Economic effects of earthquakes: focusing on the health sector

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Abstract: This paper aims to clarify the effects of earthquake as a shock to the Iran's economy providing policy makers with insight in the impacts of such shocks. Using CGE approach, it proposes modelling the reduction of capital stock stem from the earthquake and outlining its effects on the GDP, health sectors and household's welfare. Based on simulation results, the GDP decrease and the rate of reduction depend on the severity of the earthquake. Supply side of health sector is affected more than demand side, due to the fact that healthcare centres destroy aftermath of earthquakes. Household's welfare reduces after earthquake and the urban population are more vulnerable.

Keywords: earthquakes; health; welfare; computable general equilibrium models.

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1 Introduction

Based on American Psychiatric Association (APA), the definition of disaster includes sudden, highly disruptive, time limited and public events (Vogel et al., 1993). And, also according to Norris' (1990) definition, disasters are sudden, uncontrollable, unexpected events that can be conceptualised as specific events. Although disasters have many common characteristics, each disaster has its own impact depending on the various economic situations (Saylor et al., 1993).

Earthquake is a kind of natural disaster which is quite sudden, unpredictable, and uncontrollable and lasts only a few minutes with destructive effects (Gunes, 2001). Based on the United Nation's reports, about two million people were killed due to 1,000 earthquakes over 70 countries during the past century. About 80% of all earthquakes placed in China, Japan, Iran, Turkey, India, Chile, Indonesia, Pakistan and Guatemala which more than 50% of their lands lay over faults. Located on the earthquake band, all these countries are bound to experience similar disasters and the catastrophic events. Therefore, it should be an alarm to design an applied planning to manage the impacts of any probable similar disasters (Sadeghi-Bazargani et al., 2015).

Study of possible events can give us lessons on how to manage future disasters more effectively, so this study tries to clarify the effects of earthquake as a shock to the Iran's economy. According to the previous events studies, earthquakes are a kind of commonplace natural disaster happening in Iran, which is located on the earthquake band of the Alpine Himalayas. More than 80,000 people have been killed from 1990 in five massive earthquakes (all above 6.5 on the Richter scale). In comparison with developed countries, buildings are not strong enough against earthquakes, therefore, they would easily destroy. After a quake, infrastructures such as bridges and roads which are not strong enough destroy, make it extremely hard to save people. This can lead to death of many residents. Besides, earthquake insurance is not a strong industry and almost all the houses are uninsured against quakes. Hence, after a quake people lose their assets and government should allocate a large budget to rebuild the houses and infrastructures (Shahpari et al., 2017).

Since 1990 more than five severe and important earthquakes have been occurred in Iran on the average of 7.1 magnitudes in Richter scale. According to the historical statistics, more than 80,000 people were killed by these disasters (The International Disaster Data Base, http://www.emdat.be). It is expected that in future other earthquakes will happen; so, this is necessary to plan for good strategies of making buildings and structures more resilience.

This paper proposes modelling the reduction in capital stock aftermath of earthquake and outlining its effects on the gross domestic product (GDP), production of different sectors and household's welfare using CGE approach. CGE models are widely applied for economic analysis. Some previous researches have employed CGE models for earthquakes effects on different countries, but none of them have investigated the quakes' consequences on the health sector. This study is structured as follow. In the next section the review of literature is provided. In Section 3, database and methodology are described. Section 4 presents the simulation results. And finally, Section 5 concludes with recommendations for policy.

2 Theory and review literature

After an earthquake, some post disaster phases are possible:

1 The emergency phase: every attempt in this phase is for saving people's lives. It may include searching for live people, first aid, building shelters, emergency and medical assistance, resorting transportation and communication networks temporarily, burying human corps or controlling the disease that may become epidemic afterward (Shahpari et al., 2017).

2 The rehabilitation phase: in which the emotional and psychological problems of inhabitants must be solved. By creating new jobs and providing financial resources, affected communities should get back to their normal lives. In this phase, that is named transitional phase, houses, buildings, infrastructures and public utilities will be repaired temporarily.

3 The reconstruction phase: in the final phase, physical environment should rebuild. Therefore, based on the new social priorities arise from the disaster; resources should be allocated properly (ECLAC, 1991; Sadeghi-Bazargani et al., 2015).

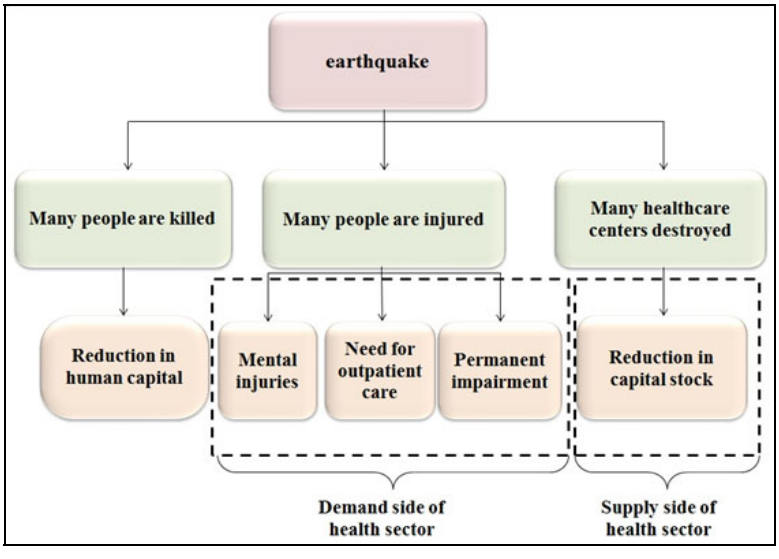
Earthquakes can cause health problems in different aspects. Many people are killed after the quake, and it is obvious that the number of dead depends on the earthquake magnitude and the resilience of the building. By comparing the average of people killed by the earthquake against their life expectancy, the loss of human capital can be quantifiable. It can also cause an unexpected number of injuries or illnesses in the affected society.

Earthquake may demolish the building of many healthcare centres, which have the critical role of helping injured people. After earthquake happens, demand for the medical health will increased dramatically. Therefore, it is necessary for the supply side of the health sector to answer this need. It is very important for the healthcare centres in at risk countries to be ready to face with severe quakes by adopting retrofitting policies. And also, for developing countries it is useful to know how to face with critical circumstances (ECLAC, 2003; Emamgholipour et al., 2014).

Earthquake can cause immigration of the victims to the areas where the healthcare centres may not answer the needs of these new people. Therefore, the result will be increasing in the rate of mortality and morbidity. And also, dislocation of a large number of populations can increase the risk of prevalence of transmissible illnesses for both host

community and immigrants. In Figure 1, which provides a conceptual framework for this paper, the effects of earthquake on the health sector has been illustrated briefly.

Figure 1 How earthquake affect health sector (see online version for colours)



Followings are explained papers that have investigated impacts of earthquake on the economy. Soberon et al. (1986) studied an earthquake which hit Mexico City in 1985. The quake had a lot of impacts on people's lives and also on important medical facilities. After the earthquake, many facilities within the healthcare system were demolished that must be reconstructed. The results showed that in the case of the quake, the majority of a community is undergone difficulties, therefore, an equipped health system will be necessary.

Anbarci et al. (2005) developed a theoretical model to study why some segments of society are incapable of arriving at what all parties perceive to be an agreeable distribution. Their finding showed that there is strong evidence of the theoretical model's predictions. The wealthy segment has self-insured against the disaster while poor segment should rely on them.

Using an ARDL approach, Sadeghi et al. (2008) studied the effects of natural disasters as a negative shock to the non-oil GDP. Their findings illustrated that during 1959–2004 there is a long run relationship between non-oil GDP and gross fixed capital. And also, they found that natural disasters loss has negative impact on GDP, while gross fixed investment has positive impact. After a natural hazard, GDP started to decrease due to the loss in the physical capital. But it will increase in the reconstruction phase; therefore, they found a U-shaped relationship between loss of the natural disasters and general level of the economic activities.

Achour et al. (2011) studied the earthquake induced damage in hospitals. Studying of the damage to 34 healthcare centres caused by earthquakes between 1994 and 2004 showed that there were differences among structural and architectural damage due to the situation. The utility supply and equipment damage were similar in the cases, because most facilities were equipped with similar technology.

Using a CGE approach, Shibusawa (2011) studied economic effects of earthquake in Japan. After earthquake, capital stock decline immediately. While in reconstruction phase, investment increases to face the losses.

Wu et al. (2012) tried to estimate indirect economic losses caused by Wenchuan earthquake occurred in 2008 China, throughout the adoptive regional input-output (ARIO) model. Using this model, they figured out changes in production capacity, economic fluctuations and adoptive behaviours of economic actors which were related to the quake. Their findings also illustrated that indirect economic losses in the housing and production sectors were about 40% of the direct losses, and the period of reconstruction was estimated eight years.

Datar et al. (2013) surveyed the indirect impacts of small and moderate natural disasters on child health in rural India. By using data from three waves of Indian National Family and Health survey with an international database of disasters (EMDAT, 2018), their results showed facing with a natural disaster in the past can increase 9%–18% of the likelihood of illnesses in children under the age of 5. Socioeconomic characteristics have also significant impacts on decreasing the side effects of natural disasters.

Huang et al. (2014) also used a CGE model to quantify economic impacts of quakes in Taiwan. As consumption level declines, they found that household welfare will be in lower levels after earthquake. Riestra (2015) focused on household welfare and found negative effects of earthquake on household welfare in Chile.

Some of other recent researches have focused on economic impacts of earthquake in recent years (e.g., Hallegatte, 2010; Huang et al., 2014; Xie et al., 2014; Carrera, 2015; Haddad et al., 2015; Riestra, 2015; Gignoux, 2016).

3 Data and methodology

According to the Walrasian general equilibrium structure, CGE models solve for the equilibrium conditions. By optimising the behaviour of consumers, producers and investors, demand and supply of commodities are determined assuming there are competitive markets. The CGE model of this study, established on the basis of standard CGE model by Lofgren et al. (2002), which is applicable for modelling developing countries (Ashena et al., 2016), creating the mechanism of interaction among economy, health and earthquake.

The model includes a representative agent, which is endowed by labour and capital as primary factors and maximises profits of the activity. Producer behaviour is specified through a nested constant elasticity of substitution (CES) production function for domestic supply, and through a zero-profit condition. Production of commodities is captured by a cost function for primary factors and a Leontief function of intermediate materials.

All goods used in the domestic market in intermediate and final demand (Armington, 1969) correspond to a CES composite. The Armington assumptions applied in combining domestic production and imports, using a CES function. The resulting homogeneous ‘Armington commodities’ are either sold domestically or exported. A constant elasticity transformation function determines the scope for choice between domestic supply and export, σ_t. All international trade links with other countries is aggregated into one additional sector, namely ‘rest of the world’ (RoW).

In the model, institutions are represented by households (urban and rural), enterprises, the government, and the RoW.

Activities are divided into agriculture, industry, services and health sectors. Based on the study purpose, the health sector is separated as a sub-sector of services. Based on social accounting matrix (SAM) 2011, 2.4% of total production in Iran is formed by health sector. The groups of commodities are also contained agriculture, industry, services and health. Factors of productions are labour and capital (Table 1).

Table 1 The sets of used in the model

The sets of used	
Activities (a)	*Commodities (c)*
Agriculture	Agriculture
Industry	Industry
Services	Services
Health	Health
Households	*Factors of production*
Urban	Labour
Rural	Capital

Activities revenue is yielded by sailing produced commodities and use this revenue for paying production factors and intermediate commodities. Prices in this model are flexible to the extent that the demand and supply will be equal in the competitive markets. The households receive their income from factors of production and also transfer from other institutions. Household consumption is allocated across different commodities based on linear expenditure system (LES). Demand functions derived from maximisation of a Stone-Geary utility function.

The government income is based on taxes and transfers from other institutions. Enterprises incomes are allocated to direct taxes, saving and transfers to other institutions and they do not consume. Factor incomes may be paid to one or more enterprises, instead of households. All transfers between the domestic institutions, factors and the RoW are fixed in foreign currency.

Database for the CGE model is a SAM, which is a comprehensive data framework. A SAM is a square matrix that their arrays show the payment from the account of its columns to the account of its row. For a standard CGE model, it is needed to apply a standard Sam. In our study, we have integrated the standard SAM of 2011, as the latest comprehensive input-output data frame.

In the CGE model, it is assumed quantities of supply and prices of activities for labour and capital, as the factors of production, are fixed. Foreign saving and marginal propensity of saving (MPS) for both urban and rural households are fixed, which are for Iran's economy appropriate assumptions (Islamic Parliament Research Center, 2014).

4 Simulations and discussion

A CGE model is applied to quantify the consequences of earthquake on the economy and health sector. This part presents the results of the analysis. Reduction in the capital stock

is assumed as the major consequences of an earthquake. For the past 60 years, earthquakes have imposed over 32 billion dollars loss to the economy of Iran. Considering the amount of loss as decline in the capital stock (which is a tricky assumption while some losses included losses to the human and livestock cannot be classified as capital stock), it can be concluded that 9% of average capital stock during past 30 years has been decline after earthquakes. Therefore, SC1, SC2 and SC3 refer to 7.5%, 10% and 12.5% decrease of the capital stock, respectively. The capital stock is considered as an exogenous variable, and then simulated three scenarios. Simulation results are reported as percentage change in economic variables from their base levels.

According to the results illustrated in Table 2, after quake, GDP will decline and the reduction rate is related to the magnitude of earthquake. Using ARDL approach Sadeghi et al. (2008) and Bazzazan and Mohammadi (2015) also found similar negative impacts on GDP after earthquake for economy of Iran.

Table 2 Macroeconomic results of simulations (% change)

Macroeconomic results of simulations			
Variables	*SC1*	*SC2*	*SC3*
GDP	–3.76	–5.04	–6.35
Domestic output			
Agriculture	–1.33	–1.78	–2.23
Industry	–5.78	–7.75	–9.73
Services	–3.7	–4.96	–6.23
Health	–2.58	–3.47	–4.36
Quantity of export			
Agriculture	–0.77	–1.01	–1.24
Industry	–5.81	–7.78	–9.77
Services	–3.58	–4.8	–6.04
Health	–2.57	–3.44	–4.34

Domestic output will decline after the earthquake and the percentage of reduction in industry is more than other sectors, which is due to capital intensive nature of industry sector. For health sector, it can be concluded that the negative effects on the supply side is more in comparison with the positive effects for demand supply. A study in Bangladesh, which is also a developing country, shows that medical care and emergency response do not efficiently respond to a disaster (Sohel and Hiroshi, 2018).

Saikia (2014) in investigating the status and problem of health service delivery in developing countries stated two main shortcomings in government spending for health services. First, institutional capacity in service delivery is a vital ingredient in providing effective services. Second, the net effect of government health services depends on the severity of market failures. From various theoretical and empirical experience, it is found that the more severe the market failures are, the greater the potential for government services to have an impact to grow positively.

In other words, although after quake there are many injured people that will increase demand for the health sector products, supply side effect is dramatically high. Supply side effects include destroy of healthcare buildings, storehouses of drugs and

infrastructure of health sector. Therefore, the output of health sector will be negative after quake. It can be concluded that healthcare structures are not resilience enough.

The reduction of export is the same as output. As it was expected, since the amount of domestic output is lowered in all sectors, the amount of export will be lowered, too. To study the effects of earthquake on the welfare, income, consumption and saving of household, the result is quantified in Tables 3 to 6.

Table 3 Results of simulations on household income from production factors (% change)

Simulations on household income from production factors			
Household income	*SC1*	*SC2*	*SC3*
Labour	–3.81	–5.11	–6.42
Capital	–3.83	–5.15	–6.48

Table 4 Results of simulations on household saving (% change)

Simulations on household saving			
	SC1	*SC2*	*SC3*
Household saving	–3.47	–4.65	–5.86

Table 5 Results of simulations on household consumption (% change)

Simulations on household consumption				
Household consumption		*SC1*	*SC2*	*SC3*
Agriculture	Urban	–2.37	–3.17	–3.98
	Rural	–2.18	–2.91	–3.65
Industry	Urban	–5.08	–6.8	–8.53
	Rural	–4.89	–6.54	–8.21
Services	Urban	–3.32	–4.46	–5.61
	Rural	–3.13	–4.2	–5.29
Health	Urban	–3.04	–4.08	–5.14
	Rural	–2.85	–3.82	–4.81

Table 6 Household income, results of simulations (% change)

Simulation on household income			
Household income	*SC1*	*SC2*	*SC3*
Urban	–3.5	–4.7	–5.9
Rural	–3.31	–4.44	–5.59

According to the results, after the earthquake households' income from production factors, saving, consumption and household income in both rural and urban areas will be lowered. For more intense earthquake, the reduction of these variables for both urban and rural households gets higher. But the point is that urban households are more likely to suffer in all scenarios. It may be concluded that after a disaster, since the income of urban households is more dependent on the capital, they are more vulnerable.

Income, saving and consumption can reflect the impacts of earthquake on household's welfare. As it was expected, the welfare of household become in lower

levels after quake. To avoid or make the natural disaster's loss least, countries which are at risk (especially those who are located on the earthquake band such as Iran) should arrange serious actions to face with the critical situations before it happens.

Table 7 Impact of changing, σ_c, σ_t (percentage changes from base amount)

Sensitivity analysis							
		$\sigma_c = 2.4$	$\sigma_c = 2.5$	$\sigma_c = 2.6$	$\sigma_t = 1.9$	$\sigma_t = 2$	$\sigma_t = 2.1$
GDP		–5.05	–5.04	–5.048	–5.05	–5.04	–5.049
Domestic output							
Agriculture		–1.865	–1.78	–1.688	–1.791	–1.78	–1.761
Industry		–7.731	–7.75	–7.763	–7.737	–7.75	–7.756
Services		–4.968	–4.96	–4.949	–4.958	–4.96	–4.958
Health		–3.473	–3.47	–3.462	–3.469	–3.47	–3.466
Quantity of export							
Agriculture		–1.094	–1.01	–0.923	–1.061	–1.01	–0.955
Industry		–7.753	–7.78	–7.804	–7.761	–7.78	–7.796
Services		–4.809	–4.8	–4.793	–4.808	–4.8	–4.794
Health		–3.45	–3.44	–3.439	–3.447	–3.44	–3.442
Household income							
Labour		–5.125	–5.11	–5.095	–5.125	–5.11	–5.095
Capital		–5.133	–5.15	–5.158	–5.133	–5.15	–5.158
Household saving		–4.708	–4.65	–4.69	–4.708	–4.65	–4.69
Household consumption							
Agriculture	Urban	–3.18	–3.17	–3.165	–3.177	–3.17	–3.167
	Rural	–2.919	–2.91	–2.903	–2.917	–2.91	–2.906
Industry	Urban	–6.808	–6.8	–6.785	–6.804	–6.8	–6.789
	Rural	–6.558	–6.54	–6.533	–6.553	–6.54	–6.537
Services	Urban	–4.468	–4.46	–4.452	–4.465	–4.46	–4.454
	Rural	–4.211	–4.2	–4.194	–4.208	–4.2	–4.197
Health	Urban	–4.089	–4.08	–4.075	–4.087	–4.08	–4.077
	Rural	–3.831	–3.82	–3.816	–3.828	–3.82	–3.818
Household income							
Urban		–4.708	–4.7	–4.69	–4.705	–4.7	–4.693
Rural		–4.52	–4.44	–4.433	–4.448	–4.44	–4.436

The theoretical analysis of this studying identifies a number of key parameters which are likely to govern the extent of rebound including elasticity of substitution between domestic supply and export, σ_c, and elasticity of transformation between domestic supply and export, σ_t. An effective sensitivity analysis on these elasticities should be conducted given that the elasticities can change directly with the duration of time interval of the analysis. In other words, elasticities of substitution can have a strong impact on the results (Hanely et al., 2009). Therefore, in Table 7 the value of σ_c and σ_t are varied and

for conciseness, the focus is on the second scenario only. In central case these parameters take the values of 2.5 and 2, respectively. For sensitivity, each of these parameters are varies (independently) to 2.4, 2.6 and 1.9, 2.1, respectively.

From the above sensitivity analysis, it can be concluded that there is not any significant change among the results. Therefore, results are consistent and robust to generate the conclusion.

5 Conclusions

In this study, the quantitate impacts of earthquake on the economy and health sector of Iran has been surveyed. A static CGE model of Iran was developed to simulate this shock to the GDP, domestic output, and quantity of export in different sectors. And also, household's income, saving and consumption, are investigated as household welfare indicators.

Results of simulations show that after disasters, GDP decrease and the rate of reduction depends on the severity of the earthquake. A closer look to the sectors makes it clear that health sector products decline. Since after quake many people will demand health products, the reduction of health products is referring to the destruction in supply side of health sector. Therefore, it can be concluded that healthcare centres in Iran are not resilience enough and in the case of earthquake they are at risk. Although design rules for healthcare centres are different from other buildings, it seems that rules are not obeyed carefully or it is time to review rules and make them update.

To avoid or make least the natural disaster's loss, countries which are at risk (especially those who are located on the earthquake band such as Iran) should arrange serious actions to face with the critical situations before it happens. In the disaster management planning procedure, one of the most important thing that should be considered as a top priority is strengthening structures of public places. For instance, crisis management organisations should establish to legislate rules for retrofit structures and especially healthcare centres which are vital places in the case of any types of disasters. The other approach which also can be considered as a long-term solution is earthquake insurance. Insurance companies price the insurance premium based on building age, its structure and location. Then if the earthquake insurance will be obligatory, all buildings will be built based on standard methods and all buildings will be resilient to the earthquake, gradually (Shahpari et al., 2017).

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Appendix

Algebraic model summery

Sets

- $a \in$ A activities
- $c \in$ C commodities
- $c \in$ CE ($\subset$ C) exported commodities
- $c \in$ CEN ($\subset$ C) commodities not in CE
- $c \in$ CM ($\subset$ C) imported commodities
- $c \in$ CMN ($\subset$ C) commodities not in CM
- $f \in$ F factors
- $i \in$ INS institutions (domestic and RoW)
- $i \in$ INSD ($\subset$ INS) domestic institutions
- $i \in$ INSDNG ($\subset$ INSD) domestic non-government institutions
- $h \in$ H ($\subset$ INSDNG) households

Parameters

ad (*a*)	Production function shift parameter
alpha (*f*, *a*)	Share of value-added for factor fin activity *a*
aq (*c*)	Armington function shift parameter
at (*c*)	Cet function shift parameter
beta (*c*, *h*)	Marginal share of consumption spending on marketed commodity *c* for household *h*
cpi	Consumer price index
cwts (*c*)	Weight of commodity *c* in the CPI
deltaq (*c*)	Armington function share parameter
deltat (*c*)	Cet function share parameter
ica (*c*, *a*)	Quantity of *c* as intermediate input per unit of activity pwm (*c*): world market price of imports
pwe (*c*)	World market price of exports
gles (*c*)	Government consumption shares
eles (*c*)	Firm consumption shares
qent (*c*)	Quantity of intermediate goods
qinvbar (*c*)	Base-year quantity of private investment demand
rhoq (*c*)	Armington function exponent
rhot (*c*)	Cet function exponent
shryh (*h*, *f*)	Share for household in income of factor
shry (*ins*, *f*)	Share for domestic institution in income of factor
te (*c*)	Export duty rates
theta (*a*, *c*)	Yield of output *c* per unit of activity *a*
tm (*c*)	Tariff rates on imports
ta (*a*)	Activity tax rate
tq (*c*)	Sale tax rate
ty (*h*)	Income tax rate

Variables

mps (*h*)	Marginal propensity to save for domestic non-government institution
pa (*a*)	Price of activity *a*
pd (*c*)	Domestic prices

pm (*c*) Domestic price of imports

pe (*c*) Domestic price of exports

pq (*c*) Price of composite goods

pva (*a*) Value added price by sector

px (*c*) Average output price by sector

qa (*a*) Level of activity *a*

qva (*a*) Value added quantity by sector

qd (*c*) Domestic sales

qe (*c*) Exports by sector

qm (*c*) Imports

qq (*c*) Composite goods supply

qx (*c*) Domestic output by sector

qf (*f*, *a*) Quantity demanded of factor *f* from activity *a*

qfs (*f*) Labour supply by labour category (1,000 persons)

qh (*c*, *h*) Final demand for private consumption

qint (*c*, *a*) Intermediates uses

qinv (*c*) Final demand for productive investment

wf (*f*) Average wage rate by labour category

wdist (*f*, *a*) Age distortion factor for factor *f* in activity *a*

yf (*h*, *f*) Transfer of income to household from factor *f*

yh (*h*) Household income

yfe (*f*) Transfer of income to ins from factor parameters

Equations

1 $PM_c = pwm_c.(1 + tm_c).EXR$

2 $PE_c = pwe_c.(1 - te_c).EXR$

3 $PQ_c.QQ_c = PDD_c.QD_c + PM_c.QM_c\ (1 + tq_c)$

4 $PX_c.QX_c = PDS_c.QD_c + PE_c.QE_c$

5 $PA_a = \sum_{c \in C} PXAC_{ac}.\theta_{ac}$

6 $PVA_a = PA_a.(1 - ta_a).QVA_a - \sum_c ica_{ac}.PQ_c$

7 $QA_a = ad_a.\prod_f QF_{fa}^{\alpha_{fa}}$

8 $WF_f.WDIST_{fa}.QF_{fa} = PVA_a.QA_a.\alpha_{fa}$

9 $QINT_{ca} = ica_{ca}.QA_a$

10 $QX_c = \sum_a \theta_{ac}.QA_a$

11 $QQ_c = aq_c.\left(\delta_c^q.QM_c^{\rho q} + \left(1-\delta_c^q\right).QD_c^{\rho q}\right)^{-\frac{1}{\rho_c^q}}$

12 $\frac{QM_c}{QD_c} = \left(\frac{PD_c}{PM_c}.\frac{\delta_c^q}{1-\delta_c^q}\right)^{\frac{1}{1+\rho^q}}$

13 $QQ_c = QD_c + QM_c$

14 $QX_c = at_c\left(\delta_c^t.QE_c^{\rho^t} + \left(1-\delta_c^t\right).QD_c^{\rho^t}\right)^{\frac{1}{\rho t}}$

15 $\frac{QE_c}{QD_c} = \left(\frac{PE_c}{PD_c}.\frac{1-\delta_c^{q^t}}{\delta_c^t}\right)^{\frac{1}{\rho^t-1}}$

16 $QX_c = QD_c$

17 $YF_{hf} = shry_{hf}.\left(\sum_f WF_f.WDIST_{fa}.QF_{fa} + trr_f.ER\right)$

18 $YH_h = \sum_f YF_{hf} + \sum_{ins} tr_{h,ins}$

19 $QH_{ch} = \frac{\beta_{ch}.\left(1-MPS_h\right).\left(1-ty_h\right).\left(1-sh_h\right).Y_h}{PQ_c}$

20 $YG = \sum_h ty_h.Y_h + \sum_{cm} tq_c.\left(PD_c.QD_c + PM_c.QM_c\right) + \sum_{cm} tm_c.ER.pwm_c.QM_c + \sum_{ce} te_c.ER.pwe_c.Qe_c + tr_{gov,row}.er + tr_{gov,insd}$

21 $YENT = \sum_f shry_{ent,f}.\left(\sum_f WF_f.WDIST_{fa}.QF_{fa} + trr_f.ER\right) + \sum_{insd} tr_{ent,insd} + tr_{ent,row}.ER$

22 $HSAV = \sum_h MPS_h.\left(1-ty_h\right).\left(1-sh_h\right).YH_h$

23 $GSAV = YG - \sum_c PQ_c.gles_c.gdtot + \sum_{ins} tr_{ins,gov}$

24 $ENTSAV = YG - \sum_c PQ_c.entdtot + \sum_{ins} tr_{ins,ent}$

25 $QFS_f = \sum_a QF_{fa}$

26 $QQ_c = \sum_a QINT_{ca} = \sum_h qh_{ch} + PQ_c.gles.GDTOT + PQ_c.eles_c.entdtot + qinv$

27 $$\sum_{cm} pwm_c.QM_c + \sum_f trf_f + \sum_{ins} tr_{row,ins} + OCAP = \sum_{ce} pwe_c.QE_c + \sum_f trr_f + \sum_{ins} tr_{ins,row} + FSAV$$

28 $$\sum_c QINV_c.PQ_c + OCAP + WALRAS = \sum_h HSAV + GSAV + ENTSAV + FSAV.ER$$

29 $$\sum_c PQ_c.cwts_c = cpi$$

30 $$GDP = \sum_a QA_a.PA_a$$