An *Ex post* Evaluation of Economic Impacts of Foot-and-Mouth Disease on Taiwan Using a Dynamic Computable General Equilibrium Model

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Abstract

The outbreak of foot-and-mouth disease (FMD) in 1997 has resulted in significant losses to Taiwan's hog industry which was the most important industry in Taiwan's agricultural sector at that time. Hog farmers have suffered great losses due to the cost of slaughtering infected hogs and reduced revenues in the hog market. Furthermore, all pork exports are prohibited according to the Office International des Epizooties (OIE) regulation. There have been a number of *ex ante* studies that have quantified the potential impacts of FMD on Taiwan's economy (e.g., Tsai 1999, Lin and Hsu 1999). That is, the potential impact assessment was done when the event of FMD just broke out.

This article provides an *ex post* economy-wide assessment of the FMD impacts on Taiwan. The model used is Taiwan General Equilibrium Model (TAIGEM-D), a dynamic, multi-sectoral computable general equilibrium (CGE) model of the Taiwan's economy, which is derived from the Australian ORANI model and the MONASH model (Dixon, Parmenter, Sutton and Vincent, 1982; Dixon and Rimmer, 2002). The input-output database was compiled from the 150-sector Use Table of the 1996 Taiwan's Input-Output Tables.

To provide an *ex post* evaluation, we use historical closure and *ex post* closure (a closure similar to decomposition closure) originally from MONASH innovations. Comparisons with other *ex ante* FMD impact assessments are also provided. Results indicate that only a few industries like other livestock products and other processed food sectors would benefit from FMD, while almost all other industries in Taiwan suffered with output losses as well as employment and welfare reductions. Loss to gross domestic product (GDP) of Taiwan is estimated to be 0.28 percent which is much smaller than those predicted by the previous *ex ante*, partial equilibrium studies.

Keywords: Foot-and-mouth disease, *Ex post* simulation, Computable General Equilibrium (CGE)

JEL Classification: C68、E27、L16

1. Introduction

The outbreak of foot-and-mouth disease (FMD) in 1997 has resulted in significant losses to Taiwan's hog industry which was the most important industry in Taiwan's agricultural sector at that time. The production value of hogs is over 3 billion U.S. dollars in 1996, and with over 1 billion export to Japan. Hog farmers have suffered great losses due to the cost of slaughtering infected hogs and reduced revenues in the hog market. Furthermore, all pork exports are prohibited according to the Office International des Epizooties (OIE) regulation. There have been a number of *ex ante* studies that have quantified the potential impacts of FMD on Taiwan's economy (e.g., Tsai 1999, Lin and Hsu 1999). That is, the potential impact assessment was done when the event of FMD just broke out.

The *ex ante* analysis emphasizes on predicting the future economic status or the economic impact of specific events and polices, while the *ex post* analysis emphasizes on evaluating the specific events and policies which had already happened. Before proceeding the *ex ante* analysis of predicting the economic impact of specific events, accurately forecasting which were involving the setting of lots relative prediction values of exogenous variables were needed. Due to the time lag of the data, the setting of those exogenous variables was usually hard to access, unless some estimations or assumptions had made. And those assumptions do affect the accuracy of the analysis results.

However, when proceed the *ex post* analysis of evaluating the economic impact of specific events, most of the exogenous variables was known through accessing some published data. There is no need to estimate or assume. But, there is still a challenge of proceeding the *ex post* analysis, the impact of one specific event were usually mixed with others. It's crucially important to decompose the impact of one single event from the historical simulation.

Hsu et at. (1998) used the ORANI CGE model to evaluate the impact of FMD event. They assumed that the impacts of FMD event came from 30% decrease in the household demand for pork and complete halt of export of pork (-100%) in 1997. From estimation of demand side, the simulation results showed that the growth rate of real gross domestic product shrank 0.275%, employment reduced 0.001%, exports and imports reduced by 0.009%. Shaw (1997) measures soybean oil and soybean powder will decrease by 58 million U.S. dollars of output. Li (1997) measures impacts on industry by 3.17 billion U.S. dollars, including processed food sector losing 1.37 billion, feed sector decreases by 0.3 billion, pork export sector decreases by 1.38 billion. Chang et. al (1997) using APMS-Taiwan (Agricultural Policy Management System-Taiwan) including 80 agricultural commodities to evaluate FMD impact and they found that output in agricultural sector will decrease by about $US 0.97 billion. Council of Agriculture (1998) using Input output table to estimate effects of FMD is about -0.34% of GDP (about 3.3 bill). Council for economic planning and development (1997) also using input output method to estimate shocks of FMD on Taiwan, it shows about -0.45% decrease in GDP and 64,940 people will lose job. Kuo (1997) uses DMR CGE model to calculate the impacts of FMD. They found that hogs sector will decrease by about 26% to 34%, and employment of hogs sector will also decrease by 28% to 30%. According to these articles, we know that FMD indeed deeply harmed agricultural economy of Taiwan and prevent FMD will give us large benefits.

In general, the economic value of the losses caused by a FMD outbreak has four components: (1) the direct cost of dealing with the outbreak (cleaning and disinfection, compensation to producers, quarantine enforcement, etc.), (2) production losses, (3) induced price changes, and (4) the effect on other sectors of the economy. According to Ekboir (1999), different ways to estimate the value of losses have resulted in four methodologies: accounting methods, cost-benefit analysis, welfare analysis, and input-output (I/O) models.

Calculation of the first component is straightforward accounting. Estimation of the second component is usually done with an epidemiological model that estimates the physical production losses which are then converted to monetary values. If the production losses are substantial or markets are disrupted by the outbreak, then both supply and demand of pork are affected resulting in a change in prices. In addition to domestic price changes, trade restrictions can reduce the price received for exports of animals and animal products. If prices rise, consumers will lose because they will have to pay more for their pork, while the loss to producers will fall because they will receive a higher price for their reduced output. The full value of price changes can be estimated with welfare analysis.

All production establishments purchase inputs and sell outputs from other economic agents (suppliers, workers, etc.). These agents, in turn, buy and sell products inducing additional economic activities that spread to the rest of the economy. Through these direct, indirect and induced linkages, a FMD outbreak not only affects the infected premises but the whole economy. Input-output analysis estimates the direct and indirect cost of the outbreak to the whole economy.

However, through the inter-industry feedback effects, the economic impacts of FMD not only affect the hog-related industries, but also other industries and the whole economy. The main limitation of welfare analysis is that it only considers price changes in a single market and does not include effects on other sectors of the economy. This partial-equilibrium analysis nature is shared in the first three methods. Although taking into accounts of the inter-sectoral feedback effects, the main limitation of I/O analysis is that it does not include price effects and resource constraints are not imposed. Moreover, all approaches are *ex ante* assessment with many ad hoc assumptions and uncertain experts' predictions due to problems in data availability.

This article provides an *ex post* economy-wide assessment of the FMD impacts on Taiwan. The model used is Taiwan General Equilibrium Model (TAIGEM-D), a dynamic, multi-sectoral computable general equilibrium (CGE) model of the Taiwan's economy, which is derived from the Australian ORANI model and the MONASH model (Dixon, Parmenter, Sutton and Vincent, 1982; Dixon and Rimmer, 2002). The input-output database was compiled from the 150-sector Use Table of the 1996 Taiwan's Input-Output Tables.

To provide an *ex post* evaluation, we use historical closure and *ex post* closure (a closure similar to decomposition closure) originally from MONASH innovations. Comparisons with other *ex ante* FMD impact assessments are also provided. The next section briefly reviews the model structure of TAIGEM-D and its database. The third section provides scenario specification of historical simulation and *ex post* analysis. Simulation results are shown in the fourth section. The last section concludes our analysis.

2. TAIGEM-D Dynamic General Equilibrium Model

TAIGEM-D is descended from the TAIGEM model, developed specifically to analyze climate change issues, such as baseline forecasting, climate change response policies.

TAIGEM is a multisectoral, single region, computable general equilibrium (CGE) model of the Taiwan's economy derived from ORANI (Dixon, Parmenter, Sutton and Vincent, 1982). TAIGEM distinguishes 170 sectors, 6 types of labor, 8 types of margins, and 182 commodities. Additional data on energy sector, electricity sector and emissions are collected. Like ORANI, TAIGEM was designed for comparative-statics, i.e., for projecting what difference a shock would make to the economy at a point in time. In addition to ORANI model, TAIGEM-D inherits the basic dynamic mechanism from the Australian MONASH model. The most significant features that distinguish TAIGEM-D from TAIGEM are the inclusion of inter-fuel substitution, technology bundles and dynamic mechanism capable of projecting the development of the economy through time. With TAIGEM-D we have made annual projections of CO_2 emission, GDP growth rate, and other economic variables. We use historical simulations to generate up-to-date data for our baseline forecasting, and we use TAIGEM-D model to evaluate the impact on Taiwan economy for the mitigation greenhouse gases emissions policies.

2.1 Dynamic Mechanism

According to Dixon and Parmenter (1996), dynamic mechanisms of CGE model may be categorized into four broad cases, namely 1) exogenous investment, a recursive model, 2) endogenous investment but still recursive, 3) a non-recursive multi-period model, 4) a non-recursive multi-period model with optimizing investment behavior.

In Case 1 investment is exogenous. In Case 2, investment and capital accumulation in year t+1 depend on expected rates of return for year t+2, which we assume are determined by actual returns to and costs of capital in year t+1. In both Cases 1 and 2, the models are recursive, i.e., they can be solved for year 1 and then for year 2 and so on. In Case 3 expected rates of return for year t+2 are assumed to be equal to the actual rates of return for year t+2, namely, expectations are rational or consistent. In Case 4, the behavior of investors is explicitly optimizing. Relative to the recursive models in Cases 1 and 2, solution of Cases 3 and 4 models require a more sophisticated computational approach for handling the computations for all of the years simultaneously.

In our TAIGEM-D forecasting and policy simulations, we solve a large (160 industry) recursive model incorporated externally supplied, realistic macro-forecasts. That is, our approach is an application of Case 2. A dynamic model such as TAIGEM-D is beneficial when analyzing climate change policies since the timing of policy implementation and the adjustment path an economy follows are highly relevant in the climate change policy debate.

2.2 Structure of Production

TAIGEM-D allows each industry to produce several commodities, using as inputs domestic and imported commodities, labor of several types, land, capital, energy of several types and “other costs”. In addition, commodities destined for export are distinguished from those for local use. The multi-input, multi-output production specification is kept manageable by a series of separability assumptions, illustrated by the nesting shown in Figure 1 where the production structure TAIGEM-D model is shown.

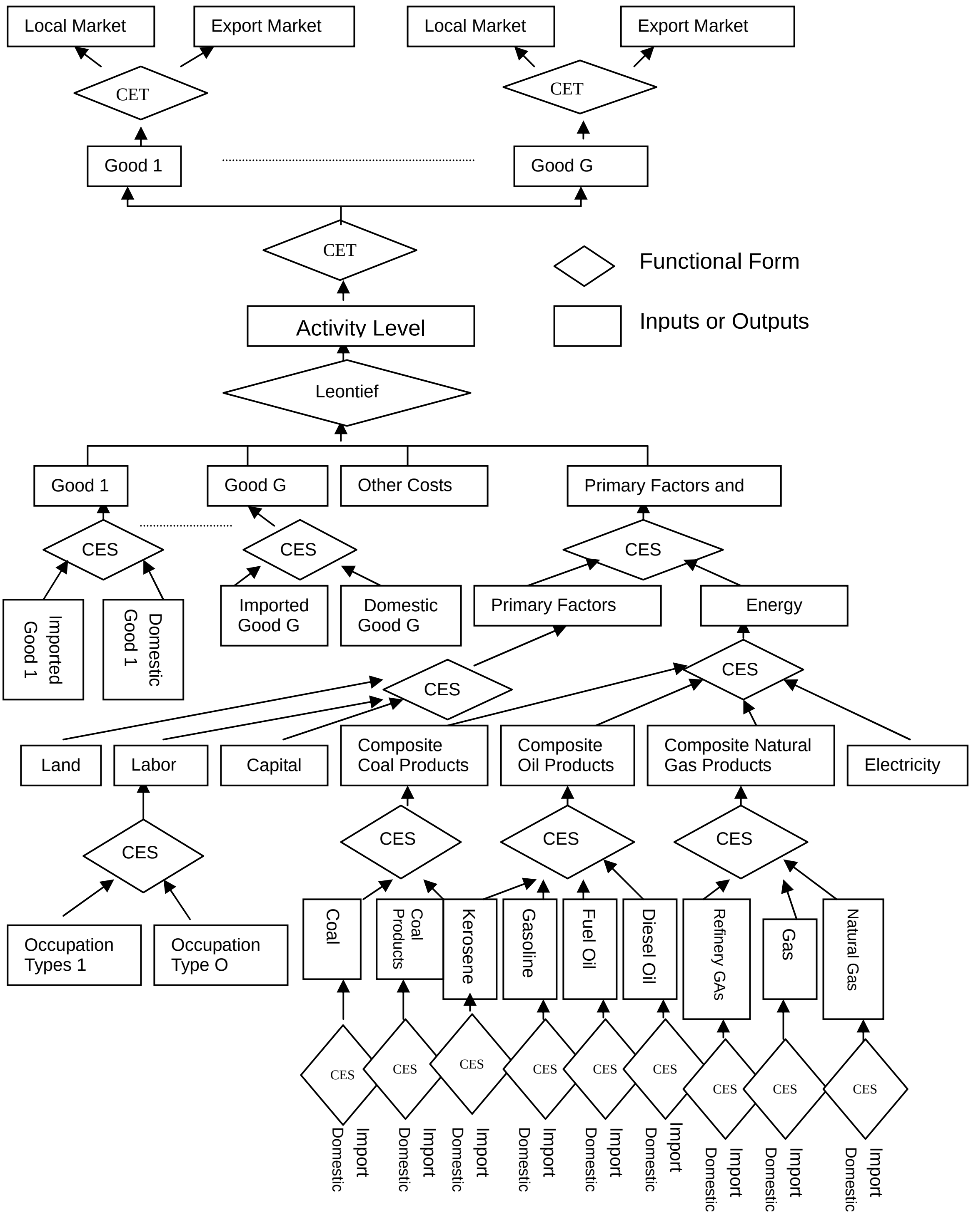


Figure 1. Structure of Production

The input demand of industry production is formulated by a five-level nested structure, and the production decision-making of each level is independent. Assuming cost minimization and technology constraint at each level of production, producers will make optimal input demand decisions. At the top level, commodity composites and a primary-factor composite are combined using a Leontief production function. Consequently, they are all demanded in direct proportion to the industry activity. At the second level, each commodity composite is a CES (constant elasticity of substitution) function of domestic goods and the imported equivalent (the Armington assumption). Energy and primary-factor composites are a CES aggregation of energy composites and primary-factor composites.

At the third level, the primary-factor composite is a CES aggregation of labor, land, and capital, and the energy composite is a CES aggregation of coal products composites, oil products composites, natural gas products composites, and electricity. At the fourth level, the labor composite is a CES aggregation of managers, professional specialists, white collar, technical, workers, and unskilled workers; the coal products composite is a CES aggregation of coal and coal products; the oil products composite is a CES aggregation of gasoline, diesel oil, fuel oil, and kerosene; the natural gas products composite is a CES aggregation of refinery gas, gas, and natural gas. At the bottom level the energy composite is a CES aggregation of domestic goods and imported goods (See Figure 1).

Like ORANI model, the output structure of TAIGEM-D allows for each industry to produce a mixture of all the commodities. Moreover, conversion of an undifferentiated commodity into goods destined for export and local use is governed by a CET (constant elasticity of transformation) transformation frontier.

3. Framework for *Ex post* Analysis

According to framework and application of MONASH Model which was developed by COPs of Monash University in Australia, the setting of simulation included four kind of closures rules: Historical and decomposition closures which were *ex post* analysis. Forecasting and policy closure which were *ex ante* analysis. In this section, we will introduce these four closures and the *ex post* closure which are the most important closure in this study.

3.1 Historical and decomposition closures

The historical and decomposition simulation both simulated the events which had happened, but the function of these two simulations is quite different. The historical simulation replicates the historical economic path by using the past data. And through the process of replication, the technology and taste variables which are endogenous in the model can be solved. And the technology and taste variables can be the benchmark of setting the technology and taste variables in the forecast closure, also they are the important information in proceeding decomposition simulation. Besides, updating the input-output table is another main objective of historical simulation. Generally, the process of accomplishing an input-output table are quite long and it requires lots of manpower and money. The time lag problem of input-output table is unavoidable. Through the process of historical simulation, the input-output table can be updated more easily.

Unlike the historical simulation, decomposition simulation decomposes the effect into different parts. In decomposition closure, the exogenous variable (e.g. policy variable, technology variable, taste variable, international variable) can be considered as independently determined and can be thought of as having their own effects on endogenous variable such as incomes, consumption, exports, imports, outputs, employment and investment.

Besides the differences mentioned above, the setting of closures of historical and decomposition closure are also different. The setting of closures is the process of setting the exogenous and endogenous variables for simulation. The closures vary between simulations. In the historical closures, there are two types of variables in the exogenous set: observable and assignable. Observables are those for which movements can be readily observed from statistical sources for the period of interest. Historical closures vary between applications depending on data availability. Assignable variables are naturally exogenous (and are therefore exogenous in decomposition closures as well as historical closures). The key feature of a assignable variable in an historical simulation is that its movement ca be assigned a value without contradicting anything that we have observed about the historical period or wish to assume about that period. In the decomposition closure we include in exogenous set all naturally exogenous variables, i.e., variables not normally explained in a CGE model. These may be observable variable such as tax rates or unobservable such as technology and preference variables.

Table 1 gives some examples of the partitioning of variables in the historical and decomposition closures. There are four kinds of variable sets: $X(H\overline{D})$, $X(\overline{H}D)$, $X(HD)$, $X(\overline{HD})$. H denotes exogenous in the historical closure. $\overline{H}$ denotes endogenous in the historical closure and D and $\overline{D}$ denotes exogenous and endogenous in the decomposition closure. Thus, for example, $X(HD)$ consists of those variables that are exogenous in both historical and decomposition closures.

By the partitioning of variables, it gives some insights about the relationship between historical and decomposition closures. Variables in $X(\overline{HD})$ are demands for intermediate inputs and demands for margins services (e.g. road transport) to facilitate commodity flows from producers to users. In the absence of end-of-period tables, movements in these variables are not readily observable or assignable and are normally explained in CGE models. Examples of variables in $X(HD)$ include population size, foreign currency prices of imports and policy variables such as tax rates, tariff rates and public consumption. Values of these variables are readily observable and are not normally explained in CGE model.

$X(\overline{H}D)$ contains the same number of variables as $X(H\overline{D})$ with each variables in $X(H\overline{D})$ having a corresponding variable in $X(\overline{H}D)$. And table 1 shows examples of corresponding pairs. In historical simulation we use shifts in household preferences to accommodate observations on consumption by commodity, shifts in commodity-specific intermediate input-saving technical change to accommodate observations on total intermediate usage by commodity, etc.

In general, we use historical closure in estimating changes in technology and tastes. Then, decomposition analysis gives us a basis for assessing the relative importance to the industry of changes in policy variables, technology variables, taste variables and international variables. The relationship between our historical and decomposition simulations is illustrated in Figure 2.

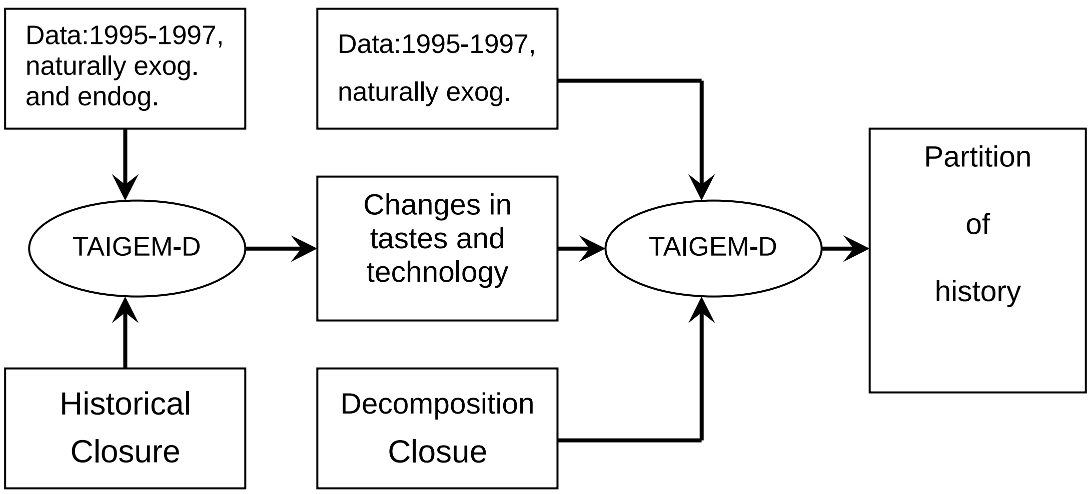
Table1. Categories of Variables in the Historical and Decomposition Closures

Selected components of $X(H\overline{D})$	Corresponding components of $X(\overline{H}D)$
Consumption by commodity	Shifts in household preferences
Total intermediate usage by commodity (deduced from information on outputs, imports and final usage)	Intermediate-input-saving technical change
Employment and capital inputs by industry	Primary-factor-saving technical change and capital/labour bias in technical change
Imports by commodity	Shifts in import/domestic preferences
Producer prices by industry	Rates of return on capital or markups on costs
Export volumes and f.o.b. prices	Shifts in foreign demand and domestic supply functions
Macro variables, e.g. aggregate consumption	Shifts in macro functions, e.g. the average propensity to consume

Selected components of $X(HD)$
Population
C.i.f. import prices in foreign currency
Policy variables, e.g. tax and tariff rates, and public consumption

Selected components of $X(\overline{HD})$
Demands for intermediate inputs and margin services

Date Sources :Dixon and Rimmer (2002)



Data Source：Modified by Dixon and Rimmer (2002)

Figure 2. The relationship between Historical and Decomposition Closure

3.2 Forecasting and policy closures

The relationship between forecasting and policy simulations is similar to that between historical and decomposition simulations. Historical simulations provide values for exogenous variables in corresponding decomposition simulations. Similarly, forecasting simulations provide values for exogenous variables in corresponding policy simulations. However there is one key difference between the relationships. An historical simulation and the corresponding decomposition simulation produce the same solution. This is because all the exogenous variables in the decomposition simulation have the values they had (either endogenously or exogenously) in the historical simulation. In a policy simulation, most of the exogenous variables have the values they had in the associated forecast simulation. The policy variables of interest are set at values that are different from those they had in the forecasts. Thus policy simulations generate deviations from forecasts.

Producing the prediction value of various economic variables and establishing the base scenario of future economic status are the main purpose of forecasting simulation. And analyzing the impact which caused by the variation of policy are the main purpose of policy simulation. Forecasting closures are similar in nature to historical closures. Instead of exogenizing everything that we know about the past, in forecasting closures we exogenize everything that we think we know about the future. (such as exports of agricultural and mineral products, tourism exports and macro variables) To allow these variables to be exogenous we need to endogenize numerous naturally exogenous such as the positions of foreign demand curves, the positions of domestic exports supply curves and macro coefficients, e.g., the average propensity to consume. Because we know less about the future than the past, forecasting closures are more conventional than historical closures. In forecasting closures, taste and technology are exogenous.

Policy closures are similar to decomposition closures. In policy closures naturally endogenous variables (such as exports of agricultural and mineral products, tourism exports and macro variables) are endogenous. They must be allowed to respond to the policy change under consideration. Correspondingly, in policy closures naturally exogenous variables (such as the positions of foreign demand curves, the positions of domestic export supply curves and macro coefficients) are exogenous. They are set at the values revealed in the forecasts.

The relationship between the forecast and policy simulations is illustrated in Figure 3. Giving the base scenario which provided by forecasting simulation, the results of policy simulation can be computed by modifying some variables in the forecasting simulation. Then comparing the results of forecasting and policy simulation, the deviations are the effects which caused by policy shock.

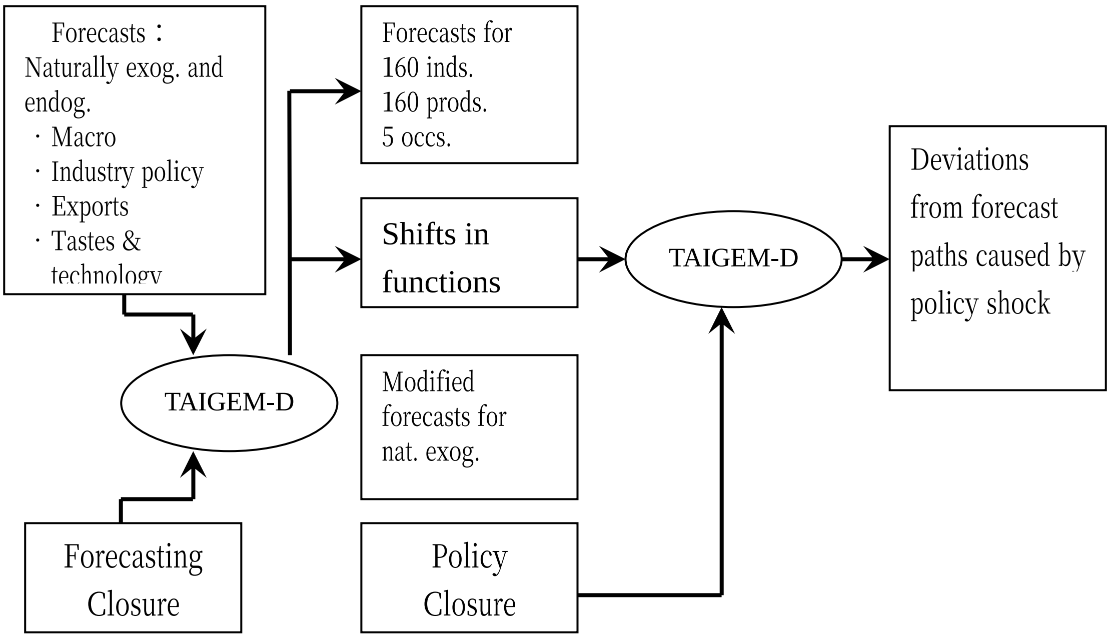


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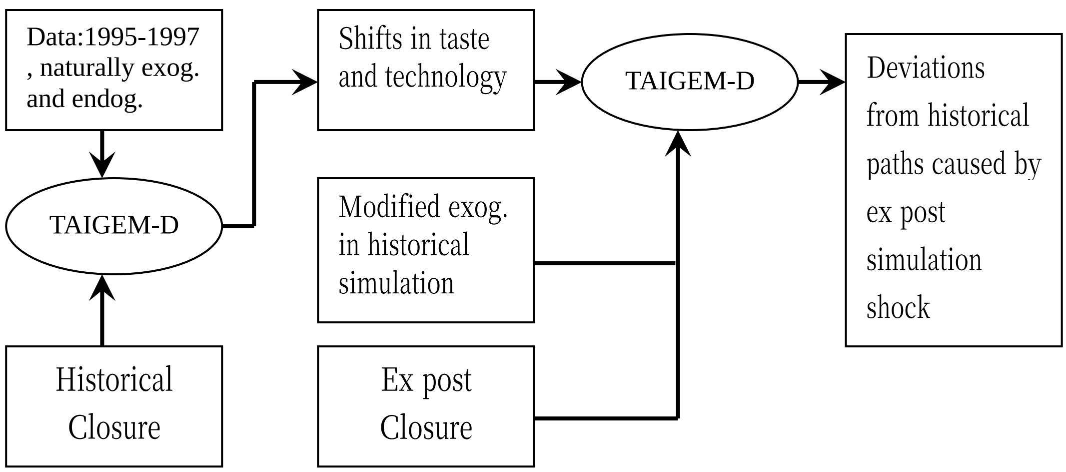
Figure 3. The relationship between Forecasting and Policy Closure

3.3 *Ex post* closure

The *ex post* simulation are the counter-factual simulation which evaluate the effect if some policy or events had not happened. The relationship between *ex post* and historical simulation are similar to the relationship between forecasting and policy simulation. Historical simulations provide values for exogenous variables in corresponding *ex post* simulations. Then, *ex post* simulation modified some exogenous variables. Thus, *ex post* simulations generate deviations from historical simulation.

The closures of *ex post* simulation are similar to policy simulation. The exogenous variable of *ex post* simulation can partition into two parts. One is the variables which provided by historical simulations. (e.g. policy variable)The other is the variables which modified and differed from historical simulations. (e.g., technology variable, taste variable, international variable, macro variables.) The relationship between ex post and historical simulation are illustrated in Figure 4.

In brief, the historical and decomposition simulation, the forecasting and policy simulation, or the *ex post* simulation are similar to each other to some degree. Historical simulation provides the values for exogenous variables in corresponding decomposition and ex post simulations. And the values for exogenous variables in policy simulation are also provided by forecasting simulation. Their relationships are quite similar. The key difference between the forecasting and historical simulation is that historical simulation and the corresponding decomposition simulation produce the same solution, and forecasting simulation and the corresponding policy simulation don't. And Like forecasting and the corresponding policy simulation, the historical and the corresponding ex post simulation don't produce the same solution. That's because policy and *ex post* simulation both modified the exogenous variable which accessed from their corresponding simulation.



Data source：Dixon and Rimmer (2002)

Figure 4. The relationship between Historical and *Ex post* Closure

4. Simulation Design

By giving the main industries impact effects which caused by FMD events, this article evaluated the "Ex post" economic impacts of FMD events by using TAIGEM-D Model. There are two simulations which need to specify: historical and ex post simulation. First, we focus on the shocks setting of FMD impacts. Then, we explain the closure and shocks of historical and ex post simulation.

4.1 Industries impacts setting of FMD

Because this article are the ex post analysis which evaluate the impacts of events what had happened, the historical data are accessible. We use the historical data as base of the setting of shocks, and modified the shocks according to the difference of each industry. While the influences of FMD event are mainly on the confidence of consumers, the willing of the investment which can't evaluate, the replacement index of evaluating the impact of FMD are needed. We use the sales value of each industry which is connected to his confidence of consumers and the willing of the investment. The data sources of sales value are from the Journal of Financial Statistics which published by Ministry of Finance.

We defined the influence period of FMD were the whole year of 1997, we set the shocks of FMD impact. In order to eliminate the effects which caused by the variation of price, we deflated the impacts of FMD by using the consumer price index of Taiwan. Then we considered the variation of sales value in 1997 as the impacts of FMD event by comparing with the average sales value in past years. The difference between sales growth trends of FMD related industry and shocks when FMD actually happened are the FMD impact of the 1997.

Besides, by considering the differences and growth trends of each industry, we used two scenarios to compare with the sales value of 1997: the average of sales value of past five years (1992-1996), past three years (1994-1996).

The influences of FMD mainly focused on the hog related industry, like hogs, pork, fodder (Soybean Cake, Bran and Scrap) and food process industry. According to the classification of 160 sectors input-out table in 1994 and other research report which evaluate the impacts of FMD. We keep hogs, pork and soybean cake, bran and scrap these three industry present main impacts on FMD. Other agricultural live industry and other food process industry can show the substitution effects on FMD industry. And the variables of micro economics included the industrial output of those FMD related sectors which were illustrated before, we used the sales values which were from the Annual Report of Agriculture Statistic to update the output of those industries in 1997.Shocks for ex post simulation of FMD is shown in Table 2.

Table2. Shocks for Ex Post Simulation of FMD

	Average Output Growth Rate between 1992-1996	Historical Simulation: Output under FMD in 1997	Ex Post Simulation I: Output without FMD
Hogs	10.19%	-61.66%	71.86%
Pork	8.74%	-49.55%	58.28%
Soybean cake, bran and scrap	12.15%	-10.60%	22.75%
	Average Output Growth Rate between 1994-1996	**Historical Simulation: Output under FMD in 1997**	**Ex Post Simulation II: Output without FMD**
Hogs	7.94%	-61.66%	69.61%
Pork	8.49%	-49.55%	58.04%
Soybean cake, bran and scrap	20.52%	-10.60%	31.11%

4.2 Historical simulation specification

As illustrated in the second section, the historical simulation not only were that revealed the historical path of past economics and estimated the technology and taste variables, but also updated the input-output table. Since the original data in the model were the 160 sectors and 170 commodities input-output table in 1994, the industrial structure of original data were far from now. The update of input-output table were needed before the simulation begin.

The database of the TAIGEM-D model can be separate into three parts: input-output table, variables of the dynamic mechanism equation, elasticity data. By using the original elasticity data as a base, the number of sectors in elasticity data expanded to 160 in order to accommodate the number of sectors of new input-output table. In the Final step, it's the update of the variables of the dynamic mechanism equation. The variables of the dynamic mechanism equation included capital stocks, rate of return and investment coefficient. We used the capital stocks which were from the journal of income statistic in 1994 to update the original capital stocks. And the rate of return of each industry which based on the original data in 1994 modified with the variation of interest.

In the historical simulation, there were two ways to update the historical data: one was updated data year by year, the other was updated the data across a period of time (e.g., form 1995 to 1997.) This article used the second method which was the same with the way historical simulation in MONASH model. Besides, the historical simulation of this article separated into two parts: First part was from 1995 to 1996 and used the database which solved as the base data of next year. Second part was from 1996 to 1997. The endogenous variable which solved in this part of historical simulation can be provided for the ex post simulation later. The relationship between two parts of historical simulation was illustrated in Figure 4.

In the closure of historical simulation, the exogenous included the variables of macroeconomics and microeconomics. The variables of macroeconomics included private consumption expenditure, gross fixed capital formation, government consumption expenditure, exports and imports of goods and services, GDP deflator, exchange rate, export price deflator, import price deflator, annual rate of employed persons, number of household and trend of employment etc. By setting the value of those exogenous variables, we can calibrate the corresponding endogenous variables which can provide for ex post simulation. The above data were mainly from the Journal of Quarterly National Economic Trends which published by DGBAS. Table 3 illustrated the annual rate of change of those exogenous variables.

According to simulation specification of Hsu et al. (1998), people fear eating pork after FMD burst out, they set taste for FMD related commodities will decrease 30%. We adopt their setting. Also, Hsu et al. (1998) set export for FMD related commodities will all shot down, we use this setting to constraint export for FMD related commodities decrease 100%.

Table3. Annual Growth rate of macro Variables in historical simulation Unit:%

Macroeconomic Variables	Historical Simulation : Actual Impacts on Taiwan Macroeconomy		
	1995	1996	1997
Private consumption expenditure	5.629	6.534	7.264
Gross fixed capital formation	7.307	1.662	10.649
Government consumption expenditure	3.150	6.657	5.867
Exports of goods and services	12.645	6.740	9.076
Imports of goods and services	9.784	6.032	13.741
GDP deflator	2.020	3.110	1.680
Exchange rate	3.925	0.807	18.734
Number of household	3.010	3.490	3.020
Annual rate of employed persons	1.190	0.250	1.190
Trend of employment	1.000	1.000	1.000

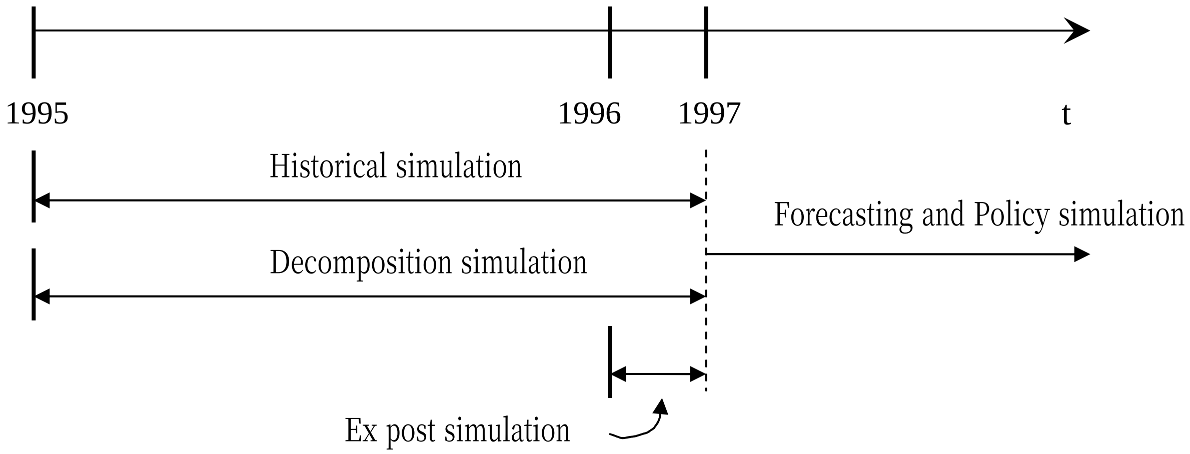


Figure 4. Relationship between each simulation

4.3 Ex post simulation specification

Before explain the ex post simulation specification, let’s focus on the feature of TAIGEM-D model. The model was comprised of enormous equation and the setting of closure was quite important in the model. Under general circumstance, all exogenous variables had the corresponding endogenous variables. e.g. the exogenous variables in historical simulation, private consumption expenditure, gross fixed capital formation, government consumption expenditure, exports and imports of goods and services, etc. Each variable had the corresponding endogenous variables which reflected the impact affected by exogenous variable. While swapped all the endogenous variables as exogenous variables and given the value of endogenous variables which solved in historical simulation, then re-run the simulation again.

The value of endogenous variables would be the same with the value of exogenous variables which we specified in the historical simulation. The ex post simulation didn't just swap all the endogenous variables which solved in historical simulation as exogenous variables. It swapped some of them and modified some exogenous variables. The only difference between historical simulation and ex post simulation was the modified exogenous variables, the value of rest exogenous variables were the same with the value of endogenous variables which solved in historical simulation. So the deviation from historical paths caused by ex post simulation shock was the influences of modified exogenous variables.

As mentioned before, there were two kinds of exogenous variables of ex post closures. One was the exogenous variables which modified. In this case, we modified the output of those industries which suffered by the impact of FMD by given the output which were under the circumstance FMD event didn't happen. By reducing the impact of FMD event, the impacts on macro economics and those industries which didn't directly suffered by FMD event could be evaluated. The growth rates of those industries which suffered by the impact of FMD event under the circumstance FMD event didn't happen were illustrated in Figure 6. Those value could be calculated by subtracting the growth rate of output in 1997 with the impact of FMD event on growth rate of output.

The other kind of exogenous variables were the corresponding variables of exogenous variables in historical simulation, e.g. shifts and technical coefficients in macro functions. And the macro variables which were exogenous in historical simulation were all endogenized in order to reflect the effect of the modified exogenous variables, e.g. private consumption expenditure, gross fixed capital formation, government consumption expenditure, exports and imports of goods and services. Besides, the output variables of those industries which didn't directly suffered by the impact of FMD event were also endogenized order to reflect the effect of the modified exogenous variables.

5. Simulation Results and Analysis

The results of historical and ex post simulation in this section were solved by using the TAIGEM-D model and GEMPACK software. And the results and analysis in this section were separated into macroeconomic and microeconomic results. For simplicity, we show 15 aggregate industries only.

5.1 Macroeconomic impacts

The results of macro variables which illustrated in table 4. FMD will decrease consumption on pork (taste drop down) and related products, and exports shot down. It causes most macroeconomic variables will drop. The growth rate of real GDP in 1997 should achieve 6.66% (ex post simulation I) to 6.81%(ex post simulation II) under the circumstance the FMD event didn't happed. The FMD event caused the growth rate of real GDP drop from 0.28%(ex post simulation I) to 0.43%(ex post simulation II). Comparing the results with previous research, Hsu, et al. (1998) using statistic ORANI CGE model which estimated the impact of FMD event on real GDP was -0.27%. And the estimation of Hsu, et al. (1998) was very similar with our results.

Something's interesting in household consumption. The growth rate of private consumption was 6.98% to 7.09% under the circumstance which FMD event was not happen. Comparing the actual growth rate in 1997, the impact of FMD event on private consumption was 0.28% to 0.17%. When people fear to consume pork they will take other substitution to eat just like beef which is more valuable meat and cause expenditure will increase. During FMD period, the price of substitutions will increase will make expenditure higher. It is different from other macroeconomic variables.

The growth rate of gross fixed capital formation was between -2.70% to -2.96% under the circumstance which FMD happened. The influence on aggregate primary inputs was between -3.07% to -3.25% because impacts on FMD decrease usage of labor, capital in FMD related industry.

Under the circumstance which FMD event wasn't happen, the growth rate of exports of goods and services was 0.35% to 10.40%. And the impact of FMD event on exports was between -1.27% to -1.32%, because of export on FMD related commodities was shot down after FMD burst up. The influence on employment wasn't severe and was between -0.02% to -0.49%. The growth rate of balance of trade/GDP will drop 0.01% while FMD happened.

According our review of other studies, the impacts of FMD on real GDP are between -0.275% to -0.45%, which are very similar with our results. It means our research using ex post simulation is accurate.

Table4. Macro Results of Historical and Ex post Simulation: Impacts of FMD

Unit:%

Macroeconomic Variables	Historical Simulation of 1997	Simulation I:Ex Post Sim. of 1997	Simulation II:Ex Post Sim. of 1997	**Impacts of FMD (His. minus Ex Post)**	
		1994-1996	1992-1996	**Ex Post Simulation I**	**Ex Post Simulation II**
Real GDP	6.38	6.66	6.81	**-0.28**	**-0.43**
Balance of trade/GDP	-0.11	-0.10	-0.10	**-0.01**	**-0.01**
Aggregate primary inputs	4.77	7.84	8.02	**-3.07**	**-3.25**
Real investment expenditure	10.65	13.35	13.61	**-2.70**	**-2.96**
Real household consumption	7.26	6.98	7.09	**0.28**	**0.17**
Export volume index	9.08	10.35	10.40	**-1.27**	**-1.32**
Employment	0.70	0.72	1.19	**-0.02**	**-0.49**
Consumer price index	8.02	11.81	11.85	**-3.79**	**-3.83**
Aggregate price of export	-10.00	7.66	7.90	**-17.66**	**-17.90**
CO2 emission	193468.20	198126.72	198462.98	**-4658.52**	**-4994.78**

5.2 Industry output impacts

The results of ex post simulation I and simulation II illustrated in table 5. Most of the industries suffered the damage caused by FMD event. Among all sectors, the output of Hogs (-69.61% and -71.86%), Pork (-67.18% and -67.43%), Soybean cake, bran and scrap (-31.14% and -22.77%) is the major industry suffer form negative impacts. It is very reasonable the output of "other agricultural and livestock products" (5.37% to 5.17%) and "other process foods" (32.04% and 32.20%) increase because the substitution effects between them. Because of the industry impact effect, other non-FMD related industry will decrease around -3% to -7% in output. Industry output results shown in Table 5.

Table5. Industry Output Results of Historical and Ex post Simulation: Impacts of FMD

Unit : %

Macroeconomic Variables Industry Output	Historical Simulation of 1997	Simulation I:Ex Post Sim. of 1997	Simulation II:Ex Post Sim. of 1997	**Impacts of FMD (His. minus Ex Post)**	
		1994-1996	1992-1996	**Ex Post Simulation I**	**Ex Post Simulation II**
Hogs	-61.67	7.94	10.19	**-69.61**	**-71.86**
Other Agricultural and Livestock Products	6.12	0.75	0.95	**5.37**	**5.17**
Forestry	6.32	13.88	14.14	**-7.56**	**-7.82**
Fishery	2.69	5.87	6.07	**-3.18**	**-3.38**
Mineral	6.53	11.54	11.79	**-5.01**	**-5.26**
Pork	-58.69	8.49	8.74	**-67.18**	**-67.43**
Soybean Cake, Bran and Scrap	-10.62	20.52	12.15	**-31.14**	**-22.77**
Other Process Foods	21.67	-10.37	-10.53	**32.04**	**32.20**
Live Industry	1.86	7.49	7.72	**-5.63**	**-5.86**
Chemical Industry	2.93	5.87	6.07	**-2.94**	**-3.14**
Metal Industry	2.85	8.46	8.70	**-5.61**	**-5.85**
Electronic Industry	-3.06	1.40	1.61	**-4.46**	**-4.67**
Utility	4.82	8.33	8.52	**-3.51**	**-3.70**
Construction	12.23	12.52	12.73	**-0.29**	**-0.50**
Service	5.60	8.49	8.65	**-2.89**	**-3.05**

6. Conclusion

This article provides an *ex post* economy-wide assessment of the FMD impacts on Taiwan. The model used is Taiwan General Equilibrium Model (TAIGEM-D), a dynamic, multi-sectoral computable general equilibrium (CGE) model of the Taiwan's economy, which is derived from the Australian ORANI model and the MONASH model (Dixon, Parmenter, Sutton and Vincent, 1982; Dixon and Rimmer, 2002). The input-output database was compiled from the 150-sector Use Table of the 1996 Taiwan's Input-Output Tables.

To provide an *ex post* evaluation, we use historical closure and *ex post* closure (a closure similar to decomposition closure) originally from MONASH innovations. Comparisons with other *ex ante* FMD impact assessments are also provided. Results indicate that only a few industries like other livestock products and other processed food sectors would benefit from FMD, while almost all other industries in Taiwan suffered with output losses as well as employment and welfare reductions. Loss to gross domestic product (GDP) of Taiwan is estimated to be between 0.28 percent and 0.43 percent which is much smaller than those predicted by the previous *ex ante*, partial equilibrium studies.

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Appendix I. Sectoral Definition of Database in TAIGEM-D model

No.	49 sectors	No.	59 commodities
1	Hogs	1	Hogs
2	Other Agricultural and Livestock Products	2	Other Agricultural and Livestock Products
3	Forest Products	3	Forest Products
4	Fisheries	4	Fisheries
5	Coal	5	Coal
6	Crude Oil, Natural Gas	6	Crude Oil
7	Other Minerals	7	Natural Gas
8	Pork	8	Other Minerals
9	Soybean Cake, Bran and Scrap	9	Pork
10	Other Process Foods	10	Soybean Cake, Bran and Scrap
11	Textile Mill Products	11	Other Process Foods
12	Wearing Apparel and Accessories	12	Textile Mill Products
13	Leather & Leather Products	13	Wearing Apparel and Accessories
14	Wood & Wood Products	14	Leather & Leather Products
15	Paper & Paper Products & Printed Matter	15	Wood & Wood Products
16	Chemical Manufactures	16	Paper & Paper Products & Printed Matter
17	Misc. Chemical Manufactures	17	Chemical Manufactures
18	Petroleum Refining Products	18	Misc. Chemical Manufactures
19	CoalProds	19	Gasoline
20	Rubber Product	20	Diesel fuels
21	Plastic Product	21	Aviation fuels
22	Non-metallic Mineral Products Manufacturing	22	Fuel oils
23	Iron and Steel Products	23	Kerosene
24	Miscellaneous Metals	24	Lubricants
25	Machinery	25	Naphtha
26	Electronic Product	26	Refinery gases
27	Transport Equipment	27	Asphalt
28	Precision Instruments & Apparatus	28	Other refining products
29	Other Manufactures	29	CoalProds
30	Hydroelecticity	30	Rubber Product
31	Stream turbine: Oil	31	Plastic Product
32	Stream turbine: Coal	32	Non-metallic Mineral Products Manufacturing
33	Stream turbine: Natural Gas	33	Iron and Steel Products
34	Combined-cycle : Oil	34	Miscellaneous Metals
35	Combined-cycle : Natural Gas	35	Machinery
36	Gas turbine : Gas	36	Electronic Product
37	Gas turbine : Natural Gas	37	Transport Equipment
38	Diesel	38	Precision Instruments & Apparatus

39 Nuclear	39 Other Manufactures
40 End use for electricity	40 Hydroelecticity
41 Gas	41 Stream turbine: Oil
42 City Water	42 Stream turbine: Coal
43 Construction	43 Stream turbine: Natural Gas
44 Commence and Sales	44 Combined-cycle : Oil
45 Hotel Services and Restaurant Services	45 Combined-cycle : Natural Gas
46 Transportation	46 Gas turbine : Gas
47 Finance, security and insurance	47 Gas turbine : Natural Gas
48 Business Services	48 Diesel
49 Other Services	49 Nuclear
	50 End use for electricity
	51 Gas
	52 City Water
	53 Construction
	54 Commence and Sales
	55 Hotel Services and Restaurant Services
	56 Transportation
	57 Finance, security and insurance
	58 Business Services
	59 Other Services