PARTIALLY ENDOGENIZED CONSUMPTION: A NEW METHOD TO INCORPORATE THE HOUSEHOLD SECTOR INTO INPUT-OUTPUT MODELS

Quanrun Chen [1 2 3], Erik Dietzenbacher[1], Bart Los[1], Cuihong Yang[2]

(1. University of Groningen, PO Box 800, 9700 AV, Groningen, The Netherlands
2. Academy of Mathematics and Systems Science, Chinese Academy of Sciences, Beijing, 100190, P.R.China
3. Graduate University of Chinese Academy of Sciences, Beijing, 100049, P.R.China)

Email:
quanrun.chen@rug.nl
h.w.a.dietzenbacher@rug.nl
b.los@rug.nl
chyang@iss.ac.cn

Abstract. The partially closed input-output model with endogenous consumption is applied to many fields, both on national level and regional level, for it takes into account the linkage between the household sector and the production sector. In our study, we find that the household consumption behavior captured by this model is not consistent with the consumption theory, because in this model the current consumption is only determined by the current income. However, from the point views of related consumption behavior hypotheses, such as the relative income hypothesis and the life cycle-permanent income hypothesis, the household consumption is also determined by many other factors such as past consumption level and future income. In that case, the linkage between the household sector and the production sector would be overestimated by this model. To address this problem, we proposed a new method to incorporate the household sector into the input-output model, which can reconcile the input-output analysis with the consumption theory. The endogenous consumption coefficients of eight categories of commodities in China from 1989 to 2008 are estimated by the time varying parameter method. Using these results, we construct our new model, partially closed input-output model with partially endogenized consumption, based on China's input-output table of 2007. Finally employing our new model, the short-term impact of the 4 trillion yuan stimulus package announced by the Chinese government on the GDP of China under different scenarios is investigated.

1. Introduction

The household sector plays an important role in economic activities. The household obtains incomes from the production sector and spends them on the products produced by the production sector. Via this income-consumption relationship, the household sector is closely related to the production sector. Hence, incorporating the household sector into the economic system to account for the income-consumption relationship between the household sector and the production sector is an important and significant work. Because of the advantages in industry linkages analysis and economic structure study, the input-output model is a good starting point to incorporate the household sector into the economic system.

The Partially closed input-output model with endogenous consumption, studied by many researchers such as Miyazawa (1976), has become a prevalent method to incorporate the household sector into the economic system. In this model, the household sector is regarded as an endogenous sector by moving the household consumption and labor input to the input-output intermediate delivery matrix. The household sector is linked to the production sector by the labor input coefficient and consumption coefficient defined in this model. As many researchers (see Batey, Madden, and Weeks, 1987, 1989; Cloutier, 1994; Wakabayashi and Hewings, 2007; Miller and Blair, 2009) pointed out, there are some limitations in this model, especially the constant consumption coefficient and ignored consumption patterns of different households. These limitations can be alleviated by disaggregating the household sector into different groups according to their characteristics. However, there is another limitation, which has been paid little attention to. We find that the household consumption behavior captured by this model is not consistent with the consumption theory, because the household consumption is fully endogenized in this model, which implies that the current consumption is totally determined by the current income. However, according to related consumption behavior hypotheses, such as the relative income hypothesis and the life cycle-permanent income hypothesis, the household consumption is also determined by many other factors such as past consumption level and future income. In that case, if the household consumption is fully endogenized, the linkage between the household sector and the production sector would be overestimated by this model, and further the results calculated from this model would be distorted.

To address this problem, we try to develop a new method to incorporate the household sector into the input-output model, which can reconcile the input-output analysis with the consumption theory. To implement this method, a specific consumption decomposition formula is required. On the one hand, it can take into account factors relevant to household consumption behavior. On the other hand, it should facilitate decomposing the household consumption into the endogenous consumption which is determined by the current household income, and the exogenous consumption which is determined by other factors; only the endogenous consumption flow should be closed into the input-output intermediate delivery matrix. Based on this method, our new model, partially closed input-output model with partially endogenized consumption, is developed. Compare to the traditional model and the partially closed input-output model with endogenous consumption, the results calculated from our new model would be closer to the realistic economic activities. Because our new model incorporates the relationship between the household sector and the production sector and at the same time captures a relatively comprehensive household consumption behavior. This idea can also be generalized to the social accounting matrix (SAM) method, since this method to incorporate the household sector is not consistent with the consumption theory either. We will show the performance of our new model by investigating the short-term impact of the 4 trillion yuan stimulus package announced by the Chinese government on the GDP of China.

The remaining content of this paper is organized as follows. Section 2 introduces the partially closed input-output model with endogenous consumption and its limitations. Section 3 describes our new method to incorporate the household sector into the input-output model. Section 4 takes China as an example to describe the procedure of constructing our new model. Section 5 investigates the short-term impact of the 4 trillion yuan stimulus package announced by the Chinese government on the GDP of China under different scenarios. Section 6 is our conclusion.

2. Partially Closed Input-Output Model with Endogenous Consumption

The traditional input-output model is $\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}(\mathbf{f}^c + \tilde{\mathbf{f}})$, where $\mathbf{x}$ represents the gross output vector; $\mathbf{A}$ represents the input coefficient matrix; $\mathbf{f}^c$ represents the household consumption vector; $\tilde{\mathbf{f}}$ represents the vector of final demands other than household consumption; $\mathbf{I}$ is an identical matrix. In the traditional input-output model, household consumption is treated as an exogenous final demand category, so there is no linkage between the household sector and the production sector. In economic activities, however, the household sector is closely related to the production sector via an income-consumption relationship. The household earns incomes from the production sector and spends them on the products produced by the production sector. In that case, the Leontief inverse matrix $(\mathbf{I} - \mathbf{A})^{-1}$ calculated from the traditional input-output model does not take into account the linkage between the household sector and the production sector.

To incorporate the income-consumption relationship into the traditional input-output model, many researchers such as Miyazawa have studied the partially closed input-output model with endogenous consumption. In this model, the household sector is moved into the intermediate delivery matrix and treated as an endogenous sector. Its inputs are consumption commodities, and output is labor. Currently, the partially closed input-output model with endogenous consumption has been applied to many fields, both on national level and on regional level (see Batey, Madden, and Weeks, 1987; Cloutier 1994; Hewings et al., 1999; Chen, Guo and Yang, 2005).

According to Miyazawa's formulation (see Miyazawa, 1976), the basic structure of the partially closed input-output model with endogenous consumption is as follows:

(1) $$\begin{bmatrix} \mathbf{A} & \mathbf{h}^c \\ \mathbf{h}^r & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix} + \begin{bmatrix} \tilde{\mathbf{f}} \\ f_{n+1}^* \end{bmatrix} = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}.$$

Where $\mathbf{A} = (a_{ij})_{n \times n}$ is a matrix of input coefficients; $\mathbf{x} = (x_i)_{n \times 1}$ is a vector of gross outputs of production sectors; x_{n+1} is the total household income ; $\tilde{\mathbf{f}}$ is a vector of final demands other than household consumption; f_{n+1}^* is the exogenous income of the household sector; $\mathbf{h}^c = (h_i^c)_{n \times 1}$ is a vector of consumption coefficients; $\mathbf{h}^r = (h_j^r)_{1 \times n}$ is a vector of labor input coefficients[1]. The consumption coefficient h_i^c is defined as $h_i^c = f_i^c / x_{n+1}$, where f_i^c is the commodity of sector i consumed by the household sector. The labor input coefficient is defined as $h_j^r = w_j / x_j$, where w_j represents the wage and salary of the household sector earned from sector j. Hereafter we call this model as the Miyazawa model.

Previous studies have pointed out that household consumption behavior is distorted in this model, because the consumption coefficients are constant and the consumption patterns of different households are ignored (see Batey, Madden, and Weeks, 1987, 1989; Cloutier, 1994; Wakabayashi and Hewings, 2007; Miller and Blair, 2009). First, the constant consumption coefficients potentially assume that the household sector will spend the same proportional (h_i^c) income on corresponding commodities given any additional amount of household earnings. An approach to addressing this problem especially at regional level is to divide the household sector into established resident sectors and new resident sectors. For the established residents, the income generated from an increase in the gross output would be an additional income to their current income, and then a series of marginal consumption coefficients are needed. For the new residents who migrate to look for jobs, the income generated from an increase in the gross output would be their total income; hence, the consumption coefficients defined above are reasonable.

Second, the consumption patterns would vary over households with different characteristics such as income levels and ages. For instance, the consumption pattern of a household with a high income level will be different from that of a household with a low income level. The model will thus lack consumption pattern variations if only one household sector is incorporated in it. An approach to addressing this problem is to disaggregate the household sector into several groups according to their characteristics. For example, disaggregate the household sector by income level: <$10000, $10001-14999, $15000-19999 and so on (see Cloutier, 1994). The income mobility should certainly be taken into account in this situation; in fact, due to the economic development, some households may shift from one income level to another.

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[1] In Miyazawa's model, $\mathbf{h}^r$ is a vector of value added ratios. According to Miller and Blair's description on Miyazawa's model, $\mathbf{h}^r$ is revised to a vector of labor input coefficients (see Miller and Blair, 2009).

We find another limitation of the Miyazawa model, which, however, has been paid little attention to. In the Miyazawa model, household consumption is fully endogenized, so the consumption coefficient is defined as $h_i^c = f_i^c / x_{n+1}$. Transforming it slightly yields $f_i^c = h_i^c x_{n+1}$, which indicates that household consumption is only determined by the current income. However, from the point of views of related consumption behavior hypotheses, the current consumption is not only determined by the current income but also determined by many other factors. For instance, according to Duesenberry's relative income hypothesis (RIH), the current consumption is also determined by the past consumption peak because consumption behavior is rather irreversible over time. It is difficult for a household to reduce its consumption level once attained; according to the life cycle/permanent income hypothesis (LCPIH), developed by Modigliani, Friedman, and Hall, consumers are forward-looking, so they can advance or defer consuming according to their plans and expectations to maximize their utilities in the long run. Hence, the consumption behavior captured by the Miyazawa model is not consistent with the consumption theory. The fully endogenized household consumption can lead to an overestimated linkage between the household sector and the production sector. Then the result calculated from the Miyazawa model will be distorted.

This suggests that a new model should be developed to reconcile the input-output analysis with the consumption theory. To do that, the aggregate household consumption is required to be decomposed into the endogenous consumption which is determined by the current income, and the exogenous consumption which is determined by other factors. Closing the endogenous consumption into the input-output intermediate delivery matrix, we can develop our new model, named the partially closed input-output model with partially endogenized consumption.

3. Partially Closed Input-Output Model with Partially Endogenized Consumption

As we discussed in section 2, many excellent studies about disaggregating the household sector into different groups have been done in the past years. Hence, this issue will not be focused on in our paper. To facilitate our study, we assume that there is only one household in our model who is a representative agent. This means that the sum of all the households' decisions is mathematically equivalent to the decision made by this representative agent.

3.1 Framework

The input-output table provides data source for constructing input-output models, and its framework usually varies with the research issues. Table 1 illustrates the framework for developing our new model.

<TABLE 1>

In this framework, imports are excluded from the intermediate delivery matrix, household consumption, and other final demands. Then $\mathbf{Z}^d = (z_{ij})_{n\times n}$ is the domestic delivery matrix; m_j is the imported product used by sector j; c_{id}^{en} is the domestic product of sector i endogenously consumed by the household sector; c_{id}^{ex} is the domestic product of sector i exogenously consumed by the household sector; c_m^{en} is the imported products endogenously consumed by the household sector; c_m^{ex} is the imported products exogenously consumed by the household sector; f_{id}^* is the product of sector i used for domestic final demands other than household consumption; f_m^* is the imported products used for domestic final demands other than household consumption; e_i is the export of sector i; x_i is the gross output of sector i, inter alia, x_{n+1} is the total household income[2]; h_j is the endogenous income of the household sector earned from sector j; h^* is the exogenous income of the household sector; $\tilde{v}_j$ is other value added of sector j, and it equals the value added of sector j (v_j) minus h_j; v^* is the income tax and saving of the household sector, and it equals the total household income minus aggregate household consumption (both the endogenous consumption and the exogenous consumption).

In some researchers' frameworks (see Cloutier, 1994; Miller and Blair, 2009), there are values in the shadow area of Table 1. They define them as household purchases of labor services. However, we set them as 0 in our framework due to the fact that there is usually a specific sector to describe household services in input-output tables. For

[2] To be consistent with the input-output accounting framework, all the incomes used in this paper refer to the gross incomes before tax.

instance, there is a sector named *household service and other social services* in China input-output tables. Household purchases of labor services can be captured in this sector's labor input. In section 4, we will describe in detail how to construct the row flows and the column flows for the household sector in our new framework.

Compared to Miyazawa's framework, besides distinguishing the endogenous consumption and the exogenous consumption, another different point in our framework is the definitions of the endogenous income and the exogenous income. In Miyazawa's framework, the value added is closed into the intermediate delivery matrix to show the income obtained by the household sector from the production sector. Hence, $\mathbf{h}^r$ defined by Miyazawa (1976) is a vector of value added ratios. Afterwards, Miller and Blair (2009) revised $\mathbf{h}^r$ to a vector of labor input coefficient. Pyatt (2001) argued that the income captured in the Miyazawa model is not the institutional income but the factorial income such as income for labor and income for capital; this is not consistent with the household income and will leave out some income source especially when the income distribution issue is studied. Considering this point, we use the institutional income instead of the factorial income in our framework. Furthermore, we divide the household income into the endogenous income and the exogenous income according to the income source.

The source of the household income is very wide. For instance, in China the household income basically comes from wages and salaries, household operations[3], properties, and transfers. Incomes from wages and salaries as well as household operations are directly related to the gross output, because they are generated during the production process. The income from wages and salaries is the remuneration for household's labor service, so it directly relates to the gross output. The income from household operations is a return of household's capital input, so it also directly relates to the gross output; moreover, the income from operation on agriculture is an important source of the rural household income[4]. In other words, these income sources have a significant relationship with the gross output, so we define them as the endogenous income. Oppositely, incomes from properties and transfers are basically generated

[3] Income from household operations refers to the income earned by households as units of production and operation. For instance, a household operates a shop; then the benefit they gain from this shop is defined as income form household operation.

[4] For example, in China, the share of income from household operations in rural household net income is around 53%, inter alia, the share of household operation on agriculture is around 42%.

outside the production process and often affected by many nonproduction influencing factors. For instance, the income from properties mainly depends on the finance market condition and the amount of household's property such as savings and houses. The income from transfers is the result of income redistribution and usually depends on institution's decisions on the household's welfare such as related government policies. Hence, we define the income from properties and transfers as the exogenous income.

From Table 1, we can derive the following accounting equations for the production sector and the household sector:

$$\sum_{j=1}^{n} z_{ij}^{d} + c_{id}^{en} + c_{id}^{ex} + f_{id}^{*} + e_i = x_i \quad (i = 1,2\ldots n)\,, \tag{3}$$

$$\sum_{j=1}^{n} h_j + h^{*} = x_{n+1}\,, \tag{4}$$

$$\sum_{i=1}^{n} z_{ij}^{d} + m_j + h_j + \tilde{v}_j = x_j \quad (j = 1,2\ldots n)\,, \tag{5}$$

$$\sum_{i=1}^{n} c_{id}^{en} + c_{m}^{en} + \sum_{i=1}^{n} c_{id}^{ex} + c_{m}^{ex} + v^{*} = x_{n+1}\,. \tag{6}$$

Equation (3) expresses that the gross output (x_i) of each sector flows to intermediate use ($\sum_{j=1}^{n} z_{ij}^{d}$), endogenous consumption (c_{id}^{en}), exogenous consumption (c_{id}^{ex}), other domestic final demands (f_{id}^{*}), and export (e_i). Equation (4) indicates that the sum of endogenous income ($\sum_{j=1}^{n} h_j$) and exogenous income (h^{*}) equals total income (x_{n+1}).Equation (5) indicates that the gross input (x_j) of each sector consists of domestic intermediate input ($\sum_{i=1}^{n} z_{ij}^{d}$), imported intermediate input (m_j), and primary input ($h_j + \tilde{v}_j$). Equation (6) indicates that the total household income (x_{n+1}) flows to household consumption ($\sum_{i=1}^{n} c_{id}^{en} + c_{m}^{en} + \sum_{i=1}^{n} c_{id}^{ex} + c_{m}^{ex}$), and income tax and saving (v^{*}).

3.2 Model

The partially closed input-output model with partially endogenized consumption can be derived from equation (3) and (4). First, we give some definitions used in our model. $\mathbf{A}^{d} = (a_{ij}^{d})_{n\times n}$ is a matrix of domestic input coefficients, where $a_{ij}^{d} = z_{ij}^{d} \big/ x_j$;

$\mathbf{w}' = (w_j)_{1\times n}$ is a row vector of endogenous income coefficients, where $w_j = h_j / x_j$; $\mathbf{c}^d = (\alpha_i^d)_{n\times 1}$ is a column vector of the endogenous consumption coefficients of domestic products, where $\alpha_i^d = c_{id}^{en} / x_{n+1}$. $\tilde{\mathbf{f}} = (\tilde{f}_i)_{n\times 1}$ is a vector of the exogenous final demands on domestic products, where $\tilde{f}_i = c_{id}^{ex} + f_{id}^* + e_i$. Then Equation (3) and (4) can be expressed as:

$$
(7) \qquad \begin{cases} \sum_{j=1}^{n} a_{ij}^d x_j + \alpha_i^d x_{n+1} + \tilde{f}_i = x_i \ (i = 1, 2 \ldots n) \\ \sum_{j=1}^{n} w_j x_j + h^* = x_{n+1} \end{cases} .
$$

Matrix form:

$$
(8) \qquad \begin{bmatrix} \mathbf{A}^d & \mathbf{c}^d \\ \mathbf{w}' & 0 \end{bmatrix} \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix} + \begin{bmatrix} \tilde{\mathbf{f}} \\ h^* \end{bmatrix} = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}.
$$

Solving Equation (8) yields the final model:

$$
(9) \qquad \mathbf{x}^* = (\mathbf{I} - \mathbf{A}^*)^{-1} \mathbf{f}^* = \mathbf{L}^* \mathbf{f}^*,
$$

where $\mathbf{A}^* = \begin{bmatrix} \mathbf{A}^d & \mathbf{c}^d \\ \mathbf{w}' & 0 \end{bmatrix}, \mathbf{x}^* = \begin{bmatrix} \mathbf{x} \\ x_{n+1} \end{bmatrix}, \mathbf{f}^* = \begin{bmatrix} \tilde{\mathbf{f}} \\ h^* \end{bmatrix}, \mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-1}$.

3.3 Multipliers

Some useful multipliers can be obtained by calculating the extended Leontief inverse matrix $\mathbf{L}^*$. The solution to $\mathbf{L}^*$ is

$$
(10) \; \mathbf{L}^* = (\mathbf{I} - \mathbf{A}^*)^{-1} = \begin{bmatrix} \mathbf{L}_{11}^* & \mathbf{l}_{12}^* \\ \mathbf{l}_{21}^* & l_{22}^* \end{bmatrix} = \begin{bmatrix} \mathbf{L}(\mathbf{I} + \mathbf{c}^d \frac{1}{1-\mathbf{w}'\mathbf{L}\mathbf{c}^d} \mathbf{w}'\mathbf{L}) & \mathbf{L}\mathbf{c}^d \frac{1}{1-\mathbf{w}'\mathbf{L}\mathbf{c}^d} \\ \frac{1}{1-\mathbf{w}'\mathbf{L}\mathbf{c}^d} \mathbf{w}'\mathbf{L} & \frac{1}{1-\mathbf{w}'\mathbf{L}\mathbf{c}^d} \end{bmatrix},
$$

where $\mathbf{L} = (\mathbf{I} - \mathbf{A}^d)^{-1}$. A vector of output multipliers $\mathbf{m}(o) = [m_1(o), m_2(o), \ldots, m_n(o)]$ can be derived based on $\mathbf{L}_{11}^*$, which equals $\mathbf{i}'\mathbf{L}_{11}^*$ [5]. $m_j(o)$ indicates the total products of all production sectors required to satisfy one unit of exogenous final demand of sector j. Similar to $\mathbf{i}'\mathbf{L}_{11}^*$, $\mathbf{i}'\mathbf{l}_{12}^*$ indicates the total products of all production sectors induced by one unit exogenous income of the household sector; we define it as income-driven output multiplier. If the household sector is disaggregated into several groups, l_{22}^* should be

[5] In this paper, $\mathbf{i}' = (1,1,\ldots 1)$ denotes a summation vector with conformable length.

expressed as $(\mathbf{I}-\mathbf{W}^{'}\mathbf{L}\mathbf{C}^{d})^{-1}$. Miyazawa (1978) defined it as the "interrelational income multiplier", which describes the effect of a change in one group's income on the incomes of all the groups. The j th element of the "multi-sector income multiplier" vector $\mathbf{l}_{21}^{*}$, which is defined by Miyazawa, indicates the total household income (earned from all the production sectors) induced by one unit exogenous final demand of sector j. The value added multiplier matrix can be obtained by $\mathbf{M}(v)=\hat{\mathbf{V}}\mathbf{L}_{11}^{*}$, where $\hat{\mathbf{V}}$ is a diagonal matrix transformed from the value added coefficient vector $\mathbf{v}^{'}=\left[v_1/x_1, v_2/x_2 \ldots v_n/x_n\right]$. The element $m_{ij}(v)$ in $\mathbf{M}(v)$ indicates the total (both direct and indirect) value added of sector i driven by one unit exogenous final demand of sector j. Finally, we give the endogenous consumption multiplier matrix $\mathbf{M}(enc)$, which can measure the consumption of each sector induced by one unit exogenous final demand of any production sector. Its formula is

(11) $$\mathbf{M}(enc)=\mathbf{c}^{d}\mathbf{l}_{21}^{*}=(\mathbf{I}-\mathbf{c}^{d}\mathbf{w}'\mathbf{L})^{-1}-\mathbf{I},$$

where again $\mathbf{L}=(\mathbf{I}-\mathbf{A}^{d})^{-1}$. The element $m_{ij}(enc)$ in $\mathbf{M}(enc)$ indicates the household consumption on sector i induced by one unit exogenous final demand of sector j.

3.4 Consumption Decomposition

The most important step to develop our new model is to decompose the household consumption into the endogenous consumption and the exogenous consumption. This requires a specific consumption decomposition formula. On the one hand, this formula can take into account factors relevant to household consumption behavior. On the other hand, it should facilitate decomposing the household consumption into the endogenous consumption which is determined by the current household income, and the exogenous consumption which is determined by other factors.

According to RIH, LCPIH, and related studies, there are many other factors influencing aggregate consumption besides the current income, such as past consumption levels (the relative income hypothesis proposed by Duesenberry), future income (see Carroll, 1994; Muellbauer and Lattimore, 1999; Luengo-Prado and Sørensen, 2008), interest rate (see Attanasio and Weber, 1993; Erlandsen and Nymoen, 2008) and demographic structures such as population age structure (see Erlandsen and Nymoen,

2008) and education structure. On the other hand, related studies on consumer preference and demand systems (see Clements and Selvanathan, 1994; Barnett and Serletis, 2008) show that the commodity price and consumer's taste play important roles in determining the budget share of each commodity category. When attempting to estimate the consumption decomposition formula for each commodity category, these two factors should also be taken into account. The reason for this is that they determine the consumer's behavior to make choices among different commodities, given the budget.

Considering these factors, we specify the consumption decomposition formula as the following form:

(12) $$c_{it} = \alpha_{it}(\tilde{e}, r, d, p, \lambda...)x_{(n+1)t} + \beta_i c_{i(t-1)} + \varepsilon_{it} \ .$$

Where c_i is the aggregate household consumption of product *i*; α_i is the endogenous consumption coefficient of product *i*; x_{n+1} again is the total household income.

$\alpha_{it}(\tilde{e}, \sigma, r, d, p, \lambda...)$ indicates that the endogenous consumption coefficient depends on the household's expectation on his future income $\tilde{e}$, interest rate r, demographic structure d, commodity price p, household's taste λ, and other related factors. It implies that these factors affect the consumption by affecting the endogenous consumption coefficient. In fact, if an increase in income occurs, a household with an optimistic expectation on its future income will spent a larger proportion of this increase than that with a pessimistic expectation on its future income. In the same sense, a household with a high dependency ratio [6] and other conductive demographic characteristics, and a low real interest rate will spent a larger proportion of an increase in income than that with a low dependency ratio, and a high real interest rate. With regard to an ordinary commodity, if its price decreases, the household sector will adjust its endogenous consumption on this commodity to a higher level, so that its consumption on this commodity will increase even if its income holds fixed. A change in the household's taste also affects the endogenous consumption coefficients. If the household's taste changes to be fond of buying commodity A, then the endogenous consumption coefficient of commodity A will increase, so that the consumption on commodity A will

[6] The term dependency ratio is defined as the number of children and retired persons to those of working age. Since an individual borrows when they are young, saves when they are in working age, and dissave when they are retired, a high dependency ratio can facilitate consumption.

increase even if the income holds fixed. The endogenous consumption coefficient α_{it} is allowed to vary over time in our model, because its influencing factors usually change over time.

As we discussed in section 2, it is difficult for a household to reduce the consumption level once attained, so the past consumption peak is an important determinant of the current consumption. Since the aggregate consumption is usually in growth, we use the consumption of the previous period $c_{i(t-1)}$ as a measure of the past consumption peak. The past consumption shows the household's consumption habit or experience. The effect of habit or experience on consumption is usually hard to change, so we deem that the coefficient β_i of the previous period consumption is invariant over time.

The estimation of α_{it} is the key to develop the consumption decomposition formula. As we discussed previously, the endogenous consumption coefficients have many influencing factors. Some of the factors such as consumer's taste are unobservable and it is difficult to find good proxy variables for them. Moreover, the function form between the endogenous consumption coefficient and its influencing factors is also difficult to specify correctly, because it is not clear how the household evaluates the changes in the influencing factors together. Considering these difficulties, we assume that the household's decision-making process on the endogenous consumption coefficient follows the random walk process: $\alpha_{it} = \alpha_{it-1} + \mu_{it}$, $\mu_{it} \sim NIID(0, \sigma^2_{\mu_i})$. This assumption implies that the household changes its decision on α_{it} only when it finds that the changes in the influencing factors $\tilde{e}$, r , d , p , λ … occur, and the decision change at current period is not affected by those made at previous periods[7].

[7] Before changing his decision on the endogenous consumption coefficient, the household will consider various changes in the influencing factors at current period. Although the household may learn something about the current situation from the history, considering uncertain changes in many factors and the forward-looking characteristic of the household, we think that the household's decision change based on his evaluation on the various changes in the influencing factors would be weakly dependent at each period. So, we think that the household's decision change at current period is mainly based on the current information and little affected by the decision change at previous periods.

Under this assumption, the endogenous consumption coefficient α_t [8] can be estimated by the following procedure. Suppose that $\hat{\alpha}_{t-1} = E_{t-1}(\alpha_{t-1})$ is a minimum mean square error (MMSE) estimator of α_{t-1} based on all the information up to period $t-1$. Then, the MMSE prediction of α_t and c_t can be obtained by $\hat{\alpha}_{t|t-1} = E_{t-1}(\alpha_{t-1} + \mu_t) = \hat{\alpha}_{t-1}$ and $\hat{c}_{t|t-1} = \hat{\alpha}_{t|t-1} x_{(n+1)t} + \beta c_{t-1}$. $\hat{\alpha}_{t|t-1}$ equals to the estimation of α_{t-1}. However, this estimation is only based on the information up to period $t-1$, and the household may change his decision on the endogenous consumption coefficient based on the information at period t. Hence, $\hat{\alpha}_{t|t-1}$ should be further adjusted. When the observation of the household consumption at period t (c_t) is available, we can obtain the prediction error $\hat{\varepsilon}_t = c_t - \hat{c}_{t|t-1}$. It contains the information about the change in α. Based on this information, $\hat{\alpha}_{t|t-1}$ can be updated to a more precise estimation of $\alpha_t : \hat{\alpha}_t = \hat{\alpha}_{t|t-1} + f(\hat{\varepsilon}_t)$. This procedure can be implemented by using the Kalman filter algorithm.

The Kalman filter (see Harvey, 1987; Hamilton, 1994) is a recursive algorithm for updating a one-step ahead estimate of the state mean given new information. It has been successfully applied to many empirical economic issues to address time varying parameter (TVP) model and unobserved component models. Suppose that a univariate TVP model is specified with an observation equation

(13) $$y_t = d_t + \mathbf{x}_t^{'}\boldsymbol{\beta} + \mathbf{z}_t^{'}\boldsymbol{\alpha}_t + \xi_t, \; t = 1, 2, \ldots T$$

and a state equation

(14) $$\boldsymbol{\alpha}_t = \mathbf{r}_t + \mathbf{T}\boldsymbol{\alpha}_{t-1} + \boldsymbol{\eta}_t, \; t = 1, 2, \ldots T \; .$$

Where y_t is the dependent variable with a fixed observation at time t; $\boldsymbol{\alpha}_t$ is a state vector ($m \times 1$) with time varying parameters of interest; $\mathbf{z}_t$ is a vector ($m \times 1$) with observed variables that affect the dependent variable; $\mathbf{x}_t$ is a vector ($n \times 1$)with observed variables that affect the dependent variable whose coefficient vector $\boldsymbol{\beta}$ $n \times 1$ is invariant over time. $\mathbf{T}$ is a fixed matrix ($m \times m$) which is specified based on prior information; d_t and $\mathbf{r}_t$ are fixed scalar and vector ($m \times 1$) respectively, which are also known in advance; the

[8] To be convenient for our statement, here the subscript i is dropped. It means that the following statements are about any commodity category.

disturbances ξ_t and $\boldsymbol{\eta}_t$ are white noise, with 0 means and variance $\sigma^2 h_t$, $\sigma^2 \mathbf{Q}_t$ respectively. ξ_t and $\boldsymbol{\eta}_t$ are assumed to be mutually serially independent.

Let $\hat{\boldsymbol{\alpha}}_{t-1}$ be the minimum mean square estimator of $\boldsymbol{\alpha}_{t-1}$ based on all the information up to time $t-1$, and let $\sigma^2 \mathbf{P}_{t-1}$ be the mean square error matrix of $\hat{\boldsymbol{\alpha}}_{t-1}$. Given $\hat{\boldsymbol{\alpha}}_{t-1}$ and $\mathbf{P}_{t-1}$ at time $t-1$, the minimum mean square estimator of $\boldsymbol{\alpha}_t$ and its mean square error matrix are:

(15) $$\hat{\boldsymbol{\alpha}}_{t|t-1} = \mathbf{T}\hat{\boldsymbol{\alpha}}_{t-1} + \mathbf{r}_t$$

(16) $$\mathbf{P}_{t|t-1} = \mathbf{T}\mathbf{P}_{t-1}\mathbf{T}' + \mathbf{Q}_t .$$

When the new observation about y at time t is available, the estimator and its mean square error matrix can be updated by the following formulas:

(17) $$\hat{\boldsymbol{\alpha}}_t = \hat{\boldsymbol{\alpha}}_{t|t-1} + \mathbf{P}_{t|t-1}\mathbf{z}_t(y_t - d_t - \mathbf{x}_t'\boldsymbol{\beta} - \mathbf{z}_t'\hat{\boldsymbol{\alpha}}_{t|t-1}) / (\mathbf{z}_t'\mathbf{P}_{t|t-1}\mathbf{z}_t + h_t)$$

(18) $$\mathbf{P}_t = \mathbf{P}_{t|t-1} - \mathbf{P}_{t|t-1}\mathbf{z}_t\mathbf{z}_t'\mathbf{P}_{t|t-1} / (\mathbf{z}_t'\mathbf{P}_{t|t-1}\mathbf{z}_t + h_t)$$

Formula (15) and (16) are referred as the prediction equations, and Formula (17) and (18) are referred as updating equations. They together make up the Kalman filter.

The consumption decomposition formula can be estimated by applying the maximum likelihood estimation method with the Kalman filter on the following TVP model:

(19) $$\begin{cases} c_{it} = \alpha_{it} x_{(n+1)t} + \beta_i c_{i(t-1)} + \varepsilon_{it} \\ \alpha_{it} = \alpha_{it-1} + \mu_{it} \end{cases} .$$

It consists of the observation equation $c_{it} = \alpha_{it} x_{(n+1)t} + \beta c_{i(t-1)} + \varepsilon_{it}$ and the state equation $\alpha_{it} = \alpha_{it-1} + \mu_{it}$ [9], in which ε_{it} and μ_{it} are assumed to be Gaussian disturbances, and they are also mutually serially independent. Based on estimated results, we can easily obtain the endogenous consumption $c_{it}^{en} = \hat{\alpha}_{it} x_{n+1}$ and the exogenous consumption $c_{it}^{ex} = c_{it} - c_{it}^{en}$.

[9] By summarizing the Kalman filter related empirical results, Engle and Watson (1987) found that when the behavioral model is concerned, for many data sets the simple random walk specification for the state equation performs well.

4. Construct China's Partially Closed Input-Output Model with Partially Endogenized Consumption of 2007

4.1 Estimate Endogenous Consumption Coefficients for Input-Output Sectors

The household's consumption preference usually varies with different commodity categories, such as food and clothing, rather than with different input-output sectors. It is because that the sectors in the input-output table are "pure" sectors; namely, each sector produces a single product, and each product can be produced by only one sector. This implies that the products are in the same characteristic no mater what it is used for, as long as they are produced by the same sector. For example, scarf and bed sheet are the same product produced by the *textile goods* sector in the input-output table, however, the household's consumption preference on them is different. This suggests that we should divide the commodities into several categories and estimate their endogenous consumption coefficients instead of directly estimating the endogenous consumption coefficients for input-output sectors. The estimated endogenous consumption coefficient of each commodity category can be further distributed to the input-output sectors by Formula (20). $\mathbf{c} = (\alpha_i)_{n\times 1}$ is a vector of endogenous consumption coefficients of input-output sectors; $\mathbf{c}^* = (\alpha_i^*)_{m\times 1}$ is a vector of endogenous consumption coefficients of commodity categories; $\mathbf{B} = (b_{ij})_{n\times m}$ is the bridge matrix , where n is the number of input-output sectors and m is the number of commodity categories.

(20) $$\mathbf{c} = \mathbf{B}\mathbf{c}^* \ .$$

China Statistical Yearbook provides the data about per capita urban household income, per capita rural household income, and eight categories of consumption commodities: *food*; *clothing*; *residence*; *household facility, article and service*; *health care and medical service*; *transport and communication*; *education, culture and recreation service*; *miscellaneous good and service*. Distinguishing domestic and imported consumption products is required in our framework. However, these eight categories of consumption data do not distinguish them. So, we decide to first estimate the endogenous consumption coefficient for each commodity ($\mathbf{c}^*$) and then distribute it to those of corresponding input-output sectors ($\mathbf{c}$) by Formula (20). Finally, obtain the endogenous consumption coefficient for domestic products ($\mathbf{c}^d$) and imported products by using the share of imported products in the aggregate domestic demand. Before estimating, the following processes are made on the data. First, multiply the per capita urban household income and rural household income with their corresponding populations and sum them to obtain the total household income. Second, deflate variables. Each category of commodity is deflated by its corresponding consumption price index; the total income is deflated by the general consumption price index.

Based on the processed data, the TVP model discussed in section 3 is estimated for each commodity category by the maximum likelihood estimation method with Kalman filter. The Kalman filter yields the estimator of the state vector only based on the available information up to time t. We further used all the information in the sample (T observations in all) to provide smoothed estimate of the state vector $\hat{\boldsymbol{\alpha}}_{t|T}$ by fixed-interval smoothing[10]. The smoothed estimate of α_{it}^* and the estimate of β_i for each commodity category are listed in Table 2.

<TABLE 2>

Table 2 illustrates a picture of changes in the endogenous consumption coefficients of the Chinese household from 1989 to 2008. The endogenous consumption coefficient of *food* maintained decreasing from 1989 to 2008. This is consistent with the Engel's law; namely, as income increases, the budget share of food falls. As a kind of basic needs, the endogenous consumption coefficient of *residence* also presents an overall pattern of decrease. The endogenous consumption coefficients of *household facility, article and service*, and *transport and communication* basically increased over time. As the households' income increases, more and more people begin to spend a larger proportion of their increased money on commodities of high value such as appliances, superior furniture and sedans. Peoples' pursuit of human wants drives the increase in the endogenous consumption coefficients of these two commodity categories. The endogenous consumption coefficient of *clothing* went through three stages of change, increasing from 1989 to 1995, decreasing from 1996 to 1998, and increasing from 1999

[10] The fixed interval smoothing is a process of calculating backward, starting with the final Kalman filter estimates $\hat{\boldsymbol{\alpha}}_T$ and $\mathbf{P}_t$. The smoothing equations consist of $\hat{\boldsymbol{\alpha}}_{t|T} = \hat{\boldsymbol{\alpha}}_t + \mathbf{P}_t^*(\hat{\boldsymbol{\alpha}}_{t+1|T} - \mathbf{T}\hat{\boldsymbol{\alpha}}_t)$ and $\mathbf{P}_{t|T} = \mathbf{P}_t + \mathbf{P}_t^*(\mathbf{P}_{t+1|T} - \mathbf{P}_{t+1|t})\mathbf{P}_t^{*\prime}$, where $\mathbf{P}_t^* = \mathbf{P}_t\mathbf{T}'\mathbf{P}_{t+1|t}^{-1}$, $t = T-1, T-2, \ldots 1$, with $\hat{\alpha}_{T|T} = \hat{\alpha}_T$, $P_{T|T} = P_T$.

to 2008. To a large extent, the decrease stage was caused by the sharply increased clothing price from 1994 to 1997 during which the clothing price increased 17.1%, 14.5%, 7.4%, and 3% respectively. However, the response seems to be somewhat lagged to the increased price. The endogenous consumption coefficients of *health care and medical service,* and *education, culture and recreation service* maintained a relatively stationery pattern in the recent years.

Some important events also had an impact on the endogenous consumption coefficients. For example, the SARS disease occurred in China and caused an obvious impact on the consumption in 2003. Compared to 2002, almost all of the endogenous consumption coefficients decreased, and the aggregate endogenous consumption coefficient decreased about 5.6%. The global financial crisis and Wenchuan earthquake occurred in 2008 also led to a relatively large impact on the consumption. Being affected by this, different degree of declines in the endogenous consumption coefficients of *food*, *transport and communication*, *education, culture and recreation service*, and *miscellaneous good and service* were caused, and the aggregate endogenous consumption coefficient decreased about 4.2%. While the aggregate endogenous consumption coefficient decreases due to the law of diminishing marginal propensity to consume, according to Table 2, this degree of decline in 2008 is much larger than that in the normal year.

In recent years, the consumption of each commodity category has grown with different magnitudes. Based on the estimated TVP model, we calculate the increase in the consumption of each commodity category from 2000 to 2008 and decompose it to the contributions of endogenous consumption and exogenous consumption by Formula (21). The results are presented in Table 3.

$$\begin{aligned} c_{i(t+s)} - c_{it} &= \hat{\alpha}^*_{i(t+s)} x_{(n+1)(t+s)} - \hat{\alpha}^*_{it} x_{(n+1)t} \\ &\quad + \hat{\beta}_i c_{i(t+s-1)} - \hat{\beta}_i c_{i(t-1)} \\ &\quad + \hat{\varepsilon}_{i(t+s)} - \hat{\varepsilon}_{it} \end{aligned} \tag{21}$$

<TABLE 3>

According to Table 3, the consumption growth of each commodity category exhibits three types: exogenous growth dominant type, endogenous growth dominant type and duo type. The growth patterns of most commodity categories, such as *residence*, *transport and communication*, and *education, culture and recreation service*, are exogenous growth dominant type. Namely, the consumption growth in these commodity categories is mainly attributed to the increase in the exogenous consumption. The exogenous growth dominant pattern implies that the increase in the consumption of these commodity categories mainly depends on the household's consumption habit or experience; the continuation or inertia of the household's consumption habit drives most part of the consumption growth in these commodity categories. The consumption growth patterns of *clothing*, and *household facility, article and service* are endogenous growth dominant type. Namely the consumption growth in these commodity categories is mainly attributed to the increase in the endogenous consumption. This implies that the consumption of these commodity categories mainly depends on the household's current income and his judgment on the current economic and social situation. If his income increases and his judgment on the current economic and social situation is optimistic, he will prefer increasing the consumption of these commodity categories. The duo pattern is given to *food* and *health care and medical service* because the contributions of the endogenous consumption and the exogenous consumption to the consumption growth in these commodity categories are comparable.

Next is to convert the endogenous consumption coefficients of eight categories of commodities in 2007 listed in Table 2 to those of input-output sectors by the bridge matrix $\mathbf{B}$. The people who have compiled input-output tables are supposed to hold more information about determining the bridge matrix. However, we only have the following information: the matching table between eight categories of commodities and forty-two sectors in *2007 China input-output table*; the consumption data about each commodity category and each input-output sector.

Based on the limited information, we estimate $\mathbf{B}$ by the following procedure. First, revise the household consumption in the input-output table to be consistent with the consumption of eight categories of commodities[11]. The revised total household

[11] Some consumption items in the input-output table are not included in the eight categories of commodities. For instance, the finance consumption, which is defined as the financial intermediation service benefited by the household during his activity of deposit and loan, is not included in the eight categories of commodities.

consumption in the input-output table should equal to the total consumption of eight categories of commodities. Second, generate a crude estimation of the matching flow matrix $R = (r_{ij})_{42\times 8}$ between input-output sectors and eight categories of commodities. if sector i matches with commodity j, then $r_{ij} = y_i^c / n_i$ $(j = 1, 2...8)$, otherwise $r_{ij} = 0$. y_i^c is the revised household consumption of sector i; n_i is the number of commodity categories that match with sector i. r_{ij} represents the amount of consumption of sector i contained in commodity j. Third, balance the crudely estimated matching flow matrix by means of the RAS method[12] to make sure that the sum of each row and each column equal to the revised household consumption of corresponding input-output sector and the consumption of corresponding commodity category respectively. Finally, divide the element in each column by the sum of corresponding column to obtain the estimation of $\mathbf{B}$. The matching table between eight categories of commodities and forty-two sectors in *2007 China input-output table*, and the estimated share of each input-output sector in its corresponding commodity category are listed in the Appendix.

After obtaining the endogenous consumption coefficient of each input-output sector by the estimated bridge matrix, we further split it into the endogenous consumption coefficient of domestic product and imported product according to the share of imported product in the aggregate domestic demand. Finally, based on the converted endogenous consumption coefficients of the input-output sectors, the aggregate consumption can be split into the endogenous consumption and the exogenous consumption by Formula (12).

4.2 Estimate Endogenous Income Coefficients for Input-Output Sectors

As we discussed in section 3, the incomes from wages and salaries, and household operations are reasonable to be treated as the endogenous income. The income from wages and salaries is a part of compensation of employees which is an item in the input-output table. With regard to the income from household operations, it is difficult to distinguish the compensation and surplus from it, so the income from household

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So, this part of consumption should be excluded from the household consumption in the input-output table and further regarded as the exogenous household consumption.

[12] RAS is a popular method to recover the entries of a matrix from limited and incomplete multisectoral economic data. See Golan et al. (1993) and Dietzenbacher (2009) for excellent discussion about this method.

operation is usually aggregated to the compensation of employees in the statistical data of China. The share of income from wages and salaries together with household operations in the compensation of employees is around 85.3% in 2007. These two income sources dominate the compensation of employees, so we assume that the structure of wage and salary income together with household operation income earned from each sector is the same as the structure of compensation of employees obtained from each sector. The latter structure is available in the input-output table. We can use the data about total wage and salary income and household operation income collected from *China Statistical Yearbook* as a control number and distribute it to each sector according to the share of each sector's compensation of employees. Then the endogenous income flow is obtained, and the endogenous income coefficient of each sector can further be calculated by dividing each sector's endogenous income over gross output.

Compared to the endogenous income, the exogenous income (consisting of income from properties and transfers) can be easily obtained, since there is detailed data about property income and transfer income of household in *China Statistical Yearbook*. Up to now, the preparations on the new features of our model have been done. Based on these preparations, China's partially closed input-output model with partially endogenized consumption of 2007 can be expressed as the form of Formula (8).

5. The Impact of 4 Trillion yuan Stimulus Package on the GDP of China in the Short Run

To alleviate the recessionary impact of global financial crisis on the economic growth of China, the Chinese central government announced a fiscal stimulus package in the fourth quarter of 2008. According to this stimulus package, from the fourth quarter of 2008 to 2010, a 4 trillion yuan investment scale will be formed in China by means of government investment and absorbing private investment. In this 4 trillion yuan stimulus package, the central government investment accounts for 1.18 trillion yuan; the other investment is afforded by the local government and the private. The composition of this stimulus package is listed in Table 4. Most of the items focus on infrastructure construction.

<TABLE 4>

From the demand-side view, the investment will directly stimulate the output of construction industry as well as the equipment and instrument related industries, and further indirectly stimulate the output of other industries via the industry linkages. In addition, due to the increase in the household income during this stimulus process, the household consumption will be induced and in turn drive the outputs of the production sectors. Hence, in the short run this stimulus package will drive the GDP growth of China. On the other hand, in an open economy this stimulus package will also increase imports, since both production and final demand require imported products[13]. In that case, the impact of this 4 trillion yuan stimulus package on the GDP of China will be weakened by the increased imports. The input-output model provides an approach for industry level impact analysis and also has an advantage in economic structure analysis. Hence, in this section, we will investigate the impact of the 4 trillion yuan stimulus package on the GDP of China by input-output models. In these models, domestic products and imported products are distinguished to take into account the involvement of imports.

We assume that the investment items in this stimulus package will be accomplished before the end of 2010, and our study will focus on this short-term. The adjustment of price and wage is usually sluggish in the short run, so we further assume that the central bank will not change the interest during the implementation of this stimulus package. We thus do not consider the crowding-out effect on the private investment, which is always argued in the context of expansionary fiscal policy. The household consumption, however, may be affected by this stimulus package, if the household is forward-looking. In the context of expansionary fiscal policy, the household would have an expectation that the government may increase the tax rate in the future to balance the fiscal deficit caused by the expansionary fiscal policy, and then its future income may be negatively affected. As we discussed in section 3, future income is an influencing factor on the current consumption and it affects the current consumption by affecting the endogenous consumption coefficient, so in this scenario the endogenous consumption coefficient may diminish.

[13] According to China's input-output table of 2007, the share of imported products (excluding products imported for processing export) in the aggregate domestic demand is around 9.3%.

Considering the possibility of household consumption behavior change, we first assume that the household has a very weak expectation that the stimulus package will affect its future income; namely, the household consumption behavior will not change under this expansionary fiscal policy. In this scenario, we calculate the short-term impact of the stimulus package on the GDP growth by the traditional input-output model, the Miyazawa model, and our new model respectively and make comparison among them. Second, we recalculate the short-term impact by our new model based on the scenario that the household consumption behavior is affected by the expansionary fiscal policy. Before calculating, we distribute the stimulus package to the fixed asset formation vector in the input-output table according to the investment composition in Table 4 and the investment matrix which contains the information about each industry's investment structure. We denote this increased investment vector as $\Delta\mathbf{f}^*$

5.1 Impact Analysis in the Absence of Household Consumption Behavior Change

We first consider the assumption that the household consumption behavior is not affected by the stimulus package. Based on this assumption, we predict the endogenous consumption coefficients for 2009 and 2010 as the same value as those in 2008. By using the value added multiplier matrix $\mathbf{M}(v)$ derived from the traditional input-output model, the Miyazawa model and our new model[14], the value added of each sector driven by the stimulus package can be calculated from $\mathbf{M}(v)\Delta\mathbf{f}^*$. The result is listed in Table 5.

<TABLE 5>

At the economy-wide level, Table 5 shows that the GDP driven by the 4 trillion yuan stimulus package calculated from the traditional input-output model, the Miyazawa model and our new model are 3235.8 billion yuan, 4160.0 billion yuan and 3533.5 billion yuan respectively. Since the traditional input-output model does not take into account the effect of the household sector, its total multiplier is less than those of the Miyazawa model and our new model. Due to the fully endogenized consumption in the Miyazawa model, its total multiplier is obviously larger than that of our new model. Because of the involvement of imported products, the total multiplier of the traditional input-output model is less than 1. The total multiplier of our new model is also less than 1, which

[14] The value added multiplier of our new model is derived in section 3. The deviations of the value added multiplier of the traditional input-output model and the Miyazawa model are similar.

implies that the domestic household consumption induced by the stimulus package is less than the imports driven by the stimulus package. On the contrary, the domestic household consumption induced by the stimulus package is overestimated by the Miyazawa model in a large degree and is larger than the increased imports, so its total multiplier is more than 1.

At the industry level, the result calculated from our new model shows that the large increment in infrastructure construction will most affect the *construction* industry (26); its increased value added accounts for 23.5% of the total value added stimulated by the stimulus package. The industries that have a close linkage (direct and indirect) with *construction* industry, such as *nonmetal mineral products* industry (13), *Metals smelting and pressing* industry (14), *transport and warehousing* industry (27), *wholesale and retail trade* industry (30), *electricity and heating power production and supply* industry (23), *finance and insurance* industry (32), and *chemicals* industry (12), are also affected in a large degree. The increased purchase of equipment and instrument to meet the investment requirement will provide an opportunity for *common and special equipment* industry (16). Due to the relatively large endogenous consumption coefficient of *food* commodity, the *agriculture* industry (1) will benefit a lot from the induced household consumption.

5.2 Impact Analysis in the Presence of Household Consumption Behavior Change

The expansionary fiscal policy can convey an expectation on the increase in tax rate in the future. In this situation, if the household is forward-looking, the household consumption will be negatively affected. This point can be usually found in the new Keynesian models used for fiscal policy analysis (see Cogan et al., 2009; Michal, 2009). Based on the scenario that the household will change its consumption behavior to respond to the stimulus package, we assume that the endogenous consumption coefficients decrease 5% and 10% respectively. Under this scenario, we recalculate the short-term impact by Formula (22) which is derived from our new model.

(22) $$\bar{\mathbf{M}}(v)\Delta\mathbf{f}^* + [\bar{\mathbf{M}}(v)\mathbf{f}^* - \mathbf{M}(v)\mathbf{f}^*]$$

Where $\Delta\mathbf{f}^*$ is the increased 4 trillion yuan investment vector; $\mathbf{f}^*$ is the exogenous final demand on domestic products in the framework constructed in Section 4.

$\mathbf{M}(v)$ and $\bar{\mathbf{M}}(v)$ are the value added multiplier matrices before and after the changes in endogenous consumption coefficients respectively.

From the results listed in the fourth and fifth column of Table 5, we find that compared to the scenario in the absence of household consumption behavior change, if the endogenous consumption coefficient of each sector decreases 5%, the GDP driven by the stimulus package will decrease 4.2%, from 3533.5 billion yuan to 3385.8 billion yuan, and the total multiplier will decrease from 0.88 to 0.85. If the household has an even worse expectation on its future income, say the endogenous consumption coefficient decreases 10%, the stimulated GDP will decrease to 3240.0 billion yuan and the total multiplier will decrease to 0.81 which is almost equal to the total multiplier calculated from the traditional input-output model. This implies that the negative effect of the stimulus package almost offsets the positive effect on the household consumption. Hence, the government should at the same time take some counter-behavior steps to stabilize the household consumption behavior in the context of an expansionary fiscal policy. At the industry level, industries with a relatively large endogenous consumption coefficient and large value added ratio, such as *health service, social guarantee and social welfare industry* (40), *education* industry (39), *manufacture of food products and tobacco processing* industry (6), *agriculture* industry (1), and *wearing apparel, leather, furs, down and related products* industry (8), will be most affected by the household's negative response to the stimulus package.

6. Conclusion

This paper has presented a new method to incorporate the household sector into input-output models. In contrast to earlier methods, this method can reconcile the input-output analysis with the consumption theory by introducing the consumption decomposition formula which can decompose the household consumption into the endogenous consumption and the exogenous consumption. The problem of overestimated linkage between the production sector and the household sector caused by previous models can thus be solved.

The consumption decomposition formula is estimated for eight categories of commodities of China by applying the maximum likelihood estimation method with the

Kalman filter. The estimated results indicate that the changes in the endogenous consumption coefficients of eight categories of commodities from 1989 to 2008 show different patterns. For example, the endogenous consumption coefficients of *food* and *residence* basically continued to decrease. Those of *household facility, article and service*, and *transport and communication* basically increased over time. The household consumption of eight categories of commodities also shows different growth pattern. The growth of most commodity categories such as *residence*, *transport and communication*, and *education, culture and recreation service* are mainly attributed to the increase in the exogenous consumption. The consumption growth of *clothing*, and *household facility, article and service* are mainly attributed to the increase in the endogenous consumption. The contributions of exogenous consumption and endogenous consumption to the growth of *food* as well as *health care and medical service* are comparable.

As an application of our new model, we evaluate the short-term impact of the 4 trillion yuan stimulus package announced by the Chinese government on the GDP of China. Based on the first scenario that the household's consumption behavior is not affected by this expansionary fiscal policy, we calculate the impact by the traditional input-output model, the Miyazawa model, and our new model respectively. Compared to our new model, the result calculated from the Miyazawa model is obviously overestimated because of the fully endogenized consumption. We also investigate the second scenario that the household will show negatively responses to this expansionary fiscal policy. Our new model shows that if the endogenous consumption coefficient of each sector decrease 5% and 10%, compared to the calculated result in the absence of household consumption behavior change, the GDP driven by the 4 trillion yuan stimulus package will decrease from 3533.5 billion yuan to 3385.8 and 3240.0 billion yuan respectively; the total multiplier will decrease from 0.88 to 0.85 and 0.81 respectively.

Our empirical result suggests that decomposing the household consumption into the endogenous consumption and the exogenous consumption is required when incorporating the household sector into the input-output model. This idea can also be generalized to the social accounting matrix (SAM) method, since this method to incorporate the household sector is not consistent with the consumption theory either.

APPENDIX

Matching table of eight categories of commodities and forty-two sectors in *2007 China input-output table*

Eight Categories of Commodities	Forty-two Sectors
Food	(0.333) Agriculture (0.473) Manufacture of food products and tobacco processing (0.006) Transport and warehousing (0.019) Wholesale and retail trade (0.159) Accommodation, eating and drinking places (0.010) Household service and other social services
Clothing	(0.048) Textile goods (0.631) Wearing apparel, leather, furs, down and related products (0.053) Transport and warehousing (0.176) Wholesale and retail trade (0.091) Household service and other social services
Residence	(0.014) Coal mining, washing and processing (0.024) Nonmetal mineral products (0.222) Electricity and heating power production and supply (0.030) Gas production and supply (0.030) Water production and supply (0.088) Construction (0.055) Transport and warehousing (0.181) Wholesale and retail trade (0.262) Real estate (0.093) Household service and other social services
Household facility, article and service	(0.009) Textile goods (0.121) Wearing apparel, leather, furs, down and related products (0.105) Sawmills and furniture (0.315) Chemicals (0.005) Nonmetal mineral products (0.083) Metal products (0.300) Electric equipment and machinery (0.010) Transport and warehousing (0.034) Wholesale and retail trade (0.018) Household service and other social services
Health care and medical service	(0.144) Manufacture of food products and tobacco processing (0.002) Textile goods (0.055) Chemicals (0.011) Common and special equipment (0.002) Transport and warehousing (0.006) Wholesale and retail trade (0.003) Household service and other social services (0.779) Health service, social guarantee and social welfare
Transport and communication	(0.067) Petroleum processing, coking and nuclear fuel processing (0.222) Transport equipment (0.121) Telecommunication equipment, computer and other electronic equipment (0.067) Transport and warehousing (0.005) Post

	(0.185) Information communication, computer service and software (0.219) Wholesale and retail trade (0.113) Household service and other social services
Education, culture and recreation service	(0.039) Paper and products, printing and record medium reproduction (0.057) Telecommunication equipment, computer and other electronic equipment (0.016) Instruments, meters, cultural and office machinery (0.031) Transport and warehousing (0.087) Information communication, computer service and software (0.103) Wholesale and retail trade (0.114) Renting and commercial service (0.027) Water conservancy, environment, and public accommodation management (0.053) Household service and other social services (0.401) Education (0.071) Culture, sports and amusements
Miscellaneous good and service	(0.167) Chemicals (0.159) Electric equipment and machinery (0.003) Instruments, meters, cultural and office machinery (0.491) Art and craft and other manufacturing products (0.005) Transport and warehousing (0.018) Wholesale and retail trade (0.148) Accommodation, eating and drinking places (0.009)Household service and other social services

Note: the term in the parentheses is the share of each input-output sector in its corresponding commodity category.

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Table 1
Framework of Partially Closed Input-Output Model with Partially Endogenized Consumption

	S 1	S 2	…	S n	Household sector		Other domestic final demands	Exports	Exogenous income	Gross output
S 1	$\mathbf{Z}^d = (z_{ij})_{n\times n}$				c_{1d}^{en}	c_{1d}^{ex}	f_{1d}^*	e_1		x_1
S 2					c_{2d}^{en}	c_{2d}^{ex}	f_{2d}^*	e_2		x_2
…					…	…	..	…		…
S n					c_{nd}^{en}	c_{nd}^{ex}	f_{nd}^*	e_n		x_n
Household sector	h_1	h_2	…	h_n					h^*	x_{n+1}
Other value added	$\tilde{v}_1$	$\tilde{v}_2$	…	$\tilde{v}_n$						
Imports	m_1	m_2	…	m_n	c_m^{en}	c_m^{ex}	f_m^*			
income tax and Saving of household					v^*					
Gross input	x_1	x_2	…	x_n	x_{n+1}					

Table 2
Estimated Results for Consumption Decomposition Formula

	F	C	R	HAS	HM	TC	ECR	M	AC
$\hat{\beta}_i$	0.500	0.395	0.708	0.282	0.523	0.926	0.653	0.785	
$\hat{\alpha}_{it}^*$:									
1989	0.221	0.054		0.051					
1990	0.252	0.057		0.051					
1991	0.238	0.062		0.053					
1992	0.220	0.064		0.054					
1993	0.223	0.069	0.029	0.056			0.020		
1994	0.204	0.070	0.029	0.059	0.013	0.009	0.022		0.405
1995	0.198	0.070	0.030	0.059	0.014	0.009	0.024		0.404
1996	0.191	0.070	0.029	0.061	0.016	0.010	0.025		0.400
1997	0.181	0.060	0.029	0.060	0.016	0.011	0.027		0.383
1998	0.172	0.052	0.029	0.059	0.016	0.013	0.030		0.371
1999	0.171	0.053	0.029	0.060	0.018	0.016	0.032	0.0068	0.385
2000	0.168	0.055	0.028	0.060	0.023	0.019	0.033	0.0092	0.396
2001	0.159	0.057	0.028	0.059	0.022	0.020	0.031	0.0074	0.383
2002	0.159	0.058	0.026	0.057	0.025	0.023	0.033	0.0063	0.387
2003	0.143	0.058	0.025	0.056	0.024	0.024	0.031	0.0047	0.365
2004	0.138	0.060	0.024	0.055	0.025	0.025	0.031	0.0062	0.364
2005	0.137	0.069	0.024	0.057	0.028	0.028	0.030	0.0072	0.380
2006	0.126	0.069	0.025	0.058	0.024	0.027	0.030	0.0068	0.365
2007	0.116	0.073	0.025	0.062	0.025	0.028	0.030	0.0068	0.364
2008	0.108	0.075	0.025	0.063	0.025	0.020	0.026	0.0064	0.349

Note: 1. F=food; C=clothing; R=residence; HAS=household facility, article and service; HM=health care and medical service; TC=transport and communication; ECR=education, culture and recreation service; M=miscellaneous good and service; AC=aggregate consumption.

2. Due to the time horizons of the available time series data are different (the longest horizon is from 1989 to 2008, and the shortest horizon is from 1999 to 2008), the time coverage of the reported result is different. The endogenous consumption coefficient of aggregate consumption is the sum of F, C, R, HAS, HM, TC, ECR, and M. The data about M is not available from 1994 to 1998, so during those periods, the endogenous consumption coefficient of aggregate consumption is the sum of F, C, R, HAS, HM, TC, and ECR.

3. With regard to the initialization of the maximum likelihood estimation, we have tested many initial values. The estimates appear to be robust to them.

Table 3

Contributions of the Endogenous Consumption and the Exogenous Consumption to Aggregate Consumption Growth (2000-2008)

Commodity category	ΔC	E_{en}	E_{ex}	
			$E_{c_{t-1}}$	E_{ε}
Food	2598.0	1306.3 (50.3)	1298.5 (50.0)	-6.7 (-0.3)
Clothing	2717.6	1799.0 (66.2)	906.8 (33.4)	11.8 (0.4)
Residence	1137.0	459.9 (40.4)	686.1 (60.4)	-9.1 (-0.8)
Household facility, article and service	1700.9	1311.6 (77.1)	412.3 (24.2)	-23.0 (-1.3)
Health care and medical service	1067.7	532.2 (49.8)	537.9 (50.4)	-2.4 (-0.2)
Transport and communication	3425.0	417.1 (12.2)	3131.5 (91.4)	-123.5 (-3.6)
Education, culture and recreation service	1247.7	422.1 (33.8)	856.5 (68.6)	-30.8 (-2.5)
Miscellaneous good and service	408.6	88.3 (21.6)	322.7 (79.0)	-2.4 (-0.6)

Note: ΔC denotes the increase in aggregate consumption; E_{en} denotes the contribution of the endogenous consumption; E_{ex} denotes the contribution of the exogenous consumption, which consists of $E_{c_{t-1}}$ the contribution of previous period consumption, and E_{ε} the contribution of residual. The terms in the parentheses are the contribution shares of each component in percentage form. The increase in consumption is measured in 100 million yuan.

Table 4

The Composition of the 4 Trillion Yuan Stimulus Package

Item	Fund (billion yuan)
Low-rent housing and indemnificatory housing construction	400
Rural people's livelihood project and rural infrastructure construction	370
Railway, highway, airport, water conservancy construction and distribution network enhancement	1500
Medical health, education and culture	150
Energy saving and emission reduction, ecological construction project	210
Independent innovation and adjustment of industry structure	370
Post-quake recovery and reconstruction	1000
Sum	4000

Table 5

Impact of the 4 Trillion Yuan Stimulus Package on the Value Added of Each Sector

(Unit: billion yuan)

sector	Traditional model	Miyazawa model	New model	Changes in endogenous consumption coefficient -5%	Changes in endogenous consumption coefficient -10%
1. Agriculture	82.2	265.1	157.5	120.2 (-23.7)	83.3 (-47.1)
2. Coal mining, washing and processing	80.1	92.5	84.3	82.2 (-2.5)	80.2 (-4.9)
3. Crude petroleum and natural gas products	87.3	103.3	92.5	89.9 (-2.8)	87.4 (-5.5)
4. Metal ore mining	43.0	45.5	43.9	43.4 (-0.9)	43.0 (-1.9)
5. Non-ferrous mineral mining	49.4	51.4	50.1	49.7 (-0.7)	49.4 (-1.5)
6. Manufacture of food products and tobacco processing	27.1	102.6	58.0	42.7 (-26.4)	27.5 (-52.5)
7. Textile goods	10.9	22.8	16.4	13.7 (-16.5)	11.0 (-32.8)
8. Wearing apparel, leather, furs, down and related products	10.6	29.3	19.8	15.2 (-23.0)	10.7 (-45.8)
9. Sawmills and furniture	31.3	35.9	33.3	32.3 (-3.0)	31.3 (-6.0)
10. Paper and products, printing and record medium reproduction	24.0	34.6	27.4	25.7 (-6.2)	24.1 (-12.2)
11. Petroleum processing, coking and nuclear fuel processing	61.4	71.8	64.7	63.1 (-2.5)	61.5 (-4.9)
12. Chemicals	113.9	150.5	128.6	121.3 (-5.7)	114.1 (-11.2)
13. Nonmetal mineral products	262.2	267.8	264.1	263.2 (-0.4)	262.3 (-0.7)
14. Metals smelting and pressing	250.1	263.6	254.7	252.4 (-0.9)	250.2 (-1.8)
15. Metal products	58.1	63.6	60.2	59.2 (-1.7)	58.2 (-3.4)
16. Common and special equipment	126.1	134.2	128.8	127.5 (-1.0)	126.2 (-2.1)
17. Transport equipment	47.2	59.8	49.8	48.5 (-2.6)	47.2 (-5.1)
18. Electric equipment and machinery	49.4	57.5	52.6	51.0 (-3.0)	49.5 (-6.0)
19. Telecommunication equipment, computer and other electronic equipment	14.3	19.4	15.4	14.9 (-3.6)	14.3 (-7.1)
20. Instruments, meters, cultural and office machinery	7.0	7.8	7.2	7.1 (-1.6)	7.0 (-3.3)
21. Art and craft and other manufacturing products	10.8	16.1	12.2	11.5 (-5.5)	10.9 (-10.9)
22. Scrap and waste	59.9	65.3	61.8	60.9 (-1.5)	60.0 (-2.9)
23. Electricity and heating power	135.6	167.3	146.1	140.9 (-3.5)	135.8 (-7.1)

production and supply					
24. Gas production and supply	1.9	3.1	2.3	2.1 (-7.9)	2.0 (-15.6)
25. Water production and supply	5.0	8.0	5.9	5.4 (-8.0)	5.0 (-15.9)
26. Construction	827.7	831.5	828.8	828.3 (-0.1)	827.7 (-0.1)
27. Transport and warehousing	224.1	263.6	237.0	230.6 (-2.7)	224.3 (-5.4)
28. Post	2.1	3.3	2.5	2.3 (-6.3)	2.2 (-12.4)
29. Information communication, computer service and software	84.1	112.1	89.7	86.9 (-3.1)	84.2 (-6.2)
30. Wholesale and retail trade	141.3	218.9	165.4	153.5 (-7.2)	141.6 (-14.4)
31. Accommodation, eating and drinking places	35.3	68.1	47.5	41.5 (-12.8)	35.4 (-25.4)
32. Finance and insurance	125.2	189.3	134.9	130.1 (-3.5)	125.4 (-7.0)
33. Real estate	39.1	123.9	50.4	44.8 (-11.2)	39.2 (-22.2)
34. Renting and commercial service	21.3	33.5	24.9	23.1 (-7.1)	21.4 (-14.1)
35. Research and development	4.1	5.0	4.4	4.3 (-3.4)	4.1 (-6.7)
36. General technical services	41.6	46.0	43.2	42.4 (-1.8)	41.7 (-3.6)
37. Water conservancy, environment, and public accommodation management	2.7	5.7	3.6	3.2 (-12.4)	2.7 (-24.6)
38. Household service and other social services	20.6	48.3	28.8	24.8 (-14.1)	20.8 (-28.0)
39. Education	4.4	33.8	12.3	8.4 (-31.7)	4.5 (-63.0)
40. Health service, social guarantee and social welfare	4.5	23.8	12.4	8.5 (-31.6)	4.6 (-62.9)
41. Culture, sports and amusements	7.5	13.2	9.1	8.3 (-8.6)	7.5 (-17.2)
42. Public management and social administration	0.9	1.1	1.0	0.9 (-4.4)	0.9 (-8.7)
Sum (GDP)	3235.8	4160.0	3533.5	3385.8 (-4.2)	3240.0 (-8.3)
Total multiplier	0.81	1.04	0.88	0.85 (-4.2)	0.81 (-8.3)

Note: 1. With regard to the values in the fourth and fifth columns, the terms in the parentheses are the percentage changes to the values in the third column.
2. The total multiplier equals to the stimulated GDP divided by 4000 billion yuan.