China's Structural Reform and its Impact on Trade and Growth: an application of DPN GEM*

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Abstract

Based on an innovative input-output table developed out of China's global value chains project, we construct an ORANI-type China trade CGE model, known as DPN GEM, and applies it to study the impact of China's structural reform on trade and growth. Policy scenarios are designed to consider the slowdown of US foreign outsourcing to China, and China's efforts to steer the economy toward a new normal, which is characterised by a lower rate of investment and higher rates of consumption and innovation. It shows that, while the new growth model unambiguously raises household welfare with more domestic consumption, it is contractionary in terms of trade. Transition to the new normal may reduce the nominal GDP, but not necessarily the real GDP.

Keywords: trade, structural reform, CGE, China
JEL Codes: F13, C68, F47

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1. The new normal and structural reform

China is now in transition from a fast growing economy driven largely by investment and export to a new growth model with domestic demand and innovation as the new growth engines. This new growth model may come with a lower growth rate, and is often dubbed the 'new normal'. It will define China's growth trajectory for decades to come. To fulfil this transition, Chinese economy needs to be rebalanced from an over-reliance on export and investment to more innovation and more domestic consumption.

Trade adjustment is a key part of this transition. A distinct feature of China's foreign trade is its processing trade arrangement, in addition to its normal trade regime. Under the processing trade regime, parts and components enter China duty free and are exported after being processed or assembled. While parts and components are mostly made in ASEAN, Korea and Japan, the major destination of the assembled products is the US and the EU.

China's processing trade took off in the early 1990s. It was accelerated by the 1997 Asian financial crisis as exporting firms in crisis-stricken countries sought safe haven in China. The country's accession to the WTO in 2001 secured its access to the US market, so that more exported oriented FDI flowed into China. On the demand side, Chinese provinces were competing to attract FDI by offering various incentives. To avoid competition with local domestic firms, FDI in labour-intensive sectors has been encouraged to enter export businesses. As a result, processing trade is the natural choice of low-tech FDI.

After almost a quarter of a century of rapid growth, China's processing trade regime is now in stress. Rising labour costs are driving foreign funded processing firms to move to other cheap developing countries or even return to home countries, as evidenced by the re-industrialisation in the US. Chinese policies encouraging indigenous innovation have helped domestic production of R&D-intensive parts and components, which are increasingly replacing imported intermediates.

This development has coincided with the 2008 Global Crisis, which not only depressed firm's foreign outsourcing activities, but also slowed down normal international trade. However, the Crisis itself is a cyclical factor and its impact on trade will go away once the world economy is fully recovered. In fact, Constantinescu et al. (2014) attribute the recent slower trade growth to the slowdown of US foreign outsourcing to China. In the long run, structural factors, such as the processing trade adjustment and other reform measures, will have a permanent impact on trade.

For this set of complex policy initiatives, theory can not predict the signs of their impacts, much less about the magnitudes. Econometrics methods are good at analyzing policies with rich historical data, but are less effective in dealing with structural changes or new shocks to the economy. To quantitatively evaluate the trade and growth impact of China's transition to the new normal calls for a CGE model that has detailed depiction of the Chinese foreign trade. This paper first introduces a China trade CGE model DPN GEM in Section 2, both data and theoretical structures. Then in section 3, we design reform scenarios with different levels of implementation, and present the simulation results. Section 4 concludes.

2. The model: DPN GEM

2.1 Data structure

DPN IOT

Conventional CGE models for Chinese trade policy analysis do not differentiate processing export and the rest of the Chinese economy. Examples include the model developed by China's Development Research Center (the DRC model), which focuses on the Chinese regions, and the standard GTAP model (Hertel and Tsigas 1997). Economists have attempted to separate normal and processing trade in a CGE model for China (Ianchovichina et al. 2000, Wang 2003, Ianchovichina 2004, Ianchovichina and Martin 2004). Recently, with the availability of Chinese trade data on processing trade, Koopman et al (2013) is able to split the processing trade sector from the rest of Chinese economy and treats it as a separate economy in a GTAP-turned GVC model. The split, however, is largely based on assumptions on key input-output coefficients and does not further differentiate production for normal export and production for domestic uses.

Our proposed modeling work is an improvement along this line and is made possible through the construction of an innovative Chinese input-output table (IOT) that differentiates the production for domestic use (D), the production for processing trade (P) and the production for normal trade and other production of foreign-invested enterprises for domestic use (N) and is known as DPN IOT.

The tripartite feature of the DPN IOT is shown in Table 1 in the Appendix. There are three types of heterogeneous production technologies: type D gives the production for domestic use, type P represents the production of processing trade, and type N the production for normal trade and other production of foreign-invested enterprises for domestic use. This classification of three production technologies is justified by the theory of, and Chinese empirical evidence on, firm heterogeneity (Melitz 2003, Yao et al., 2015), and was pioneered by Chen et al. (2001) and Chen et al. (2012).

[insert Table 1 here]

DPN IOT's tripartite feature is also justified by different behaviors of foreign investors in China. While low tech FDI seeking cheap labor often forms contractual or cooperative joint ventures with local non-state firms and goes to P, high-tech FDI seeking market access usually forms equity joint ventures with state owned enterprises and goes to N (Ouyang and Yao, 2013). Thus, the tripartite feature is also a good framework for studies on FDI in China.

The DPN IOT project is data intensive. In Spring 2012, it was officially designated as China's participating project in the WTO/OECD "Made in the World" initiative. Coordinated by the Chinese Ministry of Commerce, various Chinese statistical agencies, including the Statistical Bureau, the Customs and the State Foreign Exchanges Administration, have been lending data support to the project by providing existing data and conducting firm surveys on import uses. This institutional arrangement has significantly enhanced the quality of the DPN IOT and made it the best source of economy-wide data for applied research on China's foreign trade.

The key parameters of the DPN IOT are given in Table 2 in the Appendix. Heterogeneity is evident. The left panel gives input structures in absolute values (i.e., Z), where sheer size differences are revealed. For example, the D class production was 19 times as much as P class production (97389 billion Yuan vs. 5011 billion Yuan). In terms of input share structure in the right panel, the heterogeneity is even pronounced when measured by shares of imported intermediates, which ranged from 0.04 (for D class production) to 0.56 (for P production). Since each column in right panel sum to unity (by definition), a high imported intermediates share is accompanied with a relatively low share of domestically produced intermediates and value added. The last row in the right-hand panel of the numerical table gives one more indicator: the capital-to-labour ratio. It suggests that the production type P is labour-intensive with a low K/L ratio 0.67, whereas the production type N is capital-intensive with a high K/L ratio 1.04.

[insert Table 2 here]

The detailed DPN IOT accouting relations are presented in the Appendix.

2.2 The Model: DPN GEM

Construction of a CGE model involves several typical components: namely, i) the choice of the model, ii) the functional forms, and iii) the selection of the parameter values (Shoven and Whalley, 1984). While DPN GEM has its own innovative database, it follows the ORANI in model structure and parameters (Dixon et al., 1982) and only makes minor modifications in production to accommodate the unique DPN IOT structure.

ORANI is a single country model for Australia and has been a standard template to start with in developing a CGE model for many other countries. The standard ORANI is built on a database differentiating domestic and imported inputs, typical structure of a non-competitive IOT. Its nested production structure is illustrated in Diagram 1. The basic functional form for production is characterised with constant elasticity of substitution (CES), with 0 for Leontief-type of production technology and 1 for Cobb-Douglas type. Final output is produced with a Leontief production function with inputs in fixed proportion and consisting of primary factors and other intermediates. Through a general CES production function, the primary factors are produced with labour and capital, and the intermediates are produced with domestic and imported inputs.

[insert Diagram 1 here]

DPN IOT goes beyond a non-competitive IOT, and accordingly the nested production structure is modified for DPN GEM. As shown in Figure 2, the last stage of production is still in the Leontief functional form and all other productions remain in CES form. The inputs Goods 1-C are produced with intermediates from three (rather than two) technologies (D, N or/and P), depending on their end uses. For example, if Good 1 is for processing export, then Good P can be non-zero; otherwise, Good P is zero. In other words, the production functional forms for Goods 1-C all look the same, but the end use of the output and the underlying data structure determine their actual functional forms. Our treatment of processing trade is different from Koopman et al (2013) who treat the processing trade as a separate economy in a global model. By only separating D, P and D in the database but keeping the same ORANI production functional forms, we are able to minimize the model modifications.

[insert Diagram 2 here]

The lower part of Diagram 2 further illustrates the production of intermediates Goods D, P and N. They can be in turn produced with proper inputs compatible with their end uses. While Good P can be produced with all three inputs (D, P and N), Goods D and N can not use imported Good P as input. Be aware that under N, there are three goods: goods for normal export, good imported with tariff paid, and good produced by FDI for domestic market. But only FDI produced domestic Good N can be used for production of all three Goods, while imported Good N can be used for production of Good D and Good N.

The nested structure of production is the only part our DPN GEM differ from ORANI in terms of modeling. The detailed theoretical equations for this part are provided in the Appendix. Considering China is a large country, we reduce the substitution elasticity between imports and domestic products following the literature (Hillberry and Hummels, 2013).

3. Policy scenarios and simulation results

Baseline scenario: Normal growth

Our baseline ('normal') scenario is normal annual growth based on the 2014 data. We first project the 2010 data in our model to 2014. The projection shocks are shown in Table 3. The DPN GEM does not explicitly model FDI, an important source of growth. Instead, we use capital-saving technological progress to model the effects of FDI inflows. Data on exports, investment, private consumption and government spending are all available in government publications, whereas the impact of FDI inflow and innovation are not observable and thus derived from the model subject to fitness constraints of key endogenous variables, GDP and imports, as shown in Table 4.

The normal growth rates for various variables are defined as the annualized 2010-14 growth rates as shown under the "Normal" column in Table 5[1]. Against this baseline, the processing trade adjustment and economic rebalancing are modelled to reflect (i) slower growth in foreign outsourcing, and (ii) less reliance on investment, and more reliance on domestic consumption and innovation. We set up three scenarios for each of the two types of structural changes – minor, moderate and major reforms. Counter factual growth rates for all indicators under various scenarios are listed in Table 5, and simulation results are reported in Table 6.

Foreign outsourcing slowdown

The middle panel of Table 6 reports the simulation results for foreign outsourcing slowdown. Processing export growth is slowed from the normal 4.2% to 3.7%, 3.2% and 2.7%, respectively, under the minor, moderate and major reforms. Growth of FDI inflow into processing trade production is slowed because processing trade is largely fueled by FDI. For this, we factor in slower than normal growth rates for capital-saving technology progress in processing trade production, which are 2%, 1.8% and 1.6%, respectively, for the three scenarios.

All other things being the same as in the 'normal' scenario, growth rates for both imports and exports in both real and nominal terms are also reduced compared to the normal scenario. In particular, nominal import to nominal GDP ratio grows at -4.82%, -4.91% and -5.00% under the minor, moderate and major adjustment scenarios, respectively, compared to -4.74% under normal scenario. The numbers for the same scenarios for the real import to real GDP ratio are -1.07% (minor), -1.18% (moderate), -1.30% (major) and -0.97% (normal). In both measures, trade slows down more as a result of foreign outsourcing adjustment.

[1] Since Chinese economy grew slower consecutively over 2010-14, the annualized growth rate under Normal scenario may be bigger than the extrapolated growth rate. This points to an area the paper can be revised.

Economic rebalancing: Transition to the ‘new normal’

China’s ongoing economic reforms involve more than just a processing trade adjustment. Most of the discussions on China’s economic rebalancing imply a slower growth rate, and the annual growth rate itself was a closely watched figure in the prime minister’s annual work report to the National People’s Congress in March 2015. However, the growth rate is not a policy tool but the result of a set of economic policies used to make the transition to the ‘new normal’, including domestic investment, consumption, net FDI and innovation.

Policy shocks for the transition to the ‘new normal’ scenarios are listed in the right-hand panel of Table 5. Except for normal exports, all other economic indicators will be changed under the minor, moderate and major reforms. While the processing trade adjustments remain the same, investment growth is slowed from 9.7% to 9.2%, 8.7% and 8.2%, respectively, while private (public) consumption growth is raised from 9.2% (8.8%) to 9.7% (9.3%), 10.2% (9.8%) and 10.7% (10.3%), respectively..

Growth by indigenous innovation is a core element of the ‘new normal’ growth model. We set higher growth rates for the Hicks-neutral technology progress of 1.2%, 1.3% and 1.4% to represent minor, moderate and major innovations, respectively.

We do not change the growth rate for normal exports. As a policy matter, there is less emphasis on export promotion and the growth engine is shifting from external demand to internal demand. This tends to lower the growth prospects for normal exports. However, China is also strengthening its trade relations with low-income developing countries. There has been evidence that Chinese trade patterns are evolving in contrasting directions with high-income and low-income ASEAN members since 1997. High-income ASEAN countries are specialising in the production of R&D-intensive parts, with China as an assembly centre. At the same time, the low-income ASEAN countries are becoming assembly centres for Chinese-made parts (Yao et al. 2014). When South Asia and Africa start to integrate into global value chains, they will become the assembly centres for Chinese-made parts and components. This is a realistic development, particularly for India, where the Modi administration is trying to revitalise its manufacturing sector to create jobs for unskilled workers, a strategy endorsed by prominent free trade economists (Bhagwati and Panagariya 2013). The external developments in South Asia and Africa are coinciding with China’s R&D push, which will stimulate the production of knowledge-intensive parts and components. Therefore, the integration of South Asia and Africa into global value chains provides an opportunity for China to expand its exports of parts and components, which fall into the category of normal exports. For our modelling exercise, we assume the internal and external factors are cancelled out so that normal export growth rate remains ‘normal’.

The right-hand panel of Table 6 reports the simulation results. The consumption impacts are very straightforward, as the nominal investment to consumption ratio (I/C) grows into negative territory at -0.31% for minor reform, -1.20% for moderate reform and -2.09% for major reform, respectively.

The decline of the consumption share in GDP, all in nominal terms, is contained at -1.53% when minor reform is introduced, -1.05% if moderate reform measures are taken. For bold reform, the growth rate of the consumption share stands at -0.56%.

With the real consumption growing at a rate of between 6.92% and 8.59%, household utility could grow between 10.36% and 12.86% annually, depending on how drastic the reform measures are.

Compared to consumption, the trade impacts are less straightforward, as some reform measures tend to slow down imports (e.g., reduced growth of investment), while others stimulate imports (e.g., growing consumption). As a result, the question of how economic rebalancing will impact China's foreign trade is an empirical issue. However, our simulation results suggest that rebalancing will tend to slow trade, for both imports and exports in both nominal and real terms. Deeper reform is uniformly associated with slower trade growth, as shown in the right-middle block of Table 6.

In the debate over China's reform strategy, the GDP growth rate is the most talked about number. It is believed that a slower GDP growth rate is generally associated with more radical reform, while a faster one reflects the continuation of the current growth model. Does reform necessarily depress growth? It depends. As shown in the first two lines in the lower-right block of Table 6, nominal GDP indeed grows at a slower rate if reform is more drastic, but the opposite is true for real GDP. This can be illustrated in an aggregate demand and supply relationship, as shown in the following figure.

[insert Figure here]

The structural reform generates positive supply shocks but negative demand shocks. In the above Figure, the area $P_0X_0Y_0O$ represents the nominal GDP before reform and the area $P_1X_1Y_1O$ represents the equal nominal GDP on the new aggregate supply curve AS_2. Given that the real GDP is bigger and the nominal one is smaller after implementing the reform measures, the new aggregate demand curve AD_2 will intersect with AS_2 somewhere between X_1X_1'.

The last two lines in the lower-right block of Table 6 reports the growth rates of the trade share, measured as the share of imports in GDP, under the 'new normal' scenarios. In terms of the import value over nominal GDP ratio, trade growth rates turn to negative, and more so as reform goes deeper. This pattern also holds if the trade share is measured by the ratio of import volume over real GDP.

4. Conclusion

Processing trade accounts for about 30%-50% of China's total trade. In our DPN GEM database, with core data from China's 2010 DPN IOT, the proportion is no less than 34%, which is significant. It is intuitive that adjustment in China processing trade as a result of the stagnation of production fragmentation in the US will slow down China's overall trade; it is not quite straightforward to see how the 'new normal' growth model will impact trade, as several adjustments are taking place. When considering a package of reform measures, our modelling exercise shows China's transition to the 'new normal' is also contractionary in terms of trade. The new growth model unambiguously raises household welfare with more domestic consumption. It generates a higher growth rate for real GDP, but a lower one for nominal GDP. These findings are qualitatively consistent with our previous findings based on the same DPN GEM model, but on 2010 data and assumed uniform shocks (Pei, Yang and Yao, 2015).

References

Bhagwati, J and A Panagariya (2013), *Why Growth Matters: How Economic Growth in India Reduced Poverty and the Lessons for Other Developing Countries*, New York: PublicAffairs.

Chen, X, L K Cheng, K C Fung and L J Lau (2001), "The Estimation of Domestic Value-Added and Employment Induced by Exports: An Application to Chinese Exports to the United States", available at http://www.stanford.edu/~ljlau/Presentations/Presentations/010618.pdf.

Chen, X, L K Cheng, K C Fung, L J Lau, Y-W Sung, K Zhu, C Yang, J Pei and Y Duan (2012), "Domestic value added and employment generated by Chinese exports: A quantitative estimation", *China Economic Review* 23, pp. 850-864.

Constantinescu, C, A Mattoo and M Ruta (2014), "Slow Trade", *Finance and Development* 51(4), pp. 39-41.

Dean, J.M., K.C. Fung and Z. Wang (2011). Measuring Vertical Specialization: The Case of China, Review of International Economics, 19, 609-625.

Dixon, P B, B R Parmenter, J Sutton and D P Vincent (1982), *ORANI: A Multisectoral Model of the Australian Economy*, Amsterdam: North-Holland.

Feenstra, Robert C., and J. Bradford Jensen (2012). Evaluating Estimates of Materials Offshoring from U.S. Manufacturing, NBER Working Paper No. 17916. Cambridge, MA: National Bureau of Economic Research.

Hertel, T W and M Tsigas (1997), "Structure of GTAP", in T W Hertel (ed.), *Global Trade Analysis: Modeling and Applications*, Cambridge, UK: Cambridge University Press.

Hillberry, R and D Hummels, 2013, "Trade Elasticity Parameters for a Computable General Equilibrium Model," in P Dixon and D Jorgenson (ed) *Handbook of Computable General Equilibrium Modeling*, p1213-1269

Hummels, David, Jun Ishii, Kei-Mu Yi (2001). The Nature and Growth of Vertical Specialization in World Trade, Journal of International Economics, 54, 75–96.

Ianchovichina, E, W Martin and E Fukase (2000), "Comparative Study of Trade Liberalization Regimes: The Case of China's Accession to the WTO", paper presented at the Third Annual Conference on Global Economic Analysis, Melbourne, 27-30 June.

Ianchovichina, E. (2004). Trade Policy Analysis in the Presence of Duty Drawbacks, Journal of Policy Modeling, 26, 353-371.

Ianchovichina, E and W Martin (2004), "Impacts of China's Accession to the WTO", *World Bank Economic Review* 18, pp. 3-27.

Koopman, R, M Tsigas, D Riker, and W Powers, 2013, "The implications of using value-added trade data for applied trade policy analysis," in Deborah K. Elms and Patrick Low (eds) *Global Value Chains in a Changing World,* 109-134, World Trade Organization, Geneva

Melitz, M J (2003), "The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity", *Econometrica* 71(6), pp. 1695 – 1725.

Ouyang, P and S Yao, 2013, "Developing inland China: Do heterogeneous coastal foreign direct investments and exports help?" *ARTNeT Working Paper Series*, No. 138, December, UN ESCAP, Bangkok

Pei, Jiansuo, Cuihong Yang and Shunli Yao, 2015, "Trade impact of China's transition to the 'new normal,'" in Bernard Hoekman (ed.) *The Global Trade Slowdown: A New Normal?* A VoxEU.org ebook, CEPR Press, p253-263

Shoven, John and John Whalley (1984). Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey, Journal of Economic Literature, 22(3), 1007-1051.

Wang, Z (2003), "The Impact of China's WTO Accession on Patterns of World Trade", *Journal of Policy Modeling* 25, pp. 1-41.

Yao, S, Y Tian and L Bishwanjit Singh (2014), "Trade Liberalization and Poverty Reduction in China and ASEAN", paper presented at the 8th ASEAN-China Forum on Social Development and Poverty Reduction, Nay Pyi Taw, Myanmar, 7-8 August.

Yao, S, H Ma and J Pei (2015), "Import Uses and Domestic Value Added in Chinese Exports: What can we learn from Chinese micro data?", in S N Houseman and M Mandel (eds), *Measuring Globalization: Better Trade Statistics for Better Policy*, Volume 2, Kalamazoo, MI: W.E. Upjohn Institute for Employment Research.

Appendix

Table 1. The structure of China's DPN input-output table

	Intermediate use			Final use		
	D	*P*	*N*	*DFD*	*EXP*	*TOT*
D	$\mathbf{Z}^{DD}$	$\mathbf{Z}^{DP}$	$\mathbf{Z}^{DN}$	$\mathbf{f}^{D}$	0	$\mathbf{x}^{D}$
P	0	0	0	0	$\mathbf{e}^{P}$	$\mathbf{x}^{P}$
N	$\mathbf{Z}^{ND}$	$\mathbf{Z}^{NP}$	$\mathbf{Z}^{NN}$	$\mathbf{f}^{N}$	$\mathbf{e}^{N}$	$\mathbf{x}^{N}$
IMP	$\mathbf{M}^{D}$	$\mathbf{M}^{P}$	$\mathbf{M}^{N}$	$\mathbf{f}^{M}$	0	$\mathbf{x}^{M}$
VA	$(\mathbf{v}^{D})'$	$(\mathbf{v}^{P})'$	$(\mathbf{v}^{N})'$			
TOT	$(\mathbf{x}^{D})'$	$(\mathbf{x}^{P})'$	$(\mathbf{x}^{N})'$			

Notes: D = the production for domestic use; P = the production for processing trade; N = the production for normal trade and other production of foreign-invested enterprises for domestic use; DFD = domestic final demands; EXP = exports; TOT = gross outputs (and total imports in the column TOT); IMP = imports; and VA = value added. The input-output table is expressed in monetary units (of 10,000 Yuan).

Table 2. Key parameters for China's DPN IO table, 2010

	Input structures (2010 billion Yuan)			Input structures (shares)		
	D	*P*	*N*	*D*	*P*	*N*
D	50889	1033	12621	0.52	0.21	0.54
P	0	0	0	0.00	0.00	0.00
N	8835	306	2979	0.09	0.06	0.13
IMP	3681	2819	2375	0.04	0.56	0.10
VA	33984	854	5528	0.35	0.17	0.24
*TOT / K-L**	97389	5011	23503	*0.77**	*0.67**	*1.04**

Note: K-L gives the capital-to-labour ratio (last row in right panel), an indication of capital-intensive or labour-intensive nature of specific production class, e.g. 0.67 means the type P production is labour-intensive.

Table 3. Growth projection 2010-2014

	Demand in volume					FDI	Innovation
	n exp	p exp	I	C	G	K-saving	Hicks-neutral
Growth Rates							
from real data	65	18	45	42	40		
derived from model						9	4.5

Table 4. Projection fitness, 2014

	GDP	P Imp	N Imp
Projected	58,588,197	2,937,135	9,715,172
Real data	63,646,300	3,221,100	8,821,200

Note: in million yuan

Table 5. Annual growth rates under different reform scenarios (%)

Indicators	Normal	Foreign Outsourcing Slowdown			Transition to "New Normal"		
		minor	moderate	major	minor	moderate	major
Demand in volume							
normal exp	13.3	13.3	13.3	13.3	13.3	13.3	13.3
processing exp	4.2	3.7	3.2	2.7	3.7	3.2	2.7
investment	9.7	9.7	9.7	9.7	9.2	8.7	8.2
private consumption	9.2	9.2	9.2	9.2	9.7	10.2	10.7
govnmt expenditure	8.8	8.8	8.8	8.8	9.3	9.8	10.3
FDI/Tech/Innov							
FDI (K-saving for P)	2.2	2	1.8	1.6	2	1.8	1.6
FDI (K-saving for N)	2.2	2.2	2.2	2.2	2	1.8	1.6
K-saving for D	2.2	2.2	2.2	2.2	2.2	2.2	2.2
Hicks-neutral	1.1	1.1	1.1	1.1	1.2	1.3	1.4

Table 6. Simulation results for different reform scenarios (%)

Indicators	Normal	Foreign Outsourcing Slowdown			Transition to "New Normal"		
		minor	moderate	major	minor	moderate	major
Consumption							
I/C	0.59	0.59	0.59	0.59	-0.31	-1.20	-2.09
C/GDP	-2.02	-2.00	-1.98	-1.95	-1.53	-1.05	-0.56
HH utility	9.11	9.13	9.14	9.16	10.36	11.60	12.86
Real C	6.09	6.10	6.11	6.12	6.92	7.75	8.59
Trade							
imp val	6.18	6.06	5.93	5.80	5.82	5.45	5.09
imp vol	6.18	6.06	5.93	5.80	5.82	5.45	5.09
exp val	14.84	14.62	14.41	14.20	14.36	13.90	13.44
exp vol	10.16	9.99	9.82	9.65	9.99	9.82	9.65
GDP							
Nominal GDP	11.46	11.43	11.40	11.37	11.41	11.36	11.32
Real GDP	7.22	7.21	7.20	7.19	7.58	7.94	8.30
imp val/Ngdp	-4.74	-4.82	-4.91	-5.00	-5.02	-5.31	-5.60
imp vol/Rgdp	-0.97	-1.07	-1.18	-1.30	-1.64	-2.31	-2.96

Note: I, C and GDP under "Consumption" are all in nominal terms except Real C

Source: authors' model simulations

Figure: Reform impact on nominal vs real GDP

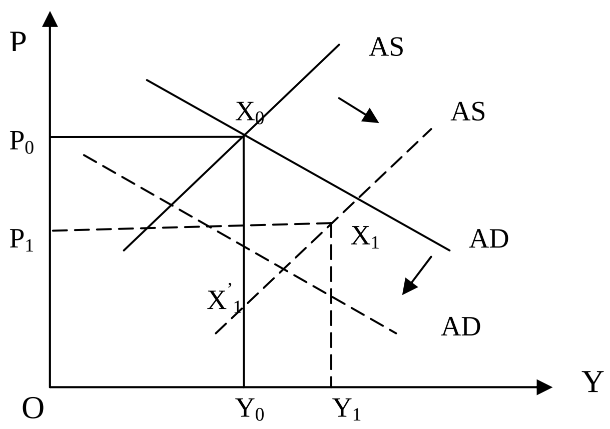


Diagram 1. Nested structure of production: ORANI

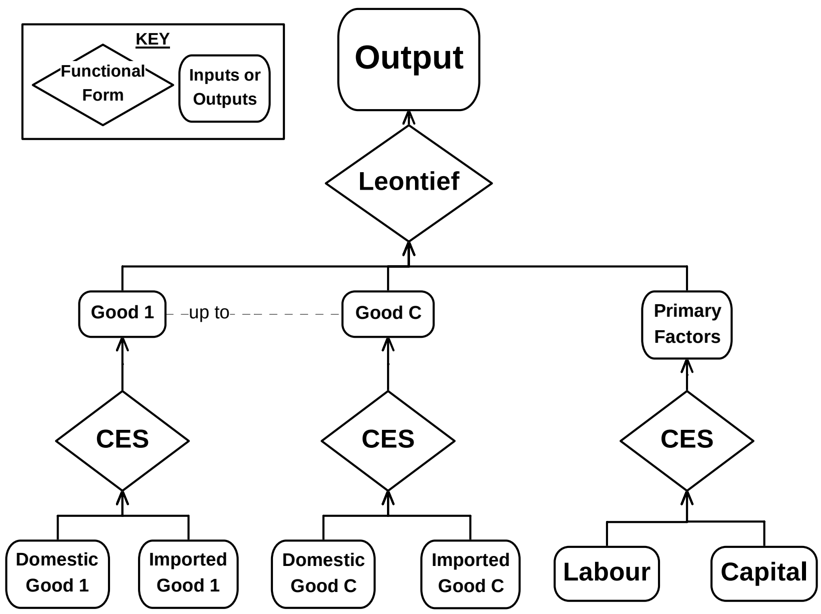
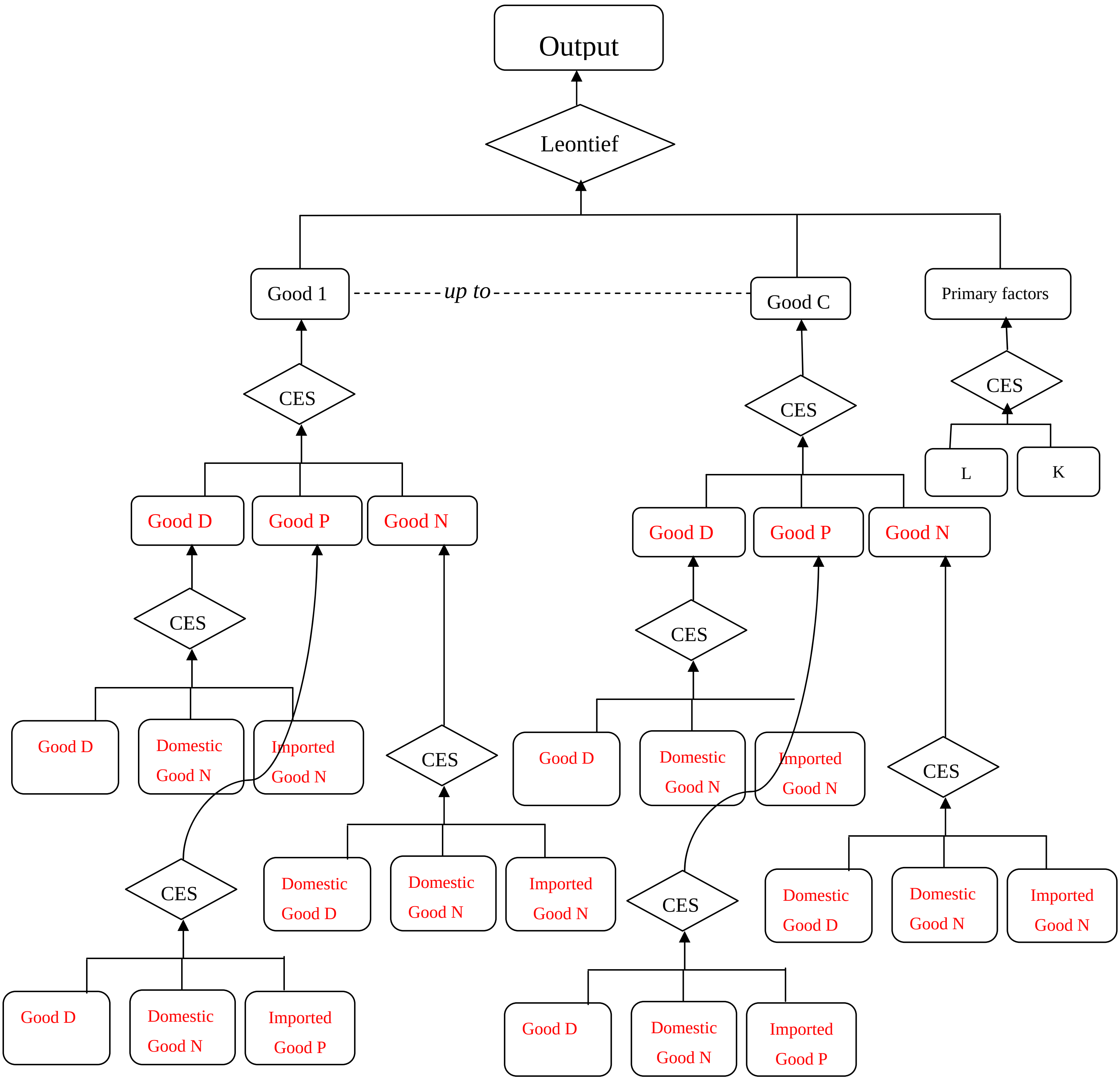


Diagram 2. Nested structure of production: DPN GEM



DPN IOT Accounting Equations

For illustrative purpose, assuming each typical firm adopting one specific production technology produces one homogeneous good, and the good can be used either for intermediate (for the case of D and N class) or final uses, resulting in a three sector economy. Processing imports can only be used for the production of processing exports. Consequently, the P class has only processing exports, which enters final uses, as its sole output. Assuming further there is no tax in this economy. Now we are in a position to formulate the accounting relationships between input and output, and market clearing conditions.

From an output perspective for product market, we have

$$\underbrace{Z^{DD} + Z^{DP} + Z^{DN}}_{INTERMEDIATE} + \underbrace{f^{D} + 0}_{FINAL} = x^{D}$$ for D class production technology;

$$\underbrace{0 + 0 + 0}_{INTERMEDIATE} + \underbrace{0 + e^{P}}_{FINAL} = x^{P}$$ for P class production technology;

$$\underbrace{Z^{ND} + Z^{NP} + Z^{NN}}_{INTERMEDIATE} + \underbrace{f^{N} + e^{N}}_{FINAL} = x^{N}$$ for N class production technology;

In compact form, and letting all prices in base year be ones, outputs (the quantity model in IO literature) are given by (i.e., market clearance condition)

$$\begin{bmatrix} A^{DD} & A^{DP} & A^{DN} \\ 0 & 0 & 0 \\ A^{ND} & A^{NP} & A^{NN} \end{bmatrix} \begin{bmatrix} x^{D} \\ x^{P} \\ x^{N} \end{bmatrix} + \begin{bmatrix} f^{D} \\ e^{P} \\ f^{N} + e^{N} \end{bmatrix} = \begin{bmatrix} x^{D} \\ x^{P} \\ x^{N} \end{bmatrix}$$

In a similar fashion, from an input perspective, we have

$$\underbrace{\underbrace{Z^{DD} + 0 + Z^{ND}}_{DOMESTIC} + \underbrace{M^{D}}_{IMPORTED}}_{INTERMEDIATE} + \underbrace{v^{D}}_{FACTORS} = x^{D}$$

for D class production technology;

$$\underbrace{\underbrace{Z^{DP} + 0 + Z^{NP}}_{DOMESTIC} + \underbrace{M^{P}}_{IMPORTED}}_{INTERMEDIATE} + \underbrace{v^{P}}_{FACTORS} = x^{P}$$

for P class production technology;

$$\underbrace{\underbrace{Z^{DN} + 0 + Z^{NN}}_{DOMESTIC} + \underbrace{M^{N}}_{IMPORTED}}_{INTERMEDIATE} + \underbrace{v^{N}}_{FACTORS} = x^{N}$$

for N class production technology;

Zero profit for each typical firm requires that total cost equal total revenue, that is, the sum of each column (adjusted with proper prices) equals the sum of each row (times proper prices). As long as there is no tax in the system, it is possible to normalize all prices to 1. In this way, we are essentially computing the share structure for each input. To facilitate our analysis, A is defined as the intermediate input coefficient, with its typical element given by $A^{DD} = Z^{DD}(x^D)^{-1}$ and c is defined as the value added coefficient, with its typical element expressed as $c^N = v^N(x^N)^{-1}$. Thus, the input structure can be rearranged as,

$$\underbrace{\underbrace{A^{DD}+0+A^{ND}}_{DOMESTIC}+\underbrace{A^{MD}}_{IMPORTED}}_{INTERMEDIATE}+\underbrace{c^D}_{FACTORS}=1$$ coefficients form for D class;

$$\underbrace{\underbrace{A^{DP}+0+A^{NP}}_{DOMESTIC}+\underbrace{A^{MP}}_{IMPORTED}}_{INTERMEDIATE}+\underbrace{c^P}_{FACTORS}=1$$ coefficients form for P class;

$$\underbrace{\underbrace{A^{DN}+0+A^{NN}}_{DOMESTIC}+\underbrace{A^{MN}}_{IMPORTED}}_{INTERMEDIATE}+\underbrace{c^N}_{FACTORS}=1$$ coefficients form for N class.

Introducing the price for each output, the so-called price model is obtained (cost equals revenue in equilibrium), which is a compact form for the input structure with all prices set to unity (i.e., the zero profit condition for each typical firm)

$$\underbrace{\begin{bmatrix} p^D & p^P & p^N \end{bmatrix}\begin{bmatrix} A^{DD} & A^{DP} & A^{DN} \\ 0 & 0 & 0 \\ A^{ND} & A^{NP} & A^{NN} \end{bmatrix}}_{MATERIAL-COST}+\underbrace{\begin{bmatrix} p^{vD}c^D & p^{vP}c^P & p^{vN}c^N \end{bmatrix}}_{FACTOR-COST}=\underbrace{\begin{bmatrix} p^D & p^P & p^N \end{bmatrix}}_{REVENUE}$$

Here, p^{vj} gives prices for primary factors of each production technolgoy (j = D, P, N). It is straightforward to introduce various distortions to the simple economy, for example the output tax and/or input tax. The tax will drive a wedge between the prices faced by producers and received by consumers. This shall be clear in the following section.

For income balance, we know that income side (i.e., the sum of value added) equals the expenditure side (i.e., domestic final uses plus net exports in this simplified example) of gross domestic product (GDP). In formula (all prices are normalized to

1),

$$\underbrace{v^D + v^P + v^N}_{INCOME} = \underbrace{f^D + f^N + f^M}_{CONSUMPTION} + \underbrace{\underbrace{e^P + e^N}_{EXPORT} - \underbrace{(M^D + M^P + M^N + f^M)}_{IMPORT}}_{NET-EXPORT}$$

Theoretical Equations for DPN GEM Nested Production Structure

Define superscripts $R, S \in \{D, P, N\}$ indicating the type of sub-sector, respectively stands for the D production technology, P production technology, and N production technology. As observed, joint production exists in this IO table for a typical firm, i.e. goods for exports (i.e., e^R) and domestic uses (i.e., $(x^R - e^R)$). These goods are assumed to be imperfect substitutes, and they have a constant elasticity of transformation (CET). For production, each typical firm uses value added (including capital and labor) and intermediate goods (both domestically sourced and imported), and a nested production structure is assumed. As such, R ($R \in \{D, P, N\}$) class production function is

$$x^R = g((x^R - e^R), e^R) = f(V^R, ND^R) \qquad (1)$$

Where g is output transformation function, and f is the input transformation function. Output transformation is assumed to be the CET function:

$$g((x^R - e^R), e^R) = CET((x^R - e^R), e^R) \qquad (2)$$

Following conventional treatment, the input combination of value added and intermediate composite is assumed to be a Leontief type (i.e., zero substitution). Capital and labor enters as a constant elasticity of substitution (CES) value-added aggregate. An intermediate input is an Armington aggregate of local output and import (or inflow). The typical firm regards these goods as imperfect substitutes, and these goods are assumed to exhibit CES property.

$$f(V^R, ND^R) = LF[CES(K^R, L^R), CES(CD(Z^{RR}, Z^{SR}), M^R)] \qquad (3)$$

Where, Z^{SR} gives intermediate flows from S to R, and $S \neq R$, and nested CES structure for intermediate inputs is presented. It is noted that when R = P (i.e., P class production technology) the intermediate composite becomes $LF(M^R, CD(Z^{DR}, Z^{NR}))$, acknowledging the nature of processing trade that exclusive uses of processing imports for the production of processing exports.

In addition, the Armington aggregate is assumed to be agent-specific. Thus, there is Armington aggregate (i.e., Armington composite of domestic goods and imports) used for domestic final demand. A representative agent has an endowment of primary factors of production: capital and labor. She demands final goods and collects all applicable taxes, and the demand is determined by utility maximazing behavior. Consumer utility consists of a nested CES utility index defined over Armington aggregation of domestic and imported commodities

$$U = CES(CD(f^D, f^N), f^M) \quad (4)$$

In the algebraic form, the underlying cost minimization problems for typical producers and representative agent are to be solved. The notation π_{ϑ}^{R} is used to denote the unit profit function (calculated as the difference between unit revenue and unit cost) for production technology R with CRTS ($R \in \{D, P, N\}$), where ϑ is the name assigned to the associated production activity. Differentiating the unit profit function with respect to input and output prices provides compensated demand and supply coefficients (Hotelling's lemma), which appear subsequently in the market clearance conditions.

Zero profit conditions:

(1) Production of goods:

$$\pi_x^D = p_x^D - \min[p_{ND}^D, p_V^D] \le 0$$

$$\pi_x^P = p_x^P - \min[p_{ND}^P, p_V^P] \le 0$$

$\pi_x^N = p_x^N - \min[p_{ND}^N, p_V^N] \le 0$, where $p_x^N - [\gamma_D^N p_D^{N(1+\eta)} + (1-\gamma_D^N) p_{EX}^{N(1+\eta)}]^{1/(1+\eta)} \le 0$ (CET function)

(2) Intermediate aggregate:

$$\pi_{ND}^D = p_{ND}^D - [\alpha_{ND}^D p_D^{D(1-\sigma_{ND}^D)} + (1-\alpha_{ND}^D) p_A^{D(1-\sigma_{ND}^D)}]^{1/(1-\sigma_{ND}^D)} \le 0$$

$$\pi_{ND}^N = p_{ND}^N - [\alpha_{ND}^N p_N^{N(1-\sigma_{ND}^R)} + (1-\alpha_{ND}^N) p_A^{N(1-\sigma_{ND}^N)}]^{1/(1-\sigma_{ND}^N)} \le 0$$

$\pi_{ND}^P = p_{ND}^P - \min[p_{DN}^P, p_M^P] \le 0$,

where $\pi_{DN}^P = p_{DN}^P - [\alpha_{DN}^P p_D^P + (1-\alpha_{DN}^P) p_N^P] \le 0$

(3) Armington agents (incl. production activities or material inputs and final uses):

$$\pi_A^D = p_A^D - [\alpha_A^D p_N^{D(1-\sigma_A^D)} + (1-\alpha_A^D) p_M^{D(1-\sigma_A^D)}]^{1/(1-\sigma_A^D)} \le 0$$

$$\pi_A^N = p_A^N - [\alpha_A^N p_D^{N(1-\sigma_A^N)} + (1-\alpha_A^N) p_M^{N(1-\sigma_A^N)}]^{1/(1-\sigma_A^N)} \le 0$$

$$\pi_U = p_U - [\alpha_{DN} p_{DN}^{(1-\sigma_{DN}^U)} + (1-\alpha_{DN}) p_{FM}^{(1-\sigma_{DN}^U)}]^{1/(1-\sigma_{DN}^U)} \le 0$$ (NOTE: Expenditure function for utility)

where, $\pi_{DN} = p_{DN} - [\alpha_{FD} p_{FD} + (1-\alpha_{FD}) p_{FN}] \le 0$

(4) Technology-specific value added aggregate:

$$\pi_V^R = p_V^R - [\alpha_L^R p_L^{(1-\sigma_{KL}^R)} + (1-\alpha_L^R) p_K^{R(1-\sigma_{KL}^R)}]^{1/(1-\sigma_{KL}^R)} \le 0$$

Market clearance conditions:

(5) Labor (mobile factor):

$$\bar{L} \ge \sum_{R\in[D,P,N]} v^R \frac{\partial \pi_V^R}{\partial p_L}$$

(6) Capital (technology-specific factor):

$$\bar{K}^R \ge v^R \frac{\partial \pi_V^R}{\partial p_K^R}$$

(7) Intermediate aggregate:

$$Z^R \ge x^R \frac{\partial \pi_x^R}{\partial p_{ND}^R}$$

(8) Value added composite:

$$v^R \ge x^R \frac{\partial \pi_x^R}{\partial p_V^R}$$

(9) Commodities:

$$x^D \ge ND^D \frac{\partial \pi_{ND}^D}{\partial p_D^D} + DN^P \frac{\partial \pi_{DN}^P}{\partial p_D^P} + A^N \frac{\partial \pi_A^N}{\partial p_N^D} + DN^U \frac{\partial \pi_{DN}^U}{\partial p_{FD}}$$

$$x^N \ge ND^N \frac{\partial \pi_{ND}^N}{\partial p_N^N} + DN^P \frac{\partial \pi_{DN}^P}{\partial p_N^P} + A^D \frac{\partial \pi_A^D}{\partial p_N^D} + DN^U \frac{\partial \pi_{DN}^U}{\partial p_{FN}} + e^N$$

$$x^P \ge e^P$$

(10) Consumption composite (define Y as the aggregate consumption):

$$Yp_U \geq p_L \overline{L} + \sum_{R \in \{D,P,N\}} p_K^R \overline{K}^R - \overline{BOP}$$

(11) Balance of payments (closure rule):

$$p_{EX}^N = \xi p^{*\varepsilon}$$

$$p_{EX}^P = p_x^P = \xi p^{*\varepsilon}$$

$$p_M^D = \varsigma p^{*\varpi}$$

$$p_M^N = \varsigma p^{*\varpi}$$

$$p_M^P = \varsigma p^{*\varpi}$$

$$p_{FM} = \varsigma p^{*\varpi}$$

$$\overline{BOP} \geq e^N \cdot \xi p^{*\varepsilon} + e^P \cdot \xi p^{*\varepsilon}$$

$$-(A^D \frac{\partial \pi_A^D}{\partial p_M^D} \cdot \varsigma p^{*\varpi} + ND^P \frac{\partial \pi_{ND}^P}{\partial p_M^P} \cdot \varsigma p^{*\varpi} + A^N \frac{\partial \pi_A^N}{\partial p_M^N} \cdot \varsigma p^{*\varpi} + Y \frac{\partial \pi_U}{\partial p_{FM}} \cdot \varsigma p^{*\varpi})$$