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Bilateral Trade between the Eurozone and China: A Zero-Sum Game Theory Approach

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Abstract

Over the last decade, the whopping growth of the Chinese economy, due to the liberalization of its market, with regard to the vulnerable Eurozone's economic activity, has led to trade disputes between the two economies. In order to best capture and describe these implications, we attempt to approach their moves and payoffs through a combination of strategic and analytical tools such as zero-sum games and multiple regression models. Data and metadata for both economies were obtained from official sources, mainly the Eurostat and the National Bureau of Statistics of China and used as input in the regression model. Subsequently, the model output was used as input in the zero-sum game. The results of this process pointed out the best strategies that the players should follow in order to avoid great losses.

Keywords: international trade, trade balance, zero-sum game, regression model

1. Introduction

The radical growth of the chinese exports (Amiti, & Freund, 2008; Zhi, 1999) and the measures which have been imposed by the global partners of China (PRC) in order to protect their internal production increasingly attracts the researchers' attention. Messerlin and Wang (2014) studied the trade relations between two nations. They began their study in 1999, at a time when China got the WTO Accession Protocol and trade relations where running smoothly between nations. However, this situation did not last long. With respect to China's emerging economic activity in the Euro area, the EU started to impose antidumping and safeguard measures against imports from China (Z. Lu, 2012). Additional issues against chinese products came up with regard to Intellectual Property Rights (IPR) (European Commission, 2013), when many EU companies complained about their products being copied by chinese manufactures. On the other hand, China had taken enough Investment Barriers to foreign companies which wanted to expand their business to China, for example, legal consulting firms (European Commission 2012; Feenstra & Wei, 2009). Last but not least, the undervalued currency of the Yuan against the Euro is an issue of major concern for the Eurozone, since it gives China 'unfair' competitive advantage (M. Lu, 2015).

Fair (2010) tried to estimate the macroeconomic effect of Chinese yuan appreciation in US economic growth, fitting econometric models. His empirical evidence showed that yuan appreciation will lead to a decrease in Chinese output, which would consequently have a negative effect on Chinese imports, hence and imports from US. An additional negative effect will be the rise of US import prices, which will then lead to an increase US domestic prices. Finally, there will be an increase in US domestic prices, which will decrease the real wealth-wages and increase the short term interest rates.

Graceffo (2015) attempted to explain the recent devaluation of RMB (renminbi), arguing that the devaluation of RMB was implemented by China in order to regain trade losses and stimulate its internal market. Data and figures before devaluation showed that the exports of China had fallen by 8% and factory output by 6% in one year (Inman, Farrer, & Ryan, 2015). In addition, Chinese stocks have dropped down significantly over the last several months, with the Shanghai index losing 32% of its value. The recent devaluation has a direct impact on China's imports-exports since imported products will be more expensive, while exported ones will be cheaper.

Hui (2012) also studied the bilateral trade imbalances between China and the EU through a combination of

Econometrics and Game Theory, considering yearly data from 2000 to 2010. The main variables analyzed in this study were the Exchange Rate, the Fiscal Deficit, the Foreign Direct Investments (FDI), the National Income, the Living Standards, International Competitiveness and the Trade Deficit of the EU against PRC. It was shown that the most critical variable describing the trade imbalances between two economies is the exchange rate, so the author advanced a dynamic game theory model in order to analyze the best policy/strategy selection between China and the EU. The payoffs of the game were stochastic and were derived from general game theory rules of dynamic trade games, based on Prisoners Dilemma Game (Tucker, 1992).

With respect to the above analysis and due to the ongoing growth of trade relations between China and the Eurozone, we attempt to describe the bilateral trade of these two economies. Our approach is based on a combination of econometrics and game theory methodology. We have applied a multiple linear regression model in quarterly official data, from 2005 to 2015, concerning critical macroeconomic indicators. These indicators are: Trade Balance in million ECU/EURO (depended variable), Exchange Rate Quarters Median, General Government Deficit (-) and Surplus (+), quarterly data EU 17, (FDI) EU17 to China (OECD, 2013), GDP and main components, Current prices EU17, Living Standards (Gross national disposable income EU 17) and International Competitiveness Index (Nominal Unit Labour Cost EU17/PRC). The outcome of the regression analysis is used as an input for the evaluation of the players' trade game payoffs. The players' available moves are based on realistic options and restrictions that each country has in order to influence their trade balance.

2. Methodology and Results

2.1 Survey Data and Metadata

The data and metadata used in this paper were extracted from the official webpages of the respective countries statistical authority, which in our case are the Eurostat and the National Bureau of Statistics of China (NBSC). More specifically, the definitions of the variables were mainly extracted from the Eurostat website while PRC data and metadata from NBSC were adjusted to the respective Euro ones. Hence, according to Eurostat definitions we have used the following terms.

Trade Balance: It is the result of the deduction between Total Exports of Goods and Total Imports of Goods. The definition Total Exports according to the Eurostat is: International trade statistics cover any movements of goods between the reporting country and the rest of the world. "Goods" means all movable property, including electrical current. The table indicates the seasonally adjusted values of the EU and euro-zone exports. Exports are evaluated FOB (Free on Board), i.e. only incidental expenses (freight, insurance) incurred in the part of the journey located on the territory of the reporting country are included. The raw values of the Member States are adjusted according to the number of working days on the basis of each national calendar and then seasonally adjusted before being aggregated to provide the EU and euro-zone totals. The definition Total Imports according to the Eurostat is: International trade statistics cover any movements of goods between the EU Member States and non-member countries (extra-EU trade), and from one Member State to another (intra-EU trade). 'Goods' means all movable property, including electrical current.

General government deficit/surplus (Eurostat Short Description): "The general government deficit/surplus is defined in the Maastricht Treaty as general government net borrowing/lending according to the European System of Accounts (ESA95). It is the difference between the revenue and the expenditure of the general government sector. The government deficit data related to the EDP (EDP B.9) differs from the deficit according to the ESA95 (B.9) for the treatment of interest relating to swaps and forward rate agreements. The general government sector comprises the sub-sectors of central government, state government, local government and social security funds. The series are presented as a percentage of GDP".

Gross disposable income (Eurostat Short Description): -Million EUR (current prices): "Gross national disposable income (ESA95, 8.95) is the sum of the gross disposable incomes of the institutional sectors. It is equal to: Gross national income plus (+) current transfers receivable from the rest of the world minus (-) current transfers payable to the rest of the world. Values are seasonally adjusted (SA). The ESA 95 regulation may be referred to for more specific explanations on methodology".

Gross domestic product, current prices -Million EUR (Eurostat Short Description): "Gross domestic product (GDP) at market prices is the final result of the production activity of resident producer units (ESA 1995, 8.89). It is defined as the value of all goods and services produced, less the value of any goods or services used in their creation. Values are seasonally adjusted (SA). The ESA 95 (European System of Accounts) regulation may be referred to for more specific explanations on methodology".

Nominal unit labour cost index (2005 = 100) -quarterly data (Eurostat Short Description): "It is the result of the

division of the EU17 index by the PRC index. Eurostat's definition is: The nominal unit labour cost (NULC) is defined as the ratio of total compensation of employees (D1), in millions of national currency per total number of employees in persons, divided by the ratio of GDP in market prices in millions, chain-linked volumes, reference year 2005 (CLV05), at 2005 exchange rates in national currency per total number of persons employed in persons. The change in nominal unit labour cost is the change in total compensation of employees per number of employees not covered by the change in labour productivity plus the change in share of employees in total employment. Input data is obtained through official transmissions of national accounts country data in the ESA95 transmission program. The NULC is calculated by the formula: (total D1 in national currency/total employees in persons)/(GDP in market prices in CLV05 in national currency/total employment in persons). Data are quarterly indexes, calendar and seasonally adjusted".

EU direct investment outward flows by extra-EU country of destination -Million ECU/EUR (Eurostat Short Description): "Direct investment (FDI) is the category of international investment made by a resident entity (direct investor) to acquire a lasting interest in an entity operating in an economy other than that of the investor (direct investment enterprise). The lasting interest is deemed to exist if the investor acquires at least 10 % of the equity capital of the enterprise. FDI stocks are the value of FDI assets (for outward FDI stocks) and FDI liabilities (for inward FDI stocks) at the end of the reference period".

The quarterly data from 2005 to 2012 with respect to the above-mentioned and defined variables used in the regression analysis are presented in Table 1.

Table 1. Regression data variables

Unit	Dependent	Independent					
Quarters (Time Series)	Trade balance in million EURO (China)	Exchange Rate Quarters Median (¥/€)	General government deficit (-) and surplus (+) quarterly data EU 17	Foreign Direct Investment (FDI) EU17 to PRC	GDP and main components-Current prices EU17	Living Standards (Gross national disposable income EU 17)	International Compet, Index (Nominal unit Labour Cost EU17/PRC)
2005 Q1	-16,098.0	0.0921	-100,400.87	999.5	1,979,412	1,954,685	1(base)
2005 Q2	-18,882.5	0.0959	-38,384.31	999.5	2,041,259	1,999,088	1.002
2005 Q3	-19,778.4	0.1008	-46,839.62	999.5	2,021,896	2,020,489	1.001
2005 Q4	-20,674.4	0.1041	-21,947.04	999.5	2,127,215	2,054,825	1.003
2006 Q1	-21,490.1	0.1035	-65,920.12	1,013	2,060,752	2,040,828	1.004
2006 Q2	-20,702.2	0.0989	-5,348.23	1,013	2,134,643	2,130,707	1.005
2006 Q3	-22,716.8	0.0984	-34,563.96	1,013	2,125,744	2,107,280	1.010
2006 Q4	-26,440.3	0.0986	-12,852.21	1,013	2,243,086	2,227,981	1.017
2007 Q1	-28,826.0	0.0982	-56,167.97	1,113	2,183,057	2,161,516	1.019
2007 Q2	-22,905.1	0.0966	16,969.28	1,113	2,251,001	2,233,456	1.024
2007 Q3	-30,656.2	0.0964	-21,004.09	1,113	2,242,225	2,213,024	1.027
2007 Q4	-30,231.1	0.0929	-1,704.51	1,113	2,354,390	2,329,173	1.029
2008 Q1	-27,500.6	0.0933	-67,585.33	998	2,262,934	2,218,720	1.013
2008 Q2	-23,848.2	0.0926	-15,288.16	998	2,336,147	2,308,901	1.018
2008 Q3	-34,141.9	0.0972	-53,906.31	998	2,297,378	2,261,902	1.030
2008 Q4	-34,429.9	0.1106	-60,679.94	998	2,346,553	2,302,847	1.034
2009 Q1	-26,236.4	0.1115	-147,411.70	1,221	2,169,995	2,125,149	1.020
2009 Q2	-28,353.3	0.1070	-118,882.06	1,221	2,220,209	2,199,570	1.029
2009 Q3	-29,221.7	0.1023	-159,144.97	1,221	2,217,740	2,189,344	1.031
2009 Q4	-33,235.8	0.0994	-141,162.26	1,221	2,313,519	2,292,335	1.027
2010 Q1	-29,727.8	0.1061	-176,368.72	825	2,207,782	2,169,850	1.025
2010 Q2	-27,535.3	0.1153	-101,165.61	825	2,290,589	2,276,614	1.029
2010 Q3	-34,980.0	0.1139	-168,729.39	825	2,289,388	2,257,589	1.031
2010 Q4	-31,250.9	0.1109	-122,429.13	825	2,379,830	2,367,860	1.029

2011 Q1	-25,980.5	0.1110	-123,435.66	3,714	2,294,812	2,264,274	1.012
2011 Q2	-24,178.6	0.1067	-76,391.90	3,714	2,360,915	2,339,498	1.013
2011 Q3	-29,363.5	0.1101	-100,646.61	3,714	2,350,925	2,323,972	1.012
2011 Q4	-23,318.8	0.1166	-90,275.12	3,714	2,417,376	2,399,278	1.022
2012 Q1	-21,872.9	0.1206	-103,181.39	3371.75	2,329,119	2,293,474	0.995
2012 Q2	-21,400.6	0.1237	-67,993.07	3371.75	2,369,480	2,349,951	1.010
2012 Q3	-26,385.5	0.1257	-87,113.58	3371.75	2,359,864	2,339,337	1.027
2012 Q4	-23,017.6	0.1232	-91,105.35	3371.75	2,425,335	2,418,978	1.024

Note. Source, Eurostat. National Bureau of Statistics of China.

2.2 The Regression Model

The dataset consists of eight variables evaluated in 32 consecutive quarters from 2005 to 2012 (cases). The trade balance variable will be treated as the dependent variable while the rest as independent. All eight variables and their acronyms are summarized in Table 2.

Table 2. Variables and acronyms

Acronym	Variable
TB	Trade Balance in million ECU/EURO (China)
EX	Exchange Rate Quarters Median
DEF	General Government Deficit (-) and surplus (+) - quarterly data EU 17
FDI	Foreign Direct Investment (FDI) EU17 to PRC
GDP	GDP and main components - Current prices EU17
GNDI	Living Standards (Gross national disposable income EU 17)
NULCI	International Competitiveness Index (Nominal unit Labour Cost EU17/PRC)

Using backward stepwise elimination at 0.1 alpha level and then testing for multicollinearity, we remove variables FDI and GNDI respectively and form a linear regression model with the remaining independent variables. This model explains almost 75% of trade balance variability (R-squared = 0.7435). The main figures of the proposed linear model are summarized in the Table 3 below.

Table 3. Regression output

Variable	Coefficient	Std. Error	t-Statistic	p-value
B	266506.3	52909.41	5.037031	0.0000
EX	156989.4	70238.62	2.273527	0.0312
DEF	0.027409	0.011423	2.399415	0.0236
GDP	-0.011491	0.006133	-1.873660	0.0718
NULCI	-276574.4	57181.80	-4.836756	0.0000

International Competitiveness Index (NULCI) is statistically significant at <0.001 level (practically at any level), with Exchange Rate (EX) and General Government Deficit (DEF) being statistically significant at 0.05 level, while GDP is marginally significant (at 0.1 level). Passing all the diagnostic tests for residuals i.i.d., normality, homoskedasticity as well as model multicollinearity, the final regression model that explains nearly 75% of the Trade Balance variability is:

$$TB = 266506.3 + 156989.4\,EX + 0.027409DEF - 0.011491GDP - 276574.4\,NULCI \quad (1)$$

The sign of the regression coefficients shows the influence of explanatory variables in trade balance, as follows:

1) EX (Exchange rate): A revaluation of remmendi to euro, leads to a rise of price of the Chinese products in euro. Additionally European products, in remmenbi, will be chipper. Hence, European exports to China will rise and imports will be reduced. Finally there will be reduction to EU trade balance deficit, and vice versa. (European Commission, 2015).

2) DEF (General Government Deficit): An increase in DEF increases the TB negative amount. Case of "twin deficit" (Baxter, 1995; Mariolis & Papoulis, 2010).
3) GDP (Gross Domestic Product): An increase in GDP increases TB negative amount. GDP can be considered as income, so an increase in income leads to a rise of consumption, hence to a rise of imports (Polak, 1947).
4) NULC (Nominal Unit Labour Cost) Index: By definition NULCI derives from EURO17 to PRC index, so an increase of EU index with fix PRC index leads to a rise of EU trade balance deficit, and vice versa. In case of simultaneous moves between the indices, we check their percentage changes (Gavroglou, 2012).

The regression output presented in table 2 will be used as input in the game theory analysis, since we are going to use the linear model coefficient estimators in order to evaluate the players' payoffs.

3. Zero-Sum Game: Currency Devaluation-Imposition of Tariffs

3.1 Overview

The regression analysis revealed UNLCI, Government Deficit and the exchange rate of renmimbi vs. euro as the statistically significant independent variables of the model at the standard 0.05 level. A further economic analysis with regard to these variables can explain the ability of the government to adapt them in time. More specifically, UNLCI is the most difficult index for the government to adapt, because lowering wages can cause social disorders. There have been attempts from European countries in order to fix their internal UNLCI such as the Agenda 2000 from Germany. Furthermore, with regard to the economic crisis, the so-called "Troika", IMF, ECB and European Commission, have attempted to impose models and measures in order to fix the UNLC Index in South-Eastern European countries. The Government Deficit is the next most critical variable under current economic conditions. It requires more time for adaptation from the players, especially for the EU, due to the fact that DEF is used as a backup plan for financing the sensitive Banking Sector and the European Stability Mechanism (ESM) program. This variable is fixed for the players' strategies.

The next critical variable is the exchange rate. This variable can be easily determined by the central bank of a country. PRC had made enough devaluations of its currency, in order to gain competitive advantage in international trade. The remmendi was devaluated from 25% to 40% till 2005. In 2005 its value was ligated to USD. This is one of the main EU arguments against PRC, because EU products cannot compete with those of PRC in price (Morrison & Labonte, 2011). Hence the EU resorts to the WTO against PRC in order to impose tariffs on chinese products. According to the Eurostat, a 15% tariff on chinese products affects the trade balance by 28.46 %. In accordance with the above arguments and conforming to Navarro and Autry (2011) and Rickards (2012) notion regarding PRC trade games, we attempt to develop a zero-sum game between the EU and PRC.

3.2 The Model

Consider that the two players, the Euro Zone (Player 1) and PRC (player 2) will go for the following strategies: i) PRC will devaluate its currency regarding USD at 10% (strategy Z), ii) or it will leave its currency unchanged. iii) the Euro zone will go to WTO against PRC in order to impose tariffs on chinese products (strategy A), iv) or it will impose no restrictions. The players' payout will be taken from the regression equation estimates depending on the above strategies. Furthermore, the independent values will be forecast through Holt-Winters / Exponential smoothing, so that the payouts will be more realistic. TB_{for} or TB_0 is the equation's constant variable which affects the final payout but it is independent regarding the players' strategy. Hence the exponential smoothing data leads to the following output:

$$EX = 0.1332 \qquad DEF = -84762.82 \qquad GDP = 2404308 \qquad NULCI = 1.022$$

The model's equation (1) is the TB 2013 forecast value is: TB_{for} = -26540.74341. Let us now estimate players' payouts under different scenarios:

1) Players' payouts regarding strategies A, Z, devaluation of currency for PRC (10%) and tariff imposition by the EU (derives to 15% reduction of Imports) will lead to:

   TB' = -159689.37*(0.1) → TB' = -15968.94

   Also the EU tariffs will reduce imports by 15%, though TB will be reduced by 28.46%. Finally, the total TB's reduction is:

   $TB_{A,Z} = TB_{for} + TB' - 0.2846 * TB_{for} \rightarrow TB_{A,Z} = 0{,}7154 * TB_{for} - 15968.94$

   So $TB_{A,Z} = -34956.18$, is the (1.1) matrix payout.

2) Players' payouts regarding strategies B, Z, when PRC does not devaluate its currency and the EU imposes tariffs on chinese products, leads to the following outcomes:

$TB_{B,Z} = TB_{for} - 0.2846 * TB_{for} \rightarrow mTB_{B,Z} = 0.7154 * TB_{for}$

So $TB_{B,Z} = -18987.25$, is the (2.1) matrix payout.

3) Players' payouts regarding strategies A, Ω, when PRC devaluates its currency and the EU does not take any restriction regarding chinese products, leads to the following outcomes:

$TB' = -159689.37 * (0.1) \rightarrow TB' = -15968.94$

Hence (1, 2) matrix payout is $TB_{A,\Omega} = TB_{for} + TB' = -42509.68$

4) Players' payouts regarding strategies B, Ω, where neither PRC nor the EU apply any "aggressive" policy, lead to the following outcomes:

$TB_{B,\Omega} = -26540.74$

Which is the (2.2) matrix payout. Matrix outcomes are summarized in table 4.

Table 4. Game payoffs

		PRC payoffs	
	Strategies	Z	Ω
EU payoffs	A	-34956,18	-42509,68
	B	-18987.25	-26540.74

Regarding the above payoff matrix, and knowing that each player will go for its max profit, the solution of the game will be reached through minimax theorem (Neumann, 1944). Let us analyze this game from the EU's point of view (player 1). Suppose that player 1 knows that player 2 wants to cause him maximum losses. So:

- If player 1 goes for strategy A, the worst case scenario for player 2 is to go for strategy Ω and cause him € -42940.65 mil Trade Balance deficit.
- If player 1 goes for strategy B, the worst case scenario for player 2 is to go for strategy Ω and cause him € -26540.74 mil Trade Balance deficit.

Hence, the optimal strategy or minimax strategy for the EU is to go for strategy B. Let us now analyze the game from PRC's (player 2) point of view:

- If player 2 goes for strategy Z, then player 1 will go for strategy B. So player 2 will get € 18987.25 mil Trade surplus.
- If player 2 goes for strategy Ω, then player 1 will go for strategy B. So player 2 will get € 26540.74 mil Trade surplus.

Hence, the optimal strategy or maximin strategy for PRC is to go for strategy Ω.

In conclusion, according to the minimax theorem, the best strategy followed by the players will be strategy B, Ω, which is a Nash equilibrium point. The strategy B, Ω says that PRC will not devaluate its currency and the EU will not go to WTO in order to impose tariffs against chinese products.

4. Conclusions and Suggestions for Further Research

Our study sought to shed light on the explanation of bilateral trade imbalances between two of the biggest economies in the world, the EU and PRC, combining methods and results from Econometrics and Game Theory. The game theory approach is used in order to provide the involved parties with critical information regarding the consequences of their followed strategies. In addition, it estimates the probability that a certain player wins the game. The game theory output, given the players' payoffs, leads to strategic equilibria, from which none of the players will have any unilateral motivation to be removed (Nash Equilibrium). What the game theory cannot do is to provide players with accurate payoffs. The linear regression model supplied the coefficient estimates for the critical macroeconomic variables that explain the bilateral trade imbalances between the Eurozone and PRC, which lead to the available payoffs regarding their chosen strategies. Using those payoffs, we have developed a zero-sum trade game, based on model hypothesis of a trade war between economies. The results pointed out the best strategies that should be followed by the players in order to avoid great losses. In our case the Eurozone should not impose any tariffs on chinese products and PRC should not devaluate its currency to USD/ EURO. The equilibria payoff is € -26,540.74 mil and the additional actual data provided by Eurostat for 2013 is € -22,513.1 mil. There is a discrepancy due to the fact that our model describes the move (variability) of the

dependent variable in a 74.35 percentage. Nevertheless, as it was mentioned, our goal was to describe approximately the consequences and trends of the chosen strategy and not the actual market data.

Future research can be addressed to different time periods, preferably larger, with different characteristics than the one studied here which has certain features due to the economic depreciation of the Eurozone. These can lead to further study of NULCI indicator impact in the trade balance stochastic model. Last but not least, a repetitive dynamic game can be applied between the two economies, in order to capture the dynamic of the game over time.

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