficients			
	α_i	r_{i1}	r_{i2}	r_{i3}
(1) Domestic Service	0.08530 (2.27)[a]	-0.004048 (-1.75)	0.000845 (0.73)	-0.003432 (-3.92)
(2) Durables Service	-0.05207 (-1.45)	0.000845 (0.73)	0.009671 (7.98)	0.000350 (0.66)
(3) Cleaning, Laundry	0.09165 (5.59)	-0.003432 (-3.92)	0.000350 (0.66)	0.005105 (4.31)
(4) Food away from Home	0.19998 (1.91)	-0.001384 (-0.31)	-0.006579 (-2.08)	-0.008442 (-3.91)
(5) Wife's Home Time	1.01190 (5.26)	0.009759 (1.75)	0.005457 (1.27)	0.006631 (2.33)

[a]The t-ratios are in parentheses.

r_{i4}	r_{i5}	β_i	δ_i	R^2	D-W
-0.001384 (-0.31)	0.009759 (1.75)	0.001306 (0.33)	-0.007749 (-3.07)	0.94	1.71
-0.006579 (-2.08)	0.005457 (1.27)	-0.014810 (-5.00)	0.016820 (7.05)	0.95	1.17
-0.008442 (-3.91)	0.006631 (2.33)	0.004833 (3.12)	-0.011190 (-9.99)	0.99	2.13
-0.007956 (-0.49)	0.012990 (0.70)	-0.006161 (-0.55)	-0.006528 (-0.95)	0.96	1.50
0.012999 (0.70)	-0.080190 (-2.71)	0.031920 (1.03)	-0.099620 (-5.41)	0.96	1.70

Table 5-5. Estimates Price, Expenditure, and Technology Elasticities of Demand for Inputs in the Household Expenditure System, U.S., 1948-1985

Input/ Equation i	Prices					Expen- diture	Tech- nology
	p_1	p_2	p_3	p_4	p_5		
(1) Domestic Service	-1.561	0.115	-0.476	-0.200	1.324	1.181	-1.089
(2) Durables Service	0.078	-0.190	0.037	-0.482	0.616	0.878	1.374
(3) Cleaning, Laundry	-0.496	0.042	-0.274	-1.242	0.854	1.692	-1.632
(4) Food away from Home	-0.028	-0.134	-0.173	-1.161	0.284	0.873	-0.135
(5) Wife's Home Time	0.070	0.037	0.047	0.083	-1.616	1.233	-0.735

Also, the females' labor force participation rate is generally increased. Such economic growth has resulted in changes in the traditional food consumption patterns, i.e., from home prepared meals to restaurant prepared meals. The results in this study is consistent with a Canadian study (Goddard, 1983).

The expenditure share for wife's home time is increased as total household expenditures increase. The share decreases as the wage rates for female increases. However, the increased real household income (expenditure) increased the total quantity demanded of wife's home time, other things equal, i.e., the demand curve shifted to the right. The second result shows that household production-consumption becomes relatively less female-time intensive when the opportunity cost of their time increases. It also implies that the demand curve for wife's home time has a negative slope. In fact the wage elasticity of demand for women's time is quite large, -1.62, showing that households are very responsive to the opportunity cost of women's time.

Both the own-price and expenditure elasticities of demand for domestic services are large. The own-price elasticity is -1.56, and the expenditure elasticity is 1.18. The cross price coefficients and elasticities show that household durable goods services (e_{12} = 0.12) and wife's home time (e_{15} = 1.32) are substitutes for domestic services, and cleaning and laundry services (e_{13} = -0.48) and food consumption away from home (e_{14} = -0.20) are complements to domestic services. The complementary relationships may seem surprising, but the determination is an empirical rather than a theoretical issue.

The main reason for employing domestic (private) household workers is for housekeeping, mainly house cleaning and miscellaneous household operation, for the working married women, or for old, disabled persons. The expenditure on cleaning and laundry is tied to clothing, not with other household operations. Moreover the major portion of the expenditure is for high quality laundry services (e.g., dry cleaning) which is an unlikely substitute for domestic services. Thus, the increasing real wage rates and labor force participation of women has resulted in changes in household demand for inputs so that domestic services and cleaning-and-laundry services are complements in household production. A similar line of reasoning can be applied to explain the complementary relationships between domestic services and food away from home.

The disembodied technical change in the household production which is proxied by an increase in patenting activity for consumer goods, has caused the budget share for domestic services to decrease. The technology elasticity of demand for domestic services is -1.09. The embodied technical change could be picked up by the changes in the household demand structure caused by the change in prices of the durable inputs services. During the time period under study, the technological progress in the food, textile, and electricity industries is remarkable. Many new consumer goods are equipment and materials that are saving on the home time of wives (and other household members). The continuous substitution and technical change may largely explain the declining budget share of domestic services over time.

The estimates of the coefficients and elasticities of the demand for household durable goods services are reasonable and are significantly different from the ones for expenditures on new household durable goods. The own-price elasticity of demand for services is -0.19, and the expenditure elasticity is 0.88. (See Appendix 5.2 for comparison of these results with results obtained using expenditures on new durable goods.) According to the data in the Surveys of Current Business, the real stock of consumer durables per household increased about three times during the last four decades. Expenditure on new durable goods (investment) can be own-price elastic, but expenditures on capital services can be price inelastic.

The estimated other price coefficients and their elasticities show that domestic service, cleaning and laundry services, and wife's home time are substitutes for household durable goods services. This provides additional evidence of households substituting household durables for domestics and wife's time in household production-consumption as the relative price of capital services have fallen. This is an appealing finding and consistent with arguments developed and evidence presented by Bryant (1986). The complementary relationship between services of household durable goods and food away from home (e_{24} = -0.48) was hinted at above. The weak cross price relationship between services of household durables and cleaning and laundry (e_{23} = 0.04) may be attributed to high quality commercial laundry services being a very different commodity than that produced at home. The technology elasticity of demand for the services of household durable goods is larger than one (e_{2T} = 1.37). Thus, increase in inventive activity increases the budget share spent of services of household durable goods.

The own-price elasticity of demand for cleaning and laundry services is relatively small (e_{33} = -0.27), but the expenditure elasticity is relatively large (e_{3E} = 1.69). An increase in inventive activity decreases the relative share of household expenditures on cleaning and laundry services (e_{3T} = -1.63).

The own-price elasticity of demand for food away from home is -1.16, and the expenditure elasticity is 0.87. Thus, although there is evidence from other studies that the income elasticity of demand for food away from home is relatively large and is larger than one, these results do not support that conclusion. This study shows that expenditure elasticities are larger for domestic services and cleaning-and-laundry services. Increased inventive activity reduces the budget share spent on food away from home, but it also shifts to the right the demand for food away from home.

The demand for wife's time is highly price or wage elastic, and the large wage elasticity is consistent with the large increase in labor force participation and average hours of market work of women over the period of analysis. An increase of household expenditure or income, holding the wife's wage constant, however, shifts the demand curve for wife's home time to the right. Thus, over the sample period rising real household income (expenditure) has been a mitigating force to increased labor force participation of women. All inputs in this demand system are substitutes for wife's home time. An increase of inventive activity reduces the budget share spent on wife's home time and shifts the demand curve for wife's home time to the left ($e_{5T} = -0.74$). Thus, increased inventive activity, which is a source of disembodied technical change in household production, has contributed to the rise in female labor force participation.

Finally, the results in this study show that the technical change in household production is not neutral on input usage. The results support the general conception about household production: the rise in the price of human time relative to the price of capital inputs and the increased market opportunities of females caused the household production technology to become labor-saving (or capital-intensive).

E. Concluding Remarks

In this chapter, we utilized the AIDS model to specify a household demand system for household inputs. Plausible estimates of own and cross price elasticities and income (or expenditure) elasticities were obtained. There is evidence of significant substitution among inputs by households as their relative prices change. Although the effect of inventive activity can not be distinguished statistically from the effects of a pure time trend, the effects of the patenting activity variable on households demand for inputs used in household production are consistent with our expectations about the effect of technical change in the household sector on demand for inputs. Disembodied technical change for household sector -- proxied by the number of patents of consumer durable goods -- has caused the demand curve for capital services to shift to the right but demand curves for other inputs have shifted to the left. The leftward shift has been especially large for domestic services and commercial laundry and cleaning services.

F. Appendix V.1. Derivation of Elasticity Formulas

Let $\log P^* = \sum_k w_k \log p_k$. Substitute this into (5-16), and multiplying both sides by (E/p_i), then we have

$$q_i = (E/p_i)(\alpha_i^* + \sum_j r_{ij} \log p_j + \beta_i \log E - \beta_i \sum_k w_k \log p_k + \delta_i \log T) \qquad (5\text{-}24)$$

Taking partial derivative (5-24) with respect to p_i:

$$q_i / p_i = -(E/p_i^2)(\alpha_i^* + \sum_j r_{ij} \log p_j + \beta_i \log E - \beta_i \sum_k w_k \log p_k + \delta_i \log T) + (E/p_i)(r_{ii}/p_i - \beta_i w_i/p_i).$$

Now multiplying both sides by (p_i/q_i), then the own price elasticity for i-th input is given by:

$$e_{ii} = (q_i / p_i)(p_i/q_i) = -1 + r_{ii}/w_i - \beta_i.$$

Taking partial derivative (5-24) with respect to p_j:

$$q_i / p_j = (E/p_i)(r_{ij}/p_j - \beta_i w_j p_j).$$

Multiplying both sides by (p_j/q_i), then the j-th price elasticity of i-th input is given by:

$$e_{ij} = (q_i / p_j)(p_j/q_i) = (p_j/q_i)(E/p_i)(r_{ij}/p_j - \beta_i w_j p_j)$$

$$= (r_{ij} - \beta_i w_j)/w_i .$$

Taking partial derivative (5-24) with respect to E:

$$\partial q_i / \partial E = (1/p_i)(\alpha_i^* + \sum_j r_{ij} \log p_j + \beta_i \log(E/P^*) + \delta_i \log T)$$
$$+ (E/p_i)\beta_i/E$$
$$= (w_i + \beta_i)/p_i .$$

Multiplying both sides by (E/q_i), then the expenditure elasticity for i-th input is given by:

$$e_{iE} = (\partial q_i/\partial E)(E/q_i) = (w_i + \beta_i)/p_i (E/q_i)$$
$$= (w_i + \beta_i)/w_i$$
$$= 1 + \beta_i/w_i .$$

Taking partial derivative (5-24) with respect to T:

$$\partial q_i/\partial T = (E/p_i)(\delta_i/T).$$

Multiplying both sides by (T/q_i), then the technology elasticity of demand for i-th input is given by:

$$e_{iT} = (\partial q_i/\partial T)(T/q_i) = \delta_i/w_i .$$

G. Appendix V.2. The Estimates of Household Demand System Using "Expenditure" on New Household Durable Goods

Appendix 5.2 summarizes the estimated results of the household demand system using the expenditures on the new household durable goods rather than services provided by them. Tables 5-6 and 5-7 report the maximum likelihood estimates of the household expenditure system with homogeneity and symmetry, and the estimates price and expenditure elasticities of demand for inputs in the system, respectively.

As a whole the results are largely consistent with the results already explored in section four. However, the results for the second equation, expenditures on new household durable goods, are sufficiently different with the results using the value of services. According to the estimates of the coefficients and elasticities given in the Tables, 5-6 and 5-7, household durable goods are own-price elastic and luxury goods. The own-price elasticity of demand is -1.30, and the expenditure elasticity is 1.55. The estimated coefficients and elasticities show that domestic services (e_{21} = 0.19) and wife's home time (e_{25} = 0.56) are substitutes for household durable goods. The complementary relationship between household durable goods and food away from home (e_{24} = -0.57) was explored previously. The expenditure elasticities in this estimation are smaller than those in the other estimation except the household durables.

Table 5-6. Maximum Likelihood Estimates of the Household Expenditure System, Homogeneity and Symmetry Restrictions Imposed, U.S., 1948-1985

Input/ Equation i	Coefficients			
	α_i	r_{i1}	r_{i2}	r_{i3}
(1) Domestic Service	0.04508 (1.34)[a]	-0.005048 (-2.73)	0.005206 (2.36)	-0.003482 (-3.77)
(2) Durable Goods	0.19170 (2.68)	0.005206 (2.36)	-0.007522 (-1.18)	-0.000567 (-0.39)
(3) Cleaning & Laundry	0.08225 (3.27)	-0.003482 (-3.77)	-0.000567 (-0.39)	0.007816 (5.24)
(4) Food away from Home	0.27424 (2.53)	-0.000481 (-0.12)	-0.014390 (-2.07)	-0.009548 (-3.80)
(5) Wife's Home Time	1.01138 (6.39)	0.003821 (0.91)	0.017050 (1.71)	0.005942 (2.29)

[a]The t-ratios are in parentheses.

r_{i4}	r_{i5}	β_i	δ_i	R^2	D-W
-0.000481 (-0.12)	0.003821 (0.91)	0.000490 (0.13)	-0.004116 (-1.28)	0.96	1.33
-0.014390 (-2.07)	0.017050 (1.71)	0.014670 (1.82)	-0.027380 (-3.10)	0.93	1.67
-0.009548 (-3.80)	0.005942 (2.29)	0.005501 (3.22)	-0.011320 (-6.06)	0.99	1.87
0.009891 (0.64)	0.013450 (0.82)	-0.023800 (-2.01)	0.000079 (0.01)	0.93	1.38
0.013450 (0.82)	-0.037740 (-1.76)	0.005254 (0.16)	-0.074070 (-2.98)	0.93	1.60

Table 5-7. Estimates Price, Expenditure, and Technology Elasticities of Demand for Inputs in the Household Expenditure System, U.S., 1948-1985

Input/ Equation i	Prices					Expen- diture	Tech- nology
	p_1	p_2	p_3	p_4	p_5		
(1) Domestic Service	-1.719	0.740	-0.496	-0.072	0.535	1.070	-0.586
(2) Durable Goods	0.192	-1.297	-0.026	-0.567	0.566	1.551	-1.028
(3) Cleaning, Laundry	-0.422	-0.085	-0.070	-1.175	0.623	1.659	-1.355
(4) Food away from Home	-0.007	-0.284	-0.193	-0.772	0.343	0.509	0.002
(5) Wife's Home Time	0.028	0.125	0.044	0.098	-0.285	1.039	-0.549

VI. SUMMARY AND CONCLUSIONS

The primary purpose of this dissertation was to examine the long-term changes in household production caused by the technical and other changes in the United States. Since it is not possible to observe such economic phenomena directly, we utilized an indirect approach. We observe the quantity demanded by household of inputs for household production -- wife's home time, domestic services, capital services and other inputs -- and labor supplied to the market. These relationships are ones where the consequences of technical and other changes in variables that are exogenous to individual households were examined in this study.

The household production model was employed to develop a conceptual framework for viewing household decisions on household production and labor supply when technical and other changes occur.

In the empirical analyses, two methodologies were used. A VAR (Vector Autoregression) was employed to search for causality. The results from the six-variable VAR system revealed very interesting interactions and causal relations between variables in the system. In the impulse responses and error decompositions for 1900-1985, the fluctuations in the number of domestics and their wage rates were shown to largely be determined by variations in U.S. immigrant rates, prices of household durable goods, the unemployment rate, and household income. Especially, the effects of variations in the prices of durable goods, which were caused by the technological progress proxied by the patenting activity, on other variables in the system were remarkable. We also found that causality went from wage rates for domestic servants to number of domestic servants and not in the reverse. This findings suggest that additional research could be undertaken to identify determination of the wage rate of domestics.

Second, a set of household input demand functions were fitted to data for 1948-1985. The almost-ideal-demand-function was fitted to expenditure shares for wife's home time, domestic services, services of household durable goods, commercial laundry services, food away from home, and a residual category. Plausible estimates of own- and cross price elasticities, income (expenditure) and technology elasticities were obtained. There is evidence of significant substitution among inputs by households as relative prices change. The effects of the patenting activity variable on household's demand for inputs are consistent with our expectations about the effect of technical change in the household sector on demand for inputs.

Further research remains to be done. For example, inclusion of the decisions on child-care services into the model would be interesting. Also, it would be nice to verify the findings in this study using micro data or to examine national aggregate data for other countries.

VII. APPENDIX. THE MARKET FOR DOMESTIC SERVICES -- A STRUCTURAL MODEL ANALYSIS --

This appendix examines the structure of the market for domestic services using the traditional structural equation system. A small simultaneous equation system is specified and fitted to U.S. aggregate data for 1929-1985.

A. The Econometric Model

A behavioral model for the market for domestic services can be represented by the market derived in Chapter 3. The econometric model to be estimated which is based on the behavioral model consists of the following set of linear equations in (A-1), (A-2), and (A-3). All variables are in logarithmic form, and the hypothetical signs of coefficients are given.

$$\text{SUPPLY: } \ln(D^s) = \alpha_0 + \alpha_1 \ln(W_d) + \alpha_2 \ln(W_t) + \alpha_3 \ln(AFDC) + \alpha_4 \ln(IMMT) + e_1,$$
$$\alpha_1 > 0,\ \alpha_2 < 0,\ \alpha_3 < 0,\ \alpha_4 > 0. \qquad \text{(A-1)}$$

$$\text{DEMAND: } \ln(D^d) = \beta_0 + \beta_1 \ln(W_d) + \beta_2 \ln(P_c) + \beta_3 \ln(Y_h) + \beta_4 \ln(FSIZE) + \beta_5 \ln(TECH) + e_2,$$
$$\beta_1 < 0,\ \beta_2 > 0,\ \beta_3 > 0,\ \beta_4 > 0,\ \beta_5 < 0. \qquad \text{(A-2)}$$

$$\text{EQUILIBRIUM: } \ln(D^d) = \ln(D^s) - \ln(HH). \qquad \text{(A-3)}$$

where:

D^d, D^s = the annual total amount of domestic services supplied, and demanded per household, respectively. D^d is obtained by dividing D^s by the total number of household (HH). Source: U.S. Department of Commerce, Survey of Current Business, several issues,

W_d = the real annual earnings of domestic service workers. Source: Leborgott, Manpower in the Economic Growth, and U.S. Department of Commerce, Historical Statistics in the U.S., several issues,

W_t = the real annual earnings of school teachers. Source: the same as in the W_d,

AFDC = the real amount of Aid to the Families with Dependent Children. Source: U.S. Social Security Administration, Social Security Bulletin, several issues,

IMMT = the total number of immigrants. Source: U.S. Immigration and Naturalization Service, Annual Report, several issues,

P_c = the real consumer price of household durable goods. The series used here is the implicit deflator of consumption expenditure on household appliances, equipments, and similar kinds. Source: U.S. Department of Commerce, Survey of

Current Business, several issues,

Y_h = the real per household income, obtained by dividing the real personal income in the National Income and Products Account by the number of households. Source: U.S. Department of Commerce, Survey of Current Business, several issues,

FSIZE = the average size of household, obtained by dividing the total population by the number of households. Source: U.S. Department of Commerce, Statistical Abstract of the United States, several issues,

TECH = the cumulative number of patents which are related to household production. Source: U.S. Patent and Trademark Office, Official Gazette, and Index to the Patent in the United States, several issues,

HH = the total number of households. Source: U.S. Department of Commerce, Statistical Abstract of the United States, several issues,

e_1, e_2 = random error terms.

In the model, the three variables, $\ln(D^s)$, $\ln(D^d)$, and $\ln(W_d)$ are endogenous. Both supply and demand equations are overidentified. The above simultaneous equation system can be estimated using well known estimation techniques, such as 2SLS (two-stage least squares).

B. The Results and Interpretations

The simultaneous system of equations (A-1), (A-2), and (A-3) is estimated by the Two-Stage Least Squares. Estimates of the model are reported in Table A-1.

All estimated coefficients have the expected signs imposed on the model. In general the model performed very well and the coefficients are statistically significant except a few. When the variables are expressed in natural logarithms, the estimated coefficients are interpreted as elasticities. Overall the supply and demand for domestics reveal relatively modest responses to changes in other variables, except household income. Some important findings are summarized and interpreted in the following.

1. The supply of domestic services

i) The wage rate elasticity of supply of domestic services is not very high (0.81), however, statistically very significant. This results may represent that in context of this model the wage rate is a dominant factor for explaining the supply behavior of domestics. A little inelastic response of supply with respect to the wage rate may suggest some socio-demographic characteristics of domestics: they are largely old, colored, and low-skilled female workers. They

Table A-1. Estimates of Econometric Model for the Market for Domestic Services, U.S., 1929-1985 [a, b]

Supply of Domestic Services

$$\ln(D^s) = \underset{(20.17)}{13.644} + \underset{(3.97)}{0.8071}\ln(W_d) - \underset{(-1.23)}{0.3502}\ln(W_t)$$

$$- \underset{(-1.39)}{0.0587}\ln(AFDC) + \underset{(1.52)}{0.05311}\ln(IMMT)$$

$R^2 = 0.99$, D.W.= 1.16

Demand for Domestic Services

$$\ln(D^d) = \underset{(2.88)}{7.7166} - \underset{(-1.47)}{0.7617}\ln(W_d) + \underset{(3.68)}{1.3317}\ln(Y_h) + \underset{(2.22)}{0.4877}\ln(P_c)$$

$$+ \underset{(1.29)}{0.4190}\ln(FSIZE) - \underset{(-3.57)}{0.6720}\ln(TECH)$$

$R^2 = 0.99$, D.W.= 1.50

[a]The set of equations were estimated by Two-Stage Least Squares.

[b]Asymptotic t-ratios are in parentheses.

neither have chances to move to other occupations nor have strong incentive to work more for higher wage rates.

ii) Higher earning power of female in other occupations does appear to shift some female domestics out of the market for domestic services. The opportunity wage rate (W_t : wage rate of school teachers in this study) elasticity of supply is relatively small (-0.35). This result suggests that W_t may capture some occupational choice effects for domestics. That is an increase in W_t makes (female) domestics exit from the market, resulting in shifting the supply curve to the left. Similar findings are given in some other studies (e.g., Rotella, 1977).

iii) AFDC which picks up the effect of non-labor income in the supply equation has the expected negative sign. Its elasticity for domestic service supply is small (-0.06). The inelastic relationship reflects, in part, the facts that the proportion of domestics among the recipients of AFDC is not high or the supply equation does not consider distinction between husband income and wife income. The result is consistent with a cross sectional study (Mattila, 1975).

iv) It is hypothesized that IMMT is a potential source for shifting the supply curve of domestics. The IMMT elasticity for supply of domestics is small (0.05) which partially supports the hypothesis. The magnitude of the coefficient is consistent with the fact that about the same percentage of total immigrants entered into the domestic service over time (U.S. Department of Commerce, 1975).

2. The demand for domestic services

The demand equation estimates exhibit better performance than those of the supply equation do. The estimates have all expected hypothetical signs, and they are overall statistically significant. Another feature is that the demand for domestics is largely determined by some exogenous factors, not by the cost of domestics, i.e., their wage rates.

i) The wage rate elasticity of demand for domestic services has a moderate magnitude (-0.76). This result suggests that domestic service has been a necessary part of the modern households whose wives are working for labor income. The magnitude of the wage elasticity is smaller than that of cross-sectional studies (Mattila, 1973, 1975). This gap implies that the demand for domestics is more elastically responded to their prices in the same time period and the cost is a dominant factor for explaining demand, but in long time period the demand is explained by other some exogenous and structural factors such as substitution and technical change.

ii) The average household income (Y_h) has the expected sign, and a large t-ratio. The income elasticity of demand for domestics is relatively large (1.33) which means domestic service is income elastic. This results may originate from which the demand for domestics is closely related with the (married) female's labor force participation.

iii) The estimates of the demand equation support the hypotheses that there have been substantial substitution of household durable goods for domestics and technical changes in household production. The elasticity of price of household durable goods (P_c) is relatively large (0.49) and significant. Also the estimated coefficient of TECH which is a proxy for technical change has a notable size (-0.67) and large t-ratio.

iv) The family size (FSIZE) has the expected sign, and has moderate size of elasticity (0.42), but not significant. This results represent that the variable describes the changes in the family structure over time, however, may not appropriately capture the effects on the demand for domestics over time. This point can be verified by comparing this results with those of cross-sectional studies.

C. Concluding Remarks

In the previous sections, we specified an econometric model for the market for domestics, estimated the model, and interpreted the results. Although the model is a small, and simplified one, overall it explained the market behaviors very well, and the interpretations were quite straightforward.

The results from this structural model analysis are largely consistent with those from the VAR (Vector Autoregression). However, more experiments are needed for more significant relationships between two methodologies.

The wage rate of domestics plays well its role in the market. Its weak power in the demand equation could be explained by the outweighing effects of other exogenous variables over time.

The demand equation is well explained by the exogenous variables, such as Y_h, P_c, and TECH, not by W_d. Such relationships are hinted by the interrelationships among the variables by the impulse responses and error decomposition in the VAR system.

The dominant explaining variable for the supply of domestics is their wage rates. The weakness of other variables in the supply equation may represent the inadequate choice of them for the supply behaviors due to the lack of information about the market. For more comprehensive understanding about the market behaviors, more disaggregated or cross-sectional analysis are suggested.

Finally, the model does need some extension in which we can take account of more variables related with the primary issues of this study. Female labor force participation and child-care service are good examples. Such extended empirical work, however, is largely restricted by the data availability.

VIII. BIBLIOGRAPHY

Alling, Elizabeth, and Agnes Leisey. Aid to Dependent Children in a Postwar Year. Social Security Bulletin 13 (August 1950): 3-5.

Amemiya, Takeshi. Advanced Econometrics. Cambridge, Massachusetts: Harvard University Press, 1985.

Bancroft, Gertrude. The American Labor Force: Its Growth and Changing Composition. New York, New York: John Wiley & Sons, Inc., 1958.

Barewal, S. and Dean Goddard. The Parameters of Consumer Food Demand in Canada. Working Paper 2/85, Marketing and Economics Branch, Agriculture Canada, 1985.

Barten, Anton P. Maximum Likelihood Estimation of a Complete System of Demand. European Economic Review 1 (Fall 1969): 7-73.

Barten, Anton P. The System of Consumer Demand Functions Approach: A Review. Econometrica 45 (January 1977): 23-51.

Becker, Gary S. A Theory of Allocation of Time. Economic Journal 75 (September 1965): 413-517.

Blanciforti, Laura A. and Richard D. Green. An Almost Ideal Demand System Incorporating Habits: An Analysis of Expenditures on Food and Aggregate Commodity Groups. Review of Economics and Statistics 65 (August 1983): 511-5.

Blanciforti, Laura A., Richard D. Green, and Gordon A. King. U.S. Consumer Behavior over the Postwar Period: An Almost Ideal Demand System Analysis. Giannini Monograph 40, August 1986.

Bockstael, Nancy E., and Kenneth E. McConnel. Welfare Measurement in Household Production Framework. American Economic Review 73 (September 1983): 806-14.

Brown, Alan and Angus Deaton. Surveys in the Applied Economics: Models of Consumer Behavior. Economic Journal 82 (December 1972): 1145-237.

Bryant, Keith W. Technical Change and the Family: An Initial Foray. In Human Resources Research, 1887 - 1987, pp. 117-26. Edited by Deacon, Ruth, and Wallace E. Huffman. Ames, Iowa: Iowa State University, 1986.

Christensen, Lauritus R., Dale W. Jorgenson, and L. J. Lau. Transcendental Logarithmic Utility Functions. American Economic Review 65 (June 1975): 367-83.

Crew, Spencer R. The Great Migration of Afro-Americans, 1915-40. Monthly Labor Review 110 (March 1987): 34-6.

Deaton, Angus and John Muellbauer. An Almost Ideal Demand System. American Economic Review 70 (June 1980a): 312-26.

Deaton, Angus and John Muellbauer. Economics and Consumer Behavior. London, England: Cambridge University Press, 1980b.

Denison, E. F. The Source of Economic Growth, New York, New York: Committee for Economic Development, 1962.

Dickinson, Katherine. Child Care. The Five Thousand American Families-Patterns of Economic Progress 3 (1975): 221-33.

Diewert, W. E. Applications of Duality Theory. In Frontiers of Quantitative Economics, Vol. 2, pp. 106-99. Edited by Michael D. Intriligator and David A. Kendrick. Amsterdam: North Holland, 1974.

Doan, Thomas A. and Robert B. Litterman. User's Manual of RATS (Version 2.00). Minneapolis, Minnesota: VAR Econometrics, 1986.

Dodden, Faye E. Serving Women: Household Service in Nineteen Century America. Middletown, Connecticut: Wesleyan University Press, 1983.

Duncan, Greg J., and Russel C. Hill. Modal Choice in Child Care Arrangements. The Five Thousand American Families-Patterns of Economic Progress 3 (1975a): 235-58.

Duncan, Greg J., and Russel C. Hill. Child Care Mode Choice of Working Mothers. The Five Thousand American Families-Patterns of Economic Progress 3 (1975b): 379-88.

Duvall, Henrietta J., et al. Aid to Families with Dependent Children: Characteristics of Recipients in 1979. Social Security Bulletin 45 (April 1982): 3-14.

Edwards, Alba M. Comparative Occupation Statistics in the United States. Washington, D.C.: Government Printing Office, 1943.

Fuller, Wayne A. Introduction to Statistical Time Series. New York, New York: John Wiley & Sons, Inc., 1976.

Fuller, Wayne A., David P. Hasza, and J. Jeffery Goebel. Estimation of the Parameters of Stochastic Difference Equations. The Annals of Statistics 9 (May 1981): 531-43.

Goddard, Dean. An Analysis of Canadian Aggregate Demand for Food at Home and Away from Home. Canadian Journal of Agricultural Economics 31 (November 1983): 289-318.

Gollop, Frank M. and Dale W. Jorgenson. U.S. Productivity Growth by Industry, 1947-73. In New Developments in Productivity Measurement and Analysis, pp. 17-136. Edited by Kendrick, John W. and B. N. Vaccara. New York, New York: NBER, 1980.

Granger, C. W. J. Investigating Causal Relations by Econometric Models and Cross-Spectral Methods. Econometrica 37 (July 1969): 424-38.

Gronau, Reuben. The Effect of Children on the Housewife's Value of Time. Journal of Political Economy 81, Part II (March/April 1973): S168-99.

Gronau, Reuben. Leisure, Home Production and Work: The Theory of the Allocation of Time Revisited. Journal of Political Economy 85 (December 1977): 1099-123.

Grossman, Allyson S. Women in Domestic Work: Yesterday and Today. Monthly Labor Review 103 (August 1980): 17-21.

Hicks, J. R. Value and Capital. Oxford: Oxford University Press, 1936.

Hicks, J. R. The Theory of Wages. 2nd ed. London: Macmillan Publishing Co., 1963.

Jorgenson, Dale W. and L. J. Lau. The Structure of Consumer Preference. Annals of Econ. Soc. Measurement 4 (Winter 1975): 49-101.

Kaplan, David L., and M. Claire Casey. Occupational Trends in the United States: 1900 to 1950. Bureau of the Census Working Paper 5. Washington, D.C.: Government Printing Office, 1958.

Katz, Arnold J. The Value of Services Provided by the Consumer Durables, 1949-79: Alternative User Cost Measures. In BEA Working Paper No.2: Measuring Nonmarket Economic Activity, pp. 42-72. Springfield, Virginia: National Technical Information Services, 1982.

Katz, Arnold J. Valuing the Services of Consumer Durables. Review of Income and Wealth, Series 29 (December 1983): 405-27.

Katz, Arnold J., and Jannice Peskin. The Value of Services Provided by the Stock of Consumer Durables, 1949-77: An Opportunity Cost Measure. Survey of Current Business 60 (July 1980): 22-31.

Katzman, David M. Seven Days a Week. New York, New York: Oxford University Press, 1978.

Kendrick, J. W. Productivity Trends in the United States. Princeton, New Jersey: Princeton University Press for NBER, 1961.

King, Willford I., Oswald W. Knauth, and Frederick R. Macaulay. Income in the United States, Its Amount and Distribution 1909-1019, Vol. II. New York. New York: NBER, 1922.

Kleinberg, S. J. Escalating Standards: Women, Housework and Household Technology in the Twentieth Century. In Technology in the Twentieth Century, pp. 1-67. Edited by Frank J. Coppa and R. Harmond. Dubuque, Iowa: Kendall/Hunt Publishing Co., 1983.

Kmenta, Jan, and Roy F. Gilbert. Small Sample Properties of Alternative Estimators of Seemingly Unrelated Regressions. Journal of American Statistical Association 63 (December 1968): 1180-200.

Kokoski, Mary F. Indices of Household Welfare and the Value of Leisure Time. Review of Economics and Statistics 69 (February 1987): 83-9.

Kuznets, S. National Income and Its Composition, 1919-1938. Vol. II. New York, New York: NBER, 1941.

Lancaster, Kelvin J. A New Approach to Consumer Theory. Journal of Political Economy 74 (April 1966): 132-57.

Lebergott, Stanley. Manpower in Economic Growth: The American Record since 1800. New York, New York: McGraw-Hill, 1964.

Leontief, Wassily. Composite Commodities and the Problem of Index Numbers. Econometrica 15 (1936): 361-73.

Lescohier, Don D. History of Labor in the United States: 1896-1932. New York, New York: Macmillan, 1935.

Litterman, Robert B. Techniques of Forecasting Using Vector Autoregressions. Working Paper No. 115. Federal Reserve Bank of Minneapolis, Minneapolis, Minnesota, 1979.

Litterman, Robert B. A Bayesian Procedure for Forecasting with Vector Autoregressions. Working Paper. Federal Reserve Bank of Minneapolis, Minneapolis, Minnesota, 1981.

Lucas, Robert E. Jr. Econometric Policy Evaluation: A Critique. In The Phillips Curve and Labor Markets, pp. 19-46. Edited by K. Brunner and A. H. Meltzer, Carnegie-Rochester Conference Studies on Public Policy. Amsterdam: North Holland, 1976.

Lucas, Robert E. Jr. and Thomas J. Sargent. After Keynesian Macroeconomics. Federal Reserve Bank of Minneapolis Quarterly Review 3 (Spring 1979): 1-16.

Maddala, G. S. Limited-Dependent and Qualitative Variables in Econometrics. Cambridge: Cambridge University Press, 1983.

Martin, Linda, and Kerry Segrave. The Servants Problem: Domestic Workers in North America. Jefferson, North Carolina: Mcfarland & Company, Inc., 1985.

Mattila, Peter J. The Effect of Extending Minimum Wages to Cover Household Maid. Journal of Human Resources 8 (Summer 1973), 365-82.

Mattila, Peter J. The Labor Supply of Household Maids. Unpublished Manuscript. Department of Economics, Iowa State University, 1975.

Mincer, Jacob. Labor Force Participation of Married Women: A Study of Labor Supply. In Aspects of Labor Economics, pp. 63-97. Edited by H. G. Lewis. Princeton, New Jersey: Princeton University Press, 1962.

Mincer, Jacob. Market Prices, Opportunity Costs, and Income Effect. In Measurement in Economics, pp. 67-82. Edited by C. F. Christ. Stanford, California: Stanford University Press, 1963.

Mizon, G. E. Inferential Procedures in Non-linear Models: An Application in a U.K. Industrial Cross-Section Study of Factor Substitution and Returns of Scale. Econometrica 45 (July 1977): 1221-42.

Muellbauer, John. Aggregation, Income Distribution and Consumer Demand. Review of Economic Studies 62 (October 1975): 525-43.

Muellbauer, John. Community Preference and the Representative Consumer. Econometrica 44 (September 1976): 979-99.

Mugge, Robert H. Aid to Families with Dependent Children: Initial Findings of the 1961 Report on Characteristics of Recipients. Social Security Bulletin 26 (March 1963): 3-15.

Musgrave, John C. Durable Goods Owned by Consumers in the United States, 1925-1977. Survey of Current Business 59 (March 1979): 17-28.

Muth, Richard F. Household Production and Consumer Demand Functions. Econometrica 34 (July 1966): 699-708.

Pollack, Robert A. A Transaction Cost Approach to Families and Households. Journal of Economic Literature 23 (June 1985): 581-608.

Pollak, Robert A. and Michael L. Wachter. The Relevance of the Household Production Function and Its Implications for the Allocation of Time. Journal of Political Economy 83 (April 1975): 255-77.

Ray, Ranjan. Analysis of a Time Series of Household Expenditure Surveys for India. Review of Economics and Statistics 62 (November 1980): 595-602.

Reid, Margaret G. Economics of Household Production. New York, New York: John Wiley & Sons, Inc., 1934.

Robinson, John P. Housework Technology and Household Work. In Women and Household Labor, pp. 53-68. Edited by S. F. Berk. Beverly Hills, California: Sage Publication Inc., 1980.

Rollins, Judith. Between Women: Domestics and Employers. Philadelphia, Pennsylvania: Temple University Press, 1985.

Rotella, Elyce J. From Home to Office: U.S. Women at Work, 1870-1930. Ann Arbor, Michigan: UMI Research Press, 1977.

Sargent, Thomas J. Estimating Vector Autoregressions Using Methods Not Based on Explicit Economic Theories. Federal Reserve Bank of Minneapolis Quarterly Review 3 (Summer 1979): 8-15.

Sargent, Thomas J. Interpreting Economic Time Series. Journal of Political Economy 89 (April 1981): 213-48.

Sargent, Thomas J. Autoregression, Expectations, and Advice. American Economic Review 74 (May 1984): 408-15.

Schmookler, J. Invention and Economic Growth. Cambridge, Massachusetts: Harvard University Press, 1966.

Scoggins, John F. Welfare Evaluation and Household Production with Non-Constant Returns to Scale. Southern Economic Journal 53 (January 1987): 643-9.

Shephard, R. W. Cost and Production Functions. Princeton, New Jersey: Princeton University Press, 1953.

Shephard, R. W. Theory of Cost and Production Functions. Princeton, New Jersey: Princeton University Press, 1970.

Sims, Christopher A. Macroeconomics and Reality. Econometrica 48 (January 1980): 1-48.

Sims, Christopher A. Are Forecasting Models Usable for Policy Analysis? Federal Reserve Bank of Minneapolis Quarterly Review 10 (Spring 1987): 2-16.

Solow, Robert M. Technical Change and the Aggregate Production Function. Review of Economics and Statistics 39 (February, 1957): 323-33.

Stigler, George J. Domestic Servants in the United States. Occasional Paper 24. New York, New York: National Bureau of Economic Research, 1946.

Stigler, George J. Economic Problems in Measuring Changes in Productivity. In Output, Input, and Productivity Measurement, pp. 47-63. Princeton, New Jersey: Princeton University Press, 1961.

Stone, Richard. The Measurement of Consumers' Expenditure and Behaviors in the United Kingdom, 1920-1938. Vol. 1. Cambridge: Cambridge University Press, 1953.

Stone, Richard. Linear Expenditure Systems and Demand Analysis: An Application to the Pattern of British Demand. Economic Journal 64 (September 1954): 511-27.

Sutherland, Daniel E. Americans and Servants: Domestic Service in the United States form 1800 to 1920. Baton Rouge, Louisiana: Louisiana State University Press, 1981.

Tacker, Herbert T. Household Employment under OASDHI, 1951-66. Social Security Bulletin 33 (June 1970): 10-17.

Theil, Henri. The Information Approach to Demand Analysis. Econometrica 33 (January 1965): 67-87.

Theil, Henri. Theory and Measurement of Consumer Demand. Vols. 1 and 2. Amsterdam: North Holland, 1976.

Torok, Steve J. and W. E. Huffman. U.S.-Mexican Trade in Winter Vegetables and Illegal Immigration. American Journal of Agricultural Economics 68 (May 1986): 246-60.

U.S. Department of Commerce, Bureau of the Census. Historical Statistics in the United States. Bicentennial ed. Washington, D.C.: Government Printing Office, 1975.

U.S. Department of Commerce, Bureau of the Census. Statistical Abstracts in the United States. Washington, D.C.: Government Printing Office, 1950-1986.

U.S. Department of Commerce, Patent and Trademark Office. Official Gazette. Washington, D.C.: Government Printing Office, 1900a-1986a.

U.S. Department of Commerce, Patent and Trademark Office. Index to the Patent in the United States. Washington, D.C.: Government Printing Office, 1900b-1986b.

U.S. Department of Labor, Bureau of Labor Statistics. Handbook of Labor Statistics. Washington, D.C.: Government Printing Office, 1945-1986.

U.S. Department of Labor, Employment Standards Administration. Domestic Service Employees. Washington, D.C.: Government Printing Office, 1979.

U.S. Department of Labor, Women's Bureau. Household Workers: A Statistical Legislative Profile. Washington, D.C.: Government Printing Office, 1978.

U.S. Immigration and Naturalization Service. Annual Report. Washington,D.C.: Government Printing Office, 1960-1986.

Vanek, Joann. Household Technology and Social Status: Rising Living Standards and Status and Residence Differences in Housework. Technology and Culture 19 (Fall 1978): 361-75.

Waggaman, Mary T. Wartime Job Opportunities for Women Household Workers in Washington, D.C. Monthly Labor Review 60 (September 1945): 575-84.

Waite, Linda J., Larry E. Suter, and Richard L. Shortlidge, Jr. Changes in Child Care Arrangements of Working Women from 1965 to 1971. Social Science Quarterly 58 (September 1977): 302-11.

Wallace, Phillis A. Black Women in the Labor Force. Cambridge, Massachusetts: MIT Press, 1980.

Wilson, G. B. L. Domestic Appliances. In A History of Technology, Vol. VII, Part II, pp. 1126-47. Edited by T. I. Williams. Oxford: Clarendon Press, 1978.

Wolfbein, Seymour L. War and Post-War Trends in Employment of Negroes. Monthly Labor Review 60 (January 1945): 1-5.

Wool, Harold. The Labor Supply for Lower-Level Occupations. New York, New York: Praeger Publisher, 1976.

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