

The Japanese economy after the March 11th, 2011 disaster

Gustavo Bardas

Abstract

A magnitude-9 earthquake hit the Tohoku area of Japan triggering a tsunami that produced huge loss of life and destruction of infrastructure. The Fukushima Dai-Ichi nuclear plant located in that area was damaged causing full melt-down of 3 of its 6 reactors. The release of radiation materials into the environment has tainted agricultural production generating uncertainty about food chain safety. There has also been an important disruption in the supply chain and shortage of electricity supply which are still constraining the recovery of the economy.

Although the crisis of the Fukushima nuclear plant is still unsolved and the government's strategy about how to deal with the future supply of energy is not clear, we attempt a preliminary evaluation of how the disaster may affect the future dynamics of the Japanese economy. We use a dynamic general equilibrium model, and estimate the expected path of the economy. We think that after an initial contraction, the economy will recover in 2012. This would be the result of the reconstruction works by the government, and later by the improvement in both exports and private investment. We predict the value of the yen and the inflation rate will follow a different pattern than the expected before the disaster. We think that in the medium term the value of the yen will follow a lower path because of the higher demand for foreign currency. This will be caused by an increase in imports of fossil fuels and food to compensate for the reduction in the Japanese supply. We also expect

capital outflows to contribute to the higher demand for foreign currency. Deflation will probably turn into inflation, although at a subdued rate due to higher costs of energy and higher raw materials.

In the longer run, the economy would be able to experience positive economic growth but well below the expected path before the disaster. The costs of the disaster will have a negative impact on real wages, what will result in a lower fertility rate and a more rapid contraction in the size of the population. This unfavorable demographic dynamics will make the public debt rise to unsustainable levels. We think that even before the economy completely recovers from the disaster, an increase in the consumption tax and in the income tax of high income earners will be unavoidable.

Keywords: deflation, debt, demographics, deficit, disaster, economic path

Introduction

The present critical situation of the Japanese economy starts even before the Tohoku disaster. It is difficult to trace a starting point but the most recent shock is the one caused by crash of the real state bubble in the United States by the end of 2007 and during 2008. Because of the crisis, in 2009 Japan's GDP was 7.4% lower than its 2007 peak. The unemployment rate also soared from 3.6% in July, 2007 to 4.6% in July, 2009. The main cause of the contraction of the Japanese economy was the dramatic fall in exports in 2008 (in dollar terms, exports fell 55% in the fiscal year 2008). This created a slack in the capital stock used in the production process which reached its bottom of almost 40% in February of 2009. High uncertainty about how the world financial crisis was to be resolved produced an influx of capital to Japan which caused a sharp yen appreciation. This not only hurt exports even more, but also made companies unwilling to invest in new capital and produced an accumulated contraction in private investment of 18.3% in the two year period 2008-2009.

However, since the first quarter of 2009 the Japanese economy has started to improve supported by the recovery of the global economy and also stimulated by expansionary fiscal and monetary policies. As the economy started to

improve, the government embarked in a series of discussions and political struggling about how to solve the “4D” that are constraining a continuous recovery of Japanese economy: “Demographics” “Deflation” and “Deficit” and “Debt”.

It was in the middle of this debate, that the economic prospects for Japan changed drastically on March 11, 2011 when a magnitude-9 earthquake and a 15-meter tsunami hit the north east of the country. According to the Japan National Police Agency, by July 20, there are 20,662 persons either dead or missing and 5,694 injured. More 170,000 persons have been living in some shelters during this period and the damage on housing and infrastructure is huge: more than 235,377 homes were totally or partially destroyed, burned or swept away by the tsunami. There are 3,559 damaged roads, 77 damaged bridges and 29 damaged railways. The public works required to clear all the rubble is expected to take several months. Total cost of the reconstruction is estimated to be in the range of ¥20 to ¥30 trillion which is more than 5% of the GDP and more than twice the total for the 1995 Kobe earthquake.

The 40-year-old Dai-Ichi nuclear plant of the Tokyo Electric Power Company (TEPCO) located in Fukushima in the area of the earthquake was swamped by the tsunami. The cooling system of the spent fuel storage pools necessary to keep the nuclear material from emitting radiation was damaged. At the moment of writing this paper the situation has not been stabilized yet and leaks of radiation to the environment continues. Radioactive materials, including iodine, cesium, and cobalt were detected in sea water near the area of the disaster. Products including rice, meat, fish, milk, tea, spinach, mushrooms and plums have been found to be contaminated with cesium and iodine as far as 360 kilometers from the Dai-Ichi nuclear plant. In July, the authorities have also discovered that more than 600 cattle from farms located in the prefectures of Fukushima, Niigata and Yamagata had been shipped to at least 40 prefectures. Contaminated beef has also already been sold in several supermarkets in Tokyo.

The government has ordered a halt to the shipment of contaminated products and also recommended not using tap water in the area of Fukushima. Fishing activities close to the area have been stopped too. Several countries have

restricted imports of Japanese agricultural products that come from the affected area. While iodine has short 8-day half-life, cesium has a half-life of 30 years which says that it will be affecting for a long time. Initially, the government established a compulsory exclusion area of a radius of 20 km from the nuclear facility and advised residents within 30 kilometers to stay indoors. Nuclear experts from the International Atomic Energy Agency advised a 40km radius of evacuation. The United States and United Kingdom have advised its citizens to evacuate from a radius of 80 km. Following this international pressure, the government has expanded the radius of evacuation, declaring “voluntary evacuation areas” as far as 60 km. TEPCO has been criticized for its lack of transparency in the supply of information, and also on the handling of the crisis. As no clear solution has been found yet about how to stop the radiation emission, 4 of the 6 reactors may be decommissioned, TEPCO has announced. Nationalization of the company should not be discarded. One month after the disaster Japan's Nuclear and Industrial Safety Agency put the severity of the crisis at the plant to the highest level, seven, which is the same as the Chernobyl disaster in Ukraine in 1986.

Several analysts have evaluated the response of the government to the crisis more efficient than the response to the Kobe earthquake in 1995. The government managed to organize the rescue operations, evacuation of victims and the coordination of shelters for the victims. Tax payment has been postponed for the most affected areas of Miyagi, Iwate, Fukushima, Ibaraki and Aomori. Enterprises badly affected by the disaster have also been exempted of paying the social security cost as a measure to avoid companies from reducing their personell. However, criticism to the government has mounted respect to the lack of transparency of the information provided to the public with respect to radiation levels released to the environment and also with respect to the lack of prevention measures respect to food contamination. On April 22nd, the government has approved a first emergency supplementary budget of ¥4 trillion for relief and reconstruction works. No new debt was issued to pay for it and financing comes from funds reserved for disasters, a retraction from some social programs like the child support and with savings from the social security fund. A second extra of ¥2 trillion is expected to be approved on July 25th. Again, no additional issue of debt is to be used to pay for it. On the other hand, the Bank of Japan has made daily cash injections into the market which totaled ¥20 trillion in the first 2 weeks to avoid any

financial disruption.

By May 15th the government approved a plan to help TEPCO compensate the victims of the crisis. Payouts per family would be about ¥1 million per family and are expected to reach ¥10 trillion. The assistance of the government would help TEPCO avoid bankruptcy but the funds are expected to be returned to the government using future profits of the company. In return, the company will fall under close government supervision and must implement massive cost cuts.

The Disaster caused by the earthquake, tsunami and emissions of radioactive material to the environment has become “5th D” to ailing Japan. The fiscal position of the government is not healthy enough to deal with these problems. Japan has the highest ratio of Government debt to GDP in the industrialized world, population and labor force has already started shrinking at a 0.3% per year. Besides, the baby-boom generation born between 1946 and 1949 has already started retiring imposing big constraints on the social security system through both higher expenditures on pensions and health care cost. Ten years of continuous deflation which finally was defeated by 2007, returned to Japan in 2008 when the world crisis hit the country.

How will the March 11, 2011 disaster affect the economy? To answer this question we make represent the behavior of economic agents, estimate the behavior functions, and analyze how the economy is expected to evolve in the next 15 years comparing to the expected economic path before and after the earthquake. The loss of life though sad as it is, may not be the biggest negative impact from the macroeconomic point of view. Nor will the temporary disruption of normal life of the local populations or even the damage to the capital stock be the biggest challenges. The biggest challenges will come from the disruptions in the supply of energy and also in the chain of production. This will continue constraining export growth even if foreign demand continues improving. Uncertainty about the extent to which radiation is affecting the food chain is undermining consumer's confidence what depresses consumption and making other countries to restrict imports of food from the contaminated areas of Japan.

According to our numerical simulations, after an initial contraction, the eco-

nomony would be able to start to positive growth as soon as 2012. Several factors will be contributing to the recovery. First, the reconstruction efforts by the government in the quake affected area will give the initial push, but private investment is expected to improve too. Secondly, as the disruptions in the supply chain gradually resolves, export growth will also return to a positive ground though at a subdued level due to a short term rise in the value of the yen. The rise in the yen will be the result of the higher demand of the Japanese currency due to both the repatriation of funds by Japanese companies to finance the reconstruction efforts and the uncertainty about the resolution of the debt problem in the United States and in some of the southern countries in the European Union. However, we expect the value of the yen to fall in the medium term as a result of an increase in the demand for foreign currency in the medium and long run. The increase in the demand for currency is due to two factors, first an increase in the volume of imports, second an outflow of capital. First, the volume of imports of fossil fuels will have to be increased to be used as a source of energy and compensate the reduction in the supply of nuclear energy. The government will keep several nuclear plants closed until it can be assured they do not impose risk to the population or to environment, and also will review the goal to expand nuclear energy supply from 30% to 50%. Imports of food and other supplies will probably rise too, because the government has not been proactive enough in the collection and dissemination of information about how leakage of radiation material has affected the agricultural production. As radiation has been affecting the supply chain of food uncertainty has been mounting among the population about which food is safe and which is not. The increase in fossil fuels and food does not come at a good time, because international prices or raw materials in general have been rising and as the world economy continues recovering they will continue in an upward trend. The second factor which will make the demand for foreign currency rise is a renewed outflow of capital which we expect to start in one or two years. This will occur basically because we expect the world economy to continue its recovery what will make interest rate rise and increase and inducing to yen carry trade operations. These are investors' purchases of currencies of countries with lower risk and higher interest rates than Japan to profit from the interest rate differential.

As the yen falls, and if the energy and supply chain disruptions are well managed and resolved, exports companies may be favored by the unfolding

events in the medium and long term. Private investment will continue expanding as companies try to incorporate new equipment and machinery to respond to the increased demand. Consumption will increase too as the real wages recover.

However, the economic trend will remain subdued basically because of the energy restrictions will impose higher costs on companies lowering profits and wages.

After 2012, the economy could be kept growing for several years, but the path will become unsustainable because the public debt will continue increasing to exploding proportions. As investors may lose confidence in the ability of the government to pay, capital may flow out of the country and the yen may fall. To avoid an economic collapse the government will have to raise taxes to start paying the debt and the Bank of Japan may also have to allow the interest rate to rise and cool down the economy.

This paper is organized as follow. First we describe the model of the economy, the behavior of the economic agents and we explain their interaction through the markets. Then we describe the results of the estimations of the parameters and exogenous variables of the model. Finally we describe the economic path that was expected before the March 11th disaster and the most probable scenario or path after that catastrophic event. Finally we explain the limitations to our estimations and predictions.

1. The Model

The economy is represented by a macroeconomic model in which the household, the enterprises, the government, the central bank and the rest of the world interact with each other through the labor market, the market of goods and services, the money market and the foreign exchange market.

The household decides how much to work, consume and save. Enterprises will choose the optimal level of labor given the stock of capital and land and will also determine the optimal level of investment. The government provides the economy with public services and uses the fiscal policy to stimulate the economy and reduce unemployment. The central bank implements its mone-

tary policy in order to assure price stability and sustained growth.

We assume that except for the labor market, all markets can achieve equilibrium by the forces of supply and demand. Instead, the labor market is, in general, at disequilibrium because nominal wage rate does not adjust responding to the free market forces but is the result of the negotiations of labor unions and enterprises. Therefore, the unemployment rate could be above or below the natural rate of unemployment depending on the general conditions of the economy.

The general equilibrium of the economy will be represented using a variation of the traditional IS-LM-BP-AD-AS model. Besides, we allow the economy to evolve on time, through the accumulation of capital, population growth, asset and debt accumulation of the households, the government and the rest of the world. The IS curve will represent the equilibrium in the market of goods & services and the LM curve the equilibrium in the money market. The simultaneous equilibrium in these two markets is represented by the aggregate demand curve (AD). The aggregate supply curve (AS) describes the optimal level of production enterprises for different price levels. Finally, the balance of payments curve (BP) represents the equilibrium in the foreign exchange market. Macroeconomic variables like the nominal interest rate, the real interest rate, the GDP, the price level, the exchange rate are all determined by the simultaneous interaction of all the markets and the details of this mechanism will be described in the following chapters.

We include some new features to the traditional AD-AS curves. The main novelties are related to the determination of the private investment in equipment, the determination of the nominal wage rate, and the consideration of risk of investment in stocks and bonds. We will describe with more detail these features in the following sections, but let us present some general ideas below.

The level of investment depends not only on the level of the real interest rate as assumed by most traditional models, but also on the difference between the net profit rate of Japan and the net profit rate of other countries. Furthermore, we also assume that when there is unutilized capital stock, companies may not invest in new machinery and factories as desired, but

instead they may use part of the idle capital once the economy recovers from a slowdown.

A second feature is related to determination of wages. We assume the wage rate is “negotiated” by enterprises and labor union. We model these negotiations as the result of three variables, the unemployment rate, the inflation rate and labor productivity. For example enterprises will be more willing to allow the wage rate rise when the inflation rate is increasing, and when the level of unemployment is close or below the natural rate of unemployment. On the other hand, labor unions will be more willing to renounce to higher real wages when the level of unemployment is high and when deflation occurs.

Another novelty of our model is related to the risk implicit in the public debt. When the ratio of the net public debt/GDP ratio increases with respect to other countries, more investors will prefer to buy debt of other countries what would induce to an outflow of capital. In turn, this will affect the exchange rate.

Finally, the household behavior will also reflect the demographic structure of Japan, and the fertility rate is allowed to respond to the variations in the real wage rate and the costs of education.

In the following chapters we describe the behavior of the economic agents, the market equilibrium and the economic policies.

2. Behavior of the economic agents

We represent separately the behavior of household by a “representative working household” and a “representative retired household” to better analyze the effects that the aging and falling population could have on the Japanese economy. Enterprises maximize profits and decide on how much to invest in equipment and infrastructure. The government provides public services, public infrastructure, administers the social security fund (pensions, health, unemployment benefits, and other transfers to the households and enterprises) and manages the fiscal policy. The Central Bank (Bank of Japan) administers its

monetary policy to assure price stability and economic growth. Relations with the rest of the world will be represented by macroeconomic export and import functions as well as capital flows. The following sections describe in detail the behavior of the economic agents.

2.1. The representative working household

The representative working household receives happiness or utility from consumption and leisure, and looks for the combination of consumption, saving, leisure, and labor which could give her the maximum wellbeing in its whole lifespan and in a way that is compatible with its life budget constraint. The level of utility U received in a certain period is represented by $U(C_t, \ell_t)$, where C_t and ℓ_t represent the level of consumption and leisure respectively. The subscript “ t ” indicates the period being considered. Formally, the optimization problem of the representative working household can be expressed as the maximization of the life span utility subject to the two constraints, the time and budget constraints.

$$\begin{aligned} \text{Max} &= \sum_0^T \frac{\text{Log}(C_t) + \varepsilon \text{Log}(\ell_t)}{(1+\rho)^t} \\ \text{s.t.} \quad &\begin{cases} \ell_t + \ell e_t = H \\ \sum_0^T \frac{(1+t_t^e) P_t C_t}{(1+r_e)^t} = A_0 + \sum_0^n \frac{w_t \ell_t (1-\tau_t) + Tr_t}{(1+r_e)^t} + \sum_{n+1}^T \frac{\eta_t}{(1+r_e)^t} \end{cases} \end{aligned} \quad (1)$$

The first function is the net present value of the utility for the T years of life of the household who is taking its decisions now, at period “0”. ρ is the annual intertemporal rate of discount (intertemporal preference rate of discount) which indicates how much important is utility in the present year with respect to the next. A high value of ρ indicates that the utility located in a distant future is less important for the household’s wellbeing and in general, present consumption will be higher. The parameter “ ε ” indicates how much utility the household receives from leisure. A lower ε indicates leisure becomes less important compared to consumption, and the household will work long hours to be able to consume more.

The time constraint $\ell_t + \ell e_t = H$, says that the individual has a total amount of hours per year, $H = 24 \times 365$ to be distributed to labor ℓ_t and leisure ℓe_t . The left side of the budget constraint will represent the net present value to total consumption during the whole life span, and the right side the net present value of income and assets. P_t is the price of the consumption good and then $(1+t_c^t)P_t C_t$ is the total value of consumption in period t , including the consumption tax (t_c^t : consumption tax in period t). The variable r_e is the expected average real interest rate as estimated by the households. A_0 is the total initial net assets at the period of making the decision (period "0"). The household expects to work during n years, ℓ_t hours per year, and will earn a wage rate w_t (nominal wage per hour worked). Therefore $w_t \ell_t (1-\tau_t)$ represents the after tax total income from labor. Taxes paid on labor income are the social security premiums t_t^p and the income tax t_t (including the inhabitant tax). As the income and inhabitant tax are computed on the labor income after paying the social security premiums, we have $1-\tau_t = (1-t_t)(1-t_t^p)$. On the other hand, Tr_t is the total annual transfers from the government (child support, disable support, education subsidies, etc.). η_t is the expected after tax annual pension to be received after retirement

The optimization problem can be solved by maximization of the Lagrangian function. As computations are rather tedious, we will only present the final results but if requested, detailed computations can be provided. First of all, the first order conditions for utility maximization give the following basic two equations.

$$\frac{(1+t_c^{t+1})P_{t+1}C_{t+1}}{(1+t_c^t)P_t C_t} = \frac{1+r_e}{1+\rho} \quad (2)$$

$$(1+t_c^t)P_t C_t \varepsilon = (1-\tau_t)w_t \ell e_t \quad (3)$$

The first equation shows the relation between consumption of two consecutive periods, and the second equation the relation between consumption and leisure. We can obtain the "consumption function" and the "labor supply" substi-

tuting the above two equations in the budget constraint and using the time constraint too. The level of consumption at the present time (subscript, "0") is determined by the formula below.

$$C_0 = \frac{1}{\Phi_w} \frac{B_0}{P_0(1+t'_0)} + \frac{1}{\Phi_w} \frac{w_0(1-\tau_0)}{P_0(1+t'_0)} \ell_0 + \frac{\Psi_w w_E(1-\tau_E)}{\Phi_w P_0(1+t'_0)} \ell_E \quad (4)$$

Where Φ_w , Ψ_w and B_0 are defined as follows:

$$\Phi_w = \frac{1+\rho}{\rho} \left[1 - \frac{1}{(1+\rho)^T} \right] \quad \text{and} \quad \Psi_w = \frac{1+g_s}{r_e - g_s} \left[1 - \left(\frac{1+g_s}{1+r_e} \right)^{n-1} \right] \quad (5)$$

$$B_0 = A_0 + \sum_0^n \frac{Tr_t}{(1+r_e)^t} + \sum_{n+1}^T \frac{\eta_t}{(1+r_e)^t}$$

w_E is the expected average wage rate which is assumed to grow at a constant average rate g_s . ℓ_E the supply of labor in the future. In general, workers may expect higher wages in the future, $w_E > w_0$ when for example, prospects for the economy improve and also when the expected inflation rate increases. τ_E is the average tax rate on labor. If for example, the government implements expansionary policies borrowing money, the household may expect higher taxes in the future. Similarly, as population ages, individuals may expect the government to raise the premiums to the social security. In either case τ_E be higher. Using equations (2) and (3) jointly with the budget and time constraints, we can find the equation for the labor supply:

$$\ell_0 = \frac{\left\{ \frac{\Phi_w - \Psi_w \left[\frac{(1-\tau_E)w_E}{(1-\tau_0)w_0} - \frac{(1+r)}{(1+\rho)} \right] \right\} H - \frac{B_0}{w_0(1-\tau_0)}}{\Psi_w \frac{(1+r)}{(1+\rho)} + \frac{\Phi_w}{\varepsilon} + 1} \quad (6)$$

After tax income which is not consumed will be saved. The households will invest in government bonds, bonds issued by companies or in other foreign assets.

2.2. The representative retired household

The retired household does not work and all the available time is assigned to leisure. Therefore, the optimization problem consists in the maximization of the utility from consumption C_t for the remaining of its life.

$$Max = \sum_0^s \frac{Log(C_t)}{(1+\rho_p)^t} \quad (7)$$

$$s.t \sum_0^s \frac{(1-t_t^c)P_t C_t}{(1+r_E)^t} = B_0 + \sum_0^s \frac{\eta_t}{(1+r_E)^t}$$

s is the number of years the household expects to live, ρ_p is the intertemporal rate of discount, r_E is the annual average expected interest rate, B_0 is the net value of assets and η_t is annual net income (pensions and other transfers, net of taxes) to be received each period. The solution to the above problem will give us the consumption function which is the following

$$C_0^P = \frac{1}{\Phi_p} \frac{1}{P_0(1+t_c)} \left(B_0 + \frac{\Psi_p + 1}{\Phi_p} \eta_0 \right) \quad (8)$$

$$\text{Here, } \Phi_p = \frac{1+\rho_p}{\rho_p} \left[1 - \frac{1}{(1+\rho_p)^s} \right] \quad \text{and} \quad \Psi_p = \frac{1+g_p}{r_E - g_p} \left[1 - \left(\frac{1+g_p}{1+r_E} \right)^{s-1} \right]$$

g_p is the expected annual growth rate of future pensions. Though we assume the retired household faces the same expected real interest rate, r_E as the working household, the intertemporal rate of substitution of the retired household are not.

To get the total volume of consumption we add equation (4) and equation (8). For any given period, "t" total consumption can be expressed as follows

$$C_t = C_t + C_t^P \quad (9)$$

2.3. Population

Population dynamics is determined by the number of birth, the number of death, and immigration. In the simulations we use a macroeconomic aggregate function to predict the future evolution of TFR and the dynamics of the population. We assume that total fertility rate (TFR) is an increasing function of the variations of the real wage rate and a possible income effect derived from any change in the policy of subsidies to families with children. Besides, the TFR will be a decreasing function of the real costs of education.

$$TFR = f_0(\text{real wage} + \text{subsidy effect}) - f_1(1 + \Delta \text{education costs}) \quad (10)$$

Where f_0 and f_1 are two positive parameters.

Although immigration of population from other countries will play a very important role in the future of the Japanese economy, our simulations assume no change in the number of immigrants. A more realistic assumption would allow for changes in the number of immigrants depending on the economic conditions and any change in the governmental policy towards this issue. We are leaving the immigration effect for future research.

2.4. The enterprises

Enterprises use capital, land, labor and imported raw materials to produce. Capital and land are fixed at the moment of producing, so enterprises will choose the level of labor demand that maximizes profits. Besides, enterprises will decide on how much to invest and increase the capital stock in the future.

2.4.1 Profit Maximization

The production function will be represented by the following equation

$$Q = \lambda N^\alpha K^\beta \quad (11)$$

Where λ, α, β are parameters such that $\lambda > 0$, $0 < \alpha, \beta < 1$ and $\alpha + \beta = 1$

Q is the total value of production, N is the level of employment and K is the aggregated value of assets effectively used in the production process. λ is an indicator of the technological level. This includes not only the stock of knowledge applied in the production of goods and services, but also the supply chain and energy technological capacity. In the following section we explain our hypothesis about technological progress. Q represents the value of gross production, which is the aggregation of the GDP and total imported materials and energy. For simplicity the amounts of imported materials and energy are assumed to be a fixed proportion of the level of production:

$$In = mQ \quad (12)$$

Here m is a parameter that reflects the content of imported energy and raw materials in the total production. The profit maximization problem is described as follows.

$$\begin{aligned} \text{Max } PQ - wN - EP_{im}^w mQ \\ \text{s.t. } Q = \lambda N^\alpha K^\beta \end{aligned} \quad (13)$$

Here, P denotes the price level, E the nominal exchange rate (yens per units of foreign currency), P_{im}^w the international price of imported oil and raw materials. As the volume of the GDP, Y excludes the imported stuff, we can write

$$Y = \mu Q \quad \text{where } \mu = 1 - \frac{E P_{im}^w m}{P} \quad (14)$$

According to the first order condition for maximization the marginal productivity of labor should equal the real wage rate. This condition will give us the labor demand function which can be expressed as follows

$$N = \left(\frac{w}{P} \frac{1}{\mu \alpha \lambda} \right)^{\frac{1}{\alpha-1}} \quad (15)$$

From (15), labor demand, N is a decreasing function of both the real wage rate and the international price of materials and energy. The exchange rate, E also affects the labor demand because of its incidence on the imported raw materials. For example, a depreciation of the currency has a positive impact

on profits because exports rises and a higher volume of activity will also induce higher prices, P . At the same time, depreciation has a negative impact on profits because it makes the imported raw materials more expensive. The total GDP, the supply by companies operating in Japan is obtained substituting the labor demand in the production function.

$$Y = \mu\lambda \left(\frac{w}{P} \frac{1}{\mu\alpha\lambda} \right)^{\frac{\alpha}{\alpha-1}} K^{\beta} \quad (16)$$

2.4.2 Technological change

The parameter λ of the production function (equation (11)), represents the technological level. We assume technological progress has two components: a constant rate of technology improvement, and a variable component which depends on the change of net profits of the enterprises. While an increase in the net profits creates a more favorable environment for adopting more efficient methods of production, a reduction makes companies retract and wait for more favorable conditions. For simplicity we assumed technological progress is without cost. The technological progress rate is modeled according to the following equation.

$$\frac{\Delta\lambda}{\lambda} = \text{constant rate} + \text{coefficient} \times \text{Max}(0, \text{Net profit growth}) \quad (17)$$

In general technological change is expected to be “progress” and then $\Delta\lambda > 0$. However, natural disasters like the one which affected Japan on March 11th, 2011, can result in $\Delta\lambda < 0$ because of the disruptions it caused on the supply chain of production and on the energy supply.

2.4.3 The investment function

Capital expands or contracts depending on the level of investment and the level of depreciation. Enterprises will not be trying to achieve the long term optimum level of capital, but instead they are assumed to be as assessing different kind of investment projects in which they would invest if the net present value of future profits is positive. For an infinite horizon project, the volume new machinery and equipment to be incorporated to the production

process, should equivalent to the

$$Investment \rightarrow \frac{Profit}{r_E + \sigma_E - g_E} \quad (18)$$

In the above equation, the numerator “Profit” stands for the expected annual permanent level of profits to be obtained from the investment. r_E, σ_E, g_E are measures of the average expected annual real interest rate, risk rate and growth rate of the permanent profits. For the economy as a whole, the level the level of investment will be the aggregate result of the decision making of all enterprises. Investment would be a decreasing function of r_E, σ_E and increasing with g_E . However, the volume of investment would not be as large as the above expression if there is excess capacity. For, example, when the economy recovers from a recession, part of the existent capital K_t may still not be completely used. Then, enterprises will not order as many machines and factories as desired, but instead, they will use part of the old idle equipment. If θ , the proportion of capital effectively being used in the production process is lower than the unity, investment expansion will not be as strong as it could be. The investment function of the whole economy is specified as follows,

$$I_t = \frac{Profit}{r_E + \sigma_E - g_E} - \xi(1-\theta)K_t \quad (19)$$

$0 < \xi < 1$ is an adjustment parameter which indicates that the idle capital $(1-\theta)$

K_t cannot be reincorporated to the production process immediately for technological reasons. We use δ to represent the annual depreciation rate of capital, and then the equation of capital accumulation is represented as follows

$$K_{t+1} = K_t(1-\delta) + I_t \quad (20)$$

2.5. The Government

The government provides public services, invests in public infrastructure, administers the social security fund (pensions, health, public assistance, unem-

ployment benefits, etc.). It also defines the fiscal policy required to stimulate the economy when it is weak. The budget of the government is represented as follows.

$$PG + Transfers = Taxes + SSC + \Delta Debt \quad (21)$$

G is the “volume” of services provided by the general government like education, security, creation of laws, justice, including the public investment. As the price level P changes the government actualizes its budget adjusting by the inflation rate of the previous year. “*Transfers*” includes all transfers from the government to the households (pensions, health, elderly care, assistance to the poor, unemployment benefits) and to the enterprises. These transfers are also adjusted according to the inflation rate. “*Taxes*” includes the income tax, asset tax, corporation tax, the inheritance tax, consumption tax, import tax, etc.. The variable SSC represents the social security contributions from employers and employees the government. When total expenditure is higher than total taxes and the SSC , then the government will have to expand its debt: $\Delta Debt > 0$.

2.6. The Bank of Japan (BOJ)

The BOJ (the central bank of Japan) controls the circulation of money in order to achieve price stability and economic growth. It will periodically set its target for the rate of inflation π_{target} which is the rate which allows the economy to operate close to full capacity. When the inflation rate observed in the economy π is below the target inflation rate, $\pi_{\text{target}} - \pi > 0$ the BOJ will increase the monetary base H ($\Delta H > 0$). It will also tend to increase the monetary base when the unemployment rate u is above the natural rate of unemployment u_n ($u - u_n > 0$).

The BOJ must also assure stability in the price of assets P_k . To avoid the formation of asset bubbles, when the price of assets increases is above the inflation rate in a percentage which surpasses the expected average growth rate of the economy (g), $\frac{\Delta P_k}{P_k} - \pi > g$, then the BOJ may implement reduce the monetary base $\Delta H < 0$.

$$H = H \left(\pi_{\text{target}} - \pi, u - u_n, \frac{\Delta P_k}{P_k} - \pi - g \right) \quad (22)$$

2.7. Trade with the rest of the world

2.7.1 The export function

Purchases from the rest of the world will be represented by an export function, which assumes that the value of exports in foreign currency X is an increasing function of both the real GDP of the rest of the world, Y_w and the real exchange rate. The real exchange rate is the ratio between the price of exported goods (measured in yens) and the price level: $e_x = \frac{E P^w}{P}$. Here, P^w is the international price of goods competitive with Japanese production, and $P^w \neq P_{im}^w$ (the international price of imported raw materials). The export function is assumed to be of a Cobb-Douglas type and is presented below.

$$X = n_0 Y_w^{n_1} e_x^{n_2} \quad (23)$$

where $n_0, n_1, n_2 > 0$ are parameters to be estimated.

2.7.2 The import function

Japan's purchases from the rest of the world will be represented by an import function, which is an increasing function of the Japan's GDP, and a decreasing function of the real exchange rate. As the basket of goods being sold and bought by the rest of the world are not the same, the price level is also different. The real exchange rate for imports is measured as $e = \frac{E P_{im}^w}{P}$, where P_{im}^w is the price level of the imported goods. Therefore, $e \neq e_x$.

Japan imports consumption goods, investment goods and raw materials. Imports of consumption and investment goods can be substituted by local production if it becomes economically beneficial, but imports of raw materials are not produced in the country, therefore demand is inelastic. As already de-

scribed in the chapter related to the maximization of profits of the enterprises, imports of raw materials are computed as a constant proportion of the total volume of production. Then, the total volume of imports IM will be the addition of the substitutable imported goods IMs and the total imports of raw materials In

$$IM = IMs + In \quad (24)$$

It is assumed that economic agents will choose between locally produced goods and imported goods in such a way that minimizes the total cost of purchases subject to a certain preference function towards the two types of goods. The preference function is a CES type function F of the local production Y (volume of GDP) and the substitutable consumption and investment imported goods IMs . Total expenditure is the addition of the value of local production, PY and the value in the local currency of the total imports. As E is the exchange rate and P^w the international price of goods, the value in local currency of total imports will be $EP_{im}^w IM$.

Because, $IN = mQ$ and $Y = (1 - em)Q$, the optimization problem is represented below.

$$\begin{aligned} \text{Min } & PY + EP_{im}^w \left(IMs + Y \frac{m}{1 - em} \right) \\ \text{s.t. } & F = \left[(Y)^\eta + m_0 (IMs)^\eta \right]^{\frac{1}{\eta}} \end{aligned} \quad (25)$$

m_0, η, m are parameters. The solution to the above optimization problem will give the relation between the substitutable imported goods and the volume of GDP. The total volume of imported goods expressed in foreign currency derived from the above problem is as follows.

$$IM = Y \frac{m}{1 - em} + Y \left[\left(\frac{1}{e} + \frac{m}{1 - em} \right) m_0 \right]^{\frac{1}{1 - \eta}} \quad (26)$$

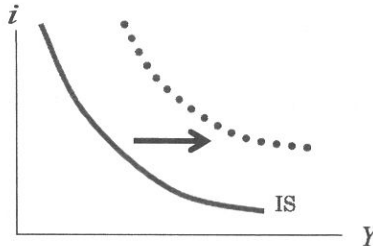
3. The market of goods & services

The equilibrium in the market of goods and services occurs when total supply equalizes total demand. Total supply is the addition of the GDP and total imports. The volume of the GDP is measured by equation (16). Because IM from equation (16) is the volume of imports of a different composition of goods than the GDP, we multiply by the real exchange rate $e = E \times P_{im}^w \div P$ to homogenize units. Then, the total volume of imports expressed in units of local production will be $e \times IM$. The volume of total demand will be the addition of total consumption (equation (9)), total government expenditures G (which includes investment in public infrastructure) total private investment (equation (19)) and total exports: $X \times E \div P$ where X is the value of exports expressed in foreign currency (equation (23)), E is the nominal exchange rate and P is the price level.

$$Y + e IM(Y, E, P) = C(Y, i) + I(r_E) + G + \frac{E}{P} X(E, P) \quad (27)$$

For simplicity we have dropped the subscript “t” which indicates the year being considered, but the above equation is valid for any period. Equation (27) represents the equilibrium in the market of goods, and can be interpreted as the IS curve. Private investment depends on the expected real interest rate r_E , but as the difference between the nominal interest rate and the real interest rate is π_E , the expected inflation rate ($i - r_E = \pi_E$), the IS curve can be represented by a graph taking the nominal interest rate in the vertical axis and the GDP in the horizontal axis as in Figure 1.

Figure1: the IS curve represents the equilibrium in the market of goods and services.



The IS curve shifts to the right in the following cases: 1) An expansionary fiscal policy (increase in government spending: $G \uparrow$, increase in subsidies or reduction in taxes: $T \downarrow$). 2) An increase in the value of assets: $A \uparrow$. 3) An increase in the expected inflation rate: $\pi^e \uparrow$. 4) An increase in the expected profit rate of the local enterprise relative to the profit rate of the rest of the world: $\rho - \rho_w^e \uparrow$. 5) A real depreciation of the currency $e \uparrow$. 6) An increase in the demand of local products from the rest of the world $Y_w \uparrow$. The IS curve shifts to the left in the opposite cases.

4. Money Market

Economic agents will hold money either to make transactions on goods and services or for speculative motive, to avoid losses on asset holding. The transaction motive indicates that the demand for money is an increasing function of the volume of transactions measured by the GDP and the price level. The amount of money held for speculative motive is a decreasing function of the interest rate, because the interest rate and the value of assets like bonds, stocks and real estate move in opposite directions. A low interest rate today means that there may be a high number of investors who believe the interest rate may increase in the near future. As a precaution to avoid capital losses more and more investors will start selling their assets and hold money.

The mathematical representation of the real demand form money, L is as follows

$$L = \frac{Y^{k_1}}{i^{k_2}} \quad (28)$$

Here, Y is the real GDP and i is the nominal interest rate. k_1 and k_2 are positive parameters. The nominal demand for money can be obtained multiplying the real demand by the price level: $P L$.

The BOJ has the monopoly of issuing money and H represents the monetary base. As private banks lend and receive deposits, the total amount of money circulating in the economy M is larger than the monetary base by k -times, the multiplier of money, which is computed as $k = (1 + cd) \div (cd + res)$ where cd stands for the ratio cash to deposits held by the public, and res is the

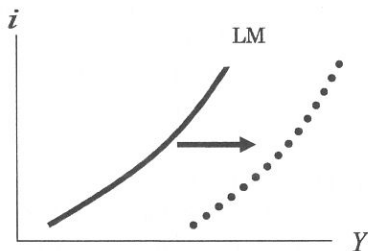
reserve ratio (legal and technical reserve).

$$M = k H \quad (29)$$

The equilibrium condition in the money market (equation (30)), is the LM curve.

$$\frac{M}{P} = \frac{Y^k}{i^k} \quad (30)$$

Figure 2: The LM curve represents the equilibrium in the money market.



The LM curve shifts to the right when: 1) the BOJ implements an expansionary monetary policy inducing an increase in the monetary base; 2) the price level falls $P \downarrow$ and 3) the BOJ reduces the legal reserve rate or private banks reduce their technical reserves: $res \downarrow$. 4) the ratio cash holdings to deposits falls: $cd \downarrow$. The LM curve shifts to the left in the opposite cases.

5. Foreign Exchange Market

The Balance of Payments (BP) includes all the transactions of the country with the rest of the world. Expressed in JPY, the BP equation is as follows

$$Trade\ balance + IFA + F = 0 \quad (31)$$

$$Trade\ balance = Exports - Imports$$

IFA stands for the net income from the total holding of foreign assets and F

is the measure of capital flow. $F > 0$ ($F < 0$) indicates an inflow (outflow) of capital to (from) Japan. As equation (32) indicates, F includes three components, 1) financial investment in assets, which will be denoted by FI , like bonds, stocks, deposits, etc., 2) direct investment which include factories, buildings, land, etc., which will be denoted by DI and 3) the change in international reserves by the government of Japan.

Financial investment FI depends on the difference in the interest rate, the difference in the risk rate and the expected devaluation rate. When the interest rate in other countries, i^w increases relative to the interest rate in Japan i , outflows of capital will increase and then $FI < 0$. A similar effect can be observed if the risk rate in Japan, σ increases with respect to the risk rate of the rest of the world σ_w . Also, when the value of the currency of a certain country is high, and it is expected to depreciate in the future, investors will be prone to send their money to countries with higher return.

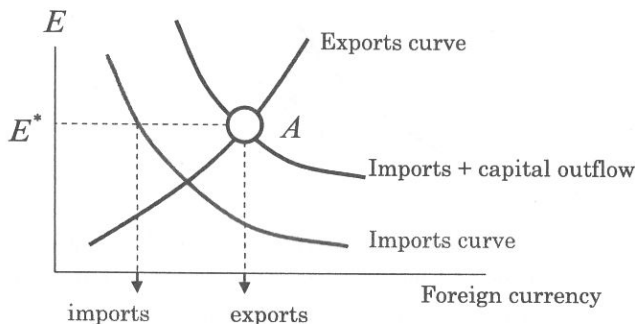
Foreign direct investment DI depends on the long term expected profits rates. For example, if the profit rate in the rest of the world is rising faster ρ^E than the profit rate in Japan ρ , investors will tend to open factories in other countries.

$$F = FI(i^w - i + \sigma_w - \sigma) + DI(\rho^E, \rho_w^E) - \Delta \text{Reserves} \quad (32)$$

Finally, " $\Delta \text{Reserves}$ " represents the change in the foreign reserves owned by the Japanese authorities. If for example the BOJ or the Ministry of Finance decides to intervene in the foreign exchange market to avoid undesirable speculative yen appreciation, it will purchase foreign currency. ($\Delta \text{Reserves} > 0$).

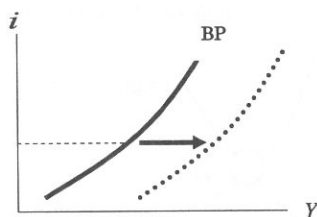
The market of foreign currency can be represented by a graph where demand and supply of currency intersect at the equilibrium like point A in the graph below. The vertical axis represents the nominal exchange rate, and the horizontal axis the volume of foreign currency being traded.

Figure 3: the equilibrium in the foreign exchange rate market is given by the intersection point between exports curve and the curve of imports + capital outflow



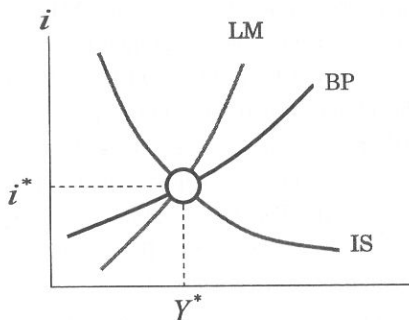
The above graph is intuitively interesting because it can be used to predict changes in the nominal interest rate. However, to analyze the macroeconomic general equilibrium, there is a more useful graphical representation of the BP equation like in Figure 4. The BP is represented as function of the interest rate and the GDP. The graph is increasing because for all the other variables constant, when the GDP rises, imports rises too and there will be a deficit in the trade balance. Equilibrium requires a higher national interest rate to produce an inflow of capital $F > 0$. The BP equation shifts to the right when for example there is a real depreciation of the JPY. This is because for a constant level of Japan's nominal interest rate, a higher real exchange rate will make exports rise and imports falls boosting the GDP. Real depreciations of the JPY may occur when there is an outflow of capital induced by for example, 1) the international interest rate rises, 2) the economic agents expect a higher devaluation rate or 3) when the profit rate in other countries rises, 4) the price level of Japans falls.

Figure 4: The BP curve represents the equilibrium in the foreign exchange market. When a real depreciation occurs, the BP curve shift to the right



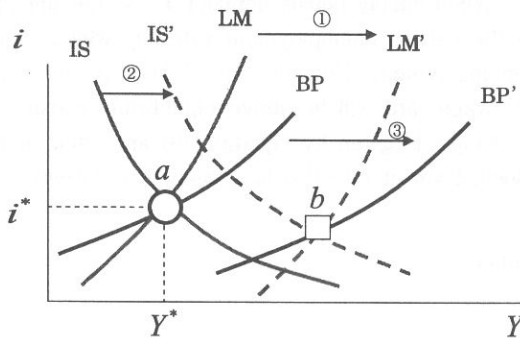
The simultaneous equilibrium in the market of goods & services, the money market and the foreign exchange market can be represented by the IS-LM-BP diagram, which shows the equilibrium of the interest rate and the GDP

Figure 5: The IS-LM-BP diagram



In the figure below we show the effects of an expansionary monetary policy as predicted by the traditional Mundell-Fleming model. Imagine the initial equilibrium is at point “a”. As the money supply increases, ① the LM curve shifts to the right, the interest rate falls, causing an outflow of capital. As the JPY depreciates exports will increase. This means ② the IS curve shifts to the right. Simultaneously, ③ the outflow of capital will make the BP curve shift the right. The final equilibrium would be in point “b”, with a higher volume of production and a lower interest rate.

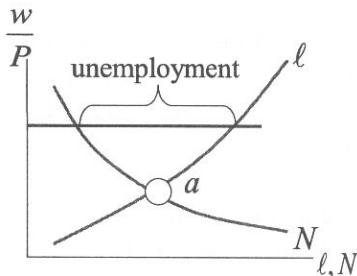
Figure 6: An expansionary monetary policy



6. Labor Market

Figure 7 represent the labor market. Labor demand is a decreasing function of the real wage rate and supply is an increasing function of the real wage rate. If the wage rate was flexible enough, the labor market would be at equilibrium (point a of the graph below) and the unemployment rate would be equal to the natural rate of unemployment. However, in general the labor market will be at disequilibrium because the real wage rate does not adjust instantaneously. We assume that labor contracts are not flexible enough and the nominal wage adjustment depends on the relative bargaining power of labor unions and enterprises in a way we will describe in the following chapter.

Figure 7: Unemployment occurs because labor contracts are not flexible



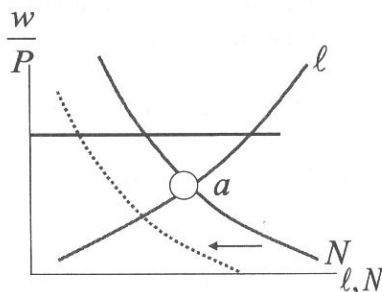
Unemployment is measured by the difference between the labor supply ℓ and labor demand N . When supply equals demand $\ell = N$ the unemployment rate will be equal to the natural unemployment rate, u_N which includes frictional and structural unemployment. However, as showed in the Figure above, in general, the real wage rate will be above equilibrium causing higher unemployment. Labor supply is given by equation (6) and labor demand by equation (15). The unemployment rate (%) is computed as follows

$$u = \frac{\ell - N}{\ell} 100 + u_N \quad (33)$$

If the TFR falls, the labor force will also reduce after 15 years. This is represented by a shift to the left of the supply curve. On the other hand, an increase in the retirement age or also an increase of the number of housewives willing to work may compensate this shrinking of the labor force.

Figure 8: a fall in capital stock or a disruption in the circulation of goods or increased cost of energy makes the demand or labor shift to the left.

As the real wage rate is rigid, unemployment rises.



We think that the March 11th disaster may have shifted the demand curve to the left because the destruction in public and private infrastructure reduced the stock of capital K , and λ must have reduced because of the supply chain and supply of energy disruptions.

Labor unions and enterprises negotiate wages every year and the resultant wage changes, are the result of their relative bargaining power. First of all, enterprises would be willing to pass to wages part of the productivity gains

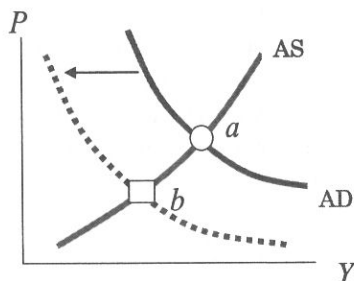
due to technological change and innovation specially when profits are improving and prospects for the economy are good. Labor unions are seen as the guardians of workers purchasing power of wages and jobs security. Their bargaining power is higher when the economy is doing well and unemployment rate is low. On the contrary, when there is recession and the unemployment rises, labor unions will not pressure for higher wages to avoid layoffs. When there is deflation and the unemployment rate is high, labor unions will be less reluctant to accept wage cuts, although usually less proportional than the deflation rate. The nominal wage rate w is the average wage which includes the basic wage and all other benefits including overtime pay, and the prorated bonus. Though the basic wage is quite sticky, the bonus component can be adjusted depending on the profits of the company what makes the average wage rate less sticky. For the above reasons, wages are somehow sticky when adjustment is downwards, but not completely so.

$$\frac{\Delta w}{w} = f \left(\text{technological change}, u^-, u_n^+, \pi^+, \frac{\Delta \text{Profit}}{\text{Profit}} \right) \quad (34)$$

7. The AD and the AS curves

The Aggregate Supply (AS) and Aggregate Demand (AD) curves give us a simple way to explain how the price level and the level of production are determined each year. The AS curve is the locus of price and GDP levels that maximizes profits of the enterprises, compatible with the nominal wage rate set by the negotiations between firms and workers. The AD curve represents the simultaneous equilibrium of the market of goods and services and the money market. In the figure below we represent the graph of the AS and AD curves as functions of the price level and the real GDP, assuming the other variables as given.

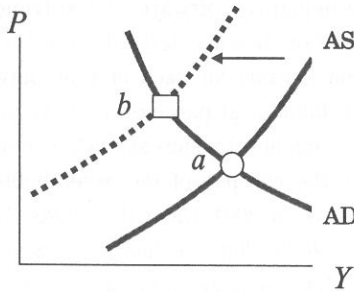
Figure 9: The equilibrium of the price level and the GDP (point a) may change if for example a recession in the rest of the world reduce exports. This makes the AD curve shift to the left pushing Japan fall into recession (point b)



The AS and the AD curve may shift either to the right or the left according to several factors. For example, the AD curve will shift to the right when 1) the global economy expands and exports growth. 2) the real interest rate falls, or if future expectations of growth improve, boosting investment, 3) expansionary monetary or fiscal policies are applied. On the contrary, factors like for example a retraction in the world economy, a deterioration in the future expectations about growth, a tightening in the fiscal or monetary policy will shift the AD curve to the left.

The AS curve shifts depending basically on factors related to the labor market. For example, when enterprises expand their capital utilization, and introduce new technologies, the labor demand curve will shift to the right. If the real wages remain at similar levels, the level of employment will rise and the AS curve will be shifting to the right. When unemployment is above the natural rate of unemployment, shifts in the labor supply do not affect immediately the AS curve. However, it may have an indirect effect because for example when the labor force shrinks, the bargaining power of workers increases. If the real wage rate rises fast, the AS may shift to the left. As explained before, the March 11th disaster may have shifted the demand for labor curve to the left thus, shifting the AS curve to the left too.

Figure10: The earthquake and tsunami that occurred in March 11th 2011 might have shifted the AS curve to the left.



8. Estimation of parameters and exogenous variables

8.1. Production function

The technology of production was estimated conditioned to be a constant return to scale Cobb-Douglas type function as indicated by equation (11). Q is the value of production defined from $Y = \mu Q$ where $\mu = 1 - em$. N is the amount of hours of labor (in trillions) and K is the volume of assets (real fixed capital) effectively used in the production process both variables estimated using the National Account statistics. There are no statistics available about the technological λ , but several estimations show technological progress rate χ may be between 1.0% ~ 1.5% per year. This rate is consistent with the average technological rate that can be estimated as the total factor productivity (TFP), which is the residual that can be obtained from the growth in the per capita GDP minus the per capita capital stock multiplied by the proportion of profits to the total GDP. To allow for different external shocks we generated a series of random infinitesimal numbers fluctuating around $\chi = 0.013$ and computed

$$\lambda = \lambda_0 (1 + \chi + random)^t \quad (35)$$

Where $-0.001 < random < 0.001$ represents a series of infinitesimal random either positive or negative shocks. The exponent t indicates “time” to make

technological progress accumulative. Then, the parameter α and λ_0 were estimated using calibrating method instead of the OLS. This calibration was performed using the Mathematica software and solving the system of two equations formed by the labor demand derived from the profit maximization problem and the production function for each of year between 1981 and 2010. As observed, the two technological parameters have been falling in in the observed period, with a tendency to increase when negative shocks to the economy occur, like after the collapse of the asset bubble in1990, when the Asian crisis occurred in 1998, in 2001 when the United States fell into recession, and finally in 2008 ~ 2009 after the financial crisis. The analysis of this pattern of “technological shift” is quite interesting and we would need much more detailed information to explain it more precisely. As this would exceed the scope of this paper, we leave it for future research. Finally we adopted the $\alpha = 0.55$ and $\lambda_0 = 58.5$ which are the ones which allowed us to reproduce better the general equilibrium of the economy for the year 2010.

8.2. Investment function

Besides, the numerator “Profits” can be specified as a certain coefficient a of the level of expected real profits Π_t that can be generated from the existing capital.

$$I_t = \frac{a \Pi_t}{r_E + \sigma_E - g_E} - \xi(1 - \theta) K_t \quad (36)$$

According to our estimations using data for the last 30 years, the values of the tow parameter consistent with the available data $a = 1.95$ and $\xi = 0.1$. The level of capital utilization was set to $\theta = 0.9$ which corresponds to the observed data for 2010 from the Ministry of Industry. Data on investment I_t , profits Π_t and private fixed capital K_t were estimated using the National Accounts.

r_E, σ_E, g_E are not observed, but information was generated using the moving historical average. This is the historical average adjusting partially according to the recent trend.

For example r_E can be generated from the following expression

$$r_E = \sum_{t=n}^t \varphi_i r_i + \Gamma \left(r_t - \sum_{t=n}^t r_i \right) \quad (37)$$

In period, “t”, the component $\sum_{t=n}^t \varphi_i r_i$ is the historical weighted average of the real interest rate observed in the past (r_i) using φ_i as weight parameters where $\varphi_i < \varphi_{i+1}$ for any i until some definite past $t-i$ years before (in our sample data from 1980). Then, $0 < \Gamma < 1$ indicates that the adjustment to the observed real interest rate of the year “t”, r_t is only partial. The real interest rate is computed from the formula below:

$$r_t = \frac{i_t - \pi_t}{1 + \pi_t} \quad (38)$$

Where i_t is the nominal interest rate on loans and π_t the inflation rate from the GDP deflator. The coefficient of adjustment which allowed us reproduce the available data is $\Gamma = 0.01$. A similar computations was performed for g_E , using the real growth rate g_t of the economy as an indicator for the potential of the growth on profits.

$$g_E = \sum_{t=n}^t \varphi_i g_i + \Gamma_g \left(g_t - \sum_{t=n}^t g_i \right) \quad (39)$$

The adjustment coefficient is slightly higher than in the case of the interest rate, $\Gamma_g = 0.05$. The variable σ_E which represents risk is more problematic because there is no proxy for it. However, for the model to be consistent with the observed data, we require $r_E + \sigma_E - g_E \geq 0$ in general, the risk of investment in capital assets should surpass the risk of financial investment in secure government bonds (σ_{fin}). We generated hypothetical values for the risk rate using the following setting.

$$\sigma_i = g_i + \sigma_{fin} + random \quad (40)$$

Where $-0.001 < random < 0.001$ represents a series of infinitesimal random either positive or negative shocks. The risk of investment is $\sigma_{fin} \rightarrow 2\% \sim 3\%$

which corresponds to the bonds of the Japanese government. Therefore, the risk of productive investment is very close to 5%.

8.3. Consumption function of the working and retired household

The consumption function, equation (4) and the labor supply, equation (6) include several parameters that were estimated. ρ, ε are the parameters to be estimated. $T, n, A_0, \tau_0, w_0, \eta_0, Tr_0, g_s, r_E$ are exogenous variables in the benchmark year 2010 but their values will be recomputed each year. ℓ_t is an endogenous variable in the benchmark year. All these variables have been already defined in the section in which the behavior of the household was introduced. Then, next we explain how all the variables and parameters were estimated.

First of all, let us explain values of the exogenous variables. As life expectancy in Japan is 82.6 and the average working household is 40 years old, the working household will live $T = 83 - 40 = 43$ more years. As the retirement age is 65, then, total remaining working years are $n = 65 - 40 = 25$. The average life expectancy is assumed to continue rising, according to the recent trend of an average 0.24 per year.

B_0 includes A_0 , the net assets owned in 2010 (including net bequests), the net present value of all transfers during the working age and all expected net income during the retirement age. $B_0 = 4,009$ trillion yens, which includes,

$A_0 = 2008$ trillions, $\sum_0^n \frac{Tr_t}{(1+r_E)^t} = 1247$ and $\sum_{n+1}^T \frac{\eta_t}{(1+r_E)^t} = 754$ trillion yens. Here,

A_0 stands for the net assets the working household expects to dispose in its own lifespan and includes the value of all fixed and financial assets owned by the household. Data of the net assets of the households can be estimated from the National Account Statistics and also using the Household Survey (Kake Chousa) to distinguish the net assets of the younger working household from the older retired households. Each year the value of A_t is recalculated adding the total saving of that period. Similarly, as

The wage rate, w_0 represents the average income per hour worked, including all benefits. In the benchmark year $w_0 = 2,550$ yens/hour. This value can be estimated using the data from the National Accounts. τ_t is the total taxes on

labor income (social security premiums t_i^p , income tax and inhabitant tax t_i).

As it has been defined in section 2.1, $\tau_i = 1 - (1 - t_i)(1 - t_i^p)$ we explain this variable when we present the variables of the government in a following section.

g_s , the average annual rate at which workers expect their wage rate to increase in the future, is not observable but it can be inferred when the general equilibrium model is calibrated for the benchmark year. As we have obtained, $g_s = 1.6\%$ a slightly lower than the expected growth rate of the economy which is close to 2%.

r_E , the permanent expected interest rate is the average rate the household uses to make its intertemporal decisions. It will differ from the real interest rate in each period because individuals do not expect the present economic conditions to remain constant in their future life. Although the observed average real interest rate in the last 15 years is 1.7% slightly lower than the potential growth rate of the economy which is close to 2%, we have set r_E equal to 2% in the benchmark year 2010. We also assume that the household adjusts every year its expectations about the real interest rate according to the changes observed in the economy. More precisely, the permanent interest rate in the next period $r_E|_{t+1}$ rate in according to the changes in the observed real interest rate during that period according to the following equation

$$r_E|_{t+1} = r_E + \Gamma(r_t - r_E) \quad \text{where } \Gamma = 0.02 \quad (41)$$

The intertemporal discount rates can be estimated using the first order condition for utility maximization. This shows the relation between consumption between two consecutive periods, the intertemporal discount rate and the permanent real interest rate, according to the optimization problem of the household.

$$\frac{(1+t_c^{t+1})P_{t+1}C_{t+1}}{(1+t_c^t)P_tC_t} = \frac{1+r_E}{1+\rho} \quad (42)$$

The above relation says that the ratio of the total value of consumption of

the household in two consecutive periods, should be equal to $\frac{1+r_E}{1+\rho}$. Then, ρ can be estimated using data about the per capita consumption and the real interest rate. Using information for the last 10 years, we found that the intertemporal discount rate is close to 1.5%. However, using data from the Kokumin Seikatsu Kiso Chousa the rate is much higher for the older households. This indicates that the household tends to reduce consumption as it grows older. According to the cross section estimations $\rho = 0.013$ (1.3%) for the working household (below 65 years old) and $\rho_p = 0.037$ (3.7%) for the older (above 65 years old).

The leisure parameter ε which represents the value of leisure compared to the value of consumption can also be estimated from using the first order condition for the optimization of the utility of the household, what says that

$$\varepsilon(1+t_c')P_t C_t = w_t \ell_t (1-\tau_t) \quad (43)$$

Using data for the last 17 years, we found that the average value is 3.4. However, we set $\varepsilon = 4$ what allowed us represent better the general equilibrium.

Workers may expect wages will rise if inflation is going up and if the economy expands. In general, we can assume that workers think they can achieve keep future wages very close to level achieve that year, then, $w_E = w_t$, where the subscript "t" indicates, time. As wages are being adjusted each year according to the wage negotiations with the enterprises, expected wages will be corrected accordingly.

Φ_w and Ψ_w have been defined as functions of the parameters and endogenous and exogenous variables in equations (5). Their values change along the path depending on the life expectancy, the number of years the household works, the expected real exchange rate and the expected average growth rate of wages: $T, n, r_E g_x$ respectively. For example, as we found for the benchmark year 2010, $\Phi_w \square 32$ and $\Psi_w \square 23$

8.4. Export function

The three parameters of the export function (equation (23)), are n_0 , n_1 and n_2 . These parameters were estimated applying the Ordinary Least Square method using 20 years data (1997 ~ 2010) to linearized function

$$\ln X = \ln n_0 + n_1 \ln Y_w + n_2 \ln e_x \quad (44)$$

Data about X , the value of exports measured in foreign currency, can be obtained from the database of the National Account of Japan of the Economic and Social Research Institute of the Cabinet Office. Y_w is the GDP of the rest of the world (total world minus Japan's GDP) measured in international dollars (purchasing power parity) according to the International Monetary Fund, World Economic Outlook Database. e_x is the effective real exchange rate of export products according to the Bank of Japan. The estimations obtained were highly significant (95%) with the student coefficients and the correlation coefficient as below

$$(n_0, n_1, n_2) = (0.05, 0.655, 0.55) \quad (45)$$

$$\text{with } t_{\text{student}} = (6, 41, 5.55, 2.05) \quad \text{and} \quad R^2 = 0.95$$

8.5. Import function

There are three parameters related to the import function (equation (26)): m , m_0 and η . The parameter m is the imported raw materials to total value of production ratio and was estimated calibrating its value using the complete model. The value obtained was $m = 0.078$ which is very close to the average for the last 10 years (0.07). The parameters m_0 and η were estimated by OLS method.

The variable IM represents the total volume of imports (real value of imports) and Y is volume of GDP (real value of imports) and m the ratio of imported raw materials to total value of production. The values of these three variables are available in the database of the National Account of Japan of the Economic and Social Research Institute of the Cabinet Office.

The effective real exchange rate of import products is computed as $e = \frac{EP_{im}^w}{P}$.

The numerator was estimated using the average prices of imported goods expressed in yens from the database of the Bank of Japan, and the denominator, P is the GDP deflator index according the National Accounts Database.

The estimation of the parameters of the import function was performed using the OLS method to the linearization of the import equation using annual data for a longer period than for the export function, we used data from 1980 ~ 2010. The estimated parameters are also significant at a 95% level.

$$(\eta, m_0) = (0.456, 0.16) \quad (46)$$

$$\text{with } t_{student} = (10.928, 52.985) \text{ and } R^2 = 0.90$$

8.6. International flow of capital

With respect to the allocation of wealth between the country and the rest of the world, the behavior of the Japanese companies and investors is different from foreign companies and investors we have made the simplified assumption of the existence of “one investor” who is in charge of taking all the decisions about international financial flows and foreign direct investment.

The variables FI and FD of equation (32) are the annual flow of financial and direct investment capital respectively. As our empirical analysis reveal us, the decision making about the portfolio allocation it is better “explained” or fitted by a decision making about the stock of both components rather than the flow, that is the total flow of financial investment, TFI and the total direct investment, TDI . Then we define the flow as the difference between stock in two consecutive periods

$$FI_t = TFI_t - TFI_{t-1} \quad \text{and} \quad FD_t = TDI_t - TDI_{t-1} \quad (47)$$

We have specified a linear function for both components TFI and TDI as follows.

$$TFI = z_0 TNFI + z_1 (i^w - i + \sigma - \sigma_w) \quad \text{with } z_0, z_1 > 0 \quad (48)$$

$$TDI = d_0 Assets + d_1 (\rho_w^E - \rho^E) \quad \text{with } d_0, d_1 > 0$$

According to our empirical analysis, the flow of financial capital depends on two components. The first component indicates that new financial investment abroad will increase proportionally (coefficient z_0) to the stock of financial net assets abroad, $TNFI$. This may be because investors diversify their portfolio and they keep a certain proportion in the local economy on other proportion on the foreign markets. Besides, they will increase their portfolio abroad when the profit rate in the foreign markets is higher than in Japan. We measure this profitability difference by taking the difference in the interest rates net of risk rates: $i^w - i + \sigma - \sigma_w$. Using data from 1996 to 2009, and applying OLS estimation method we obtain the following estimations.

$$(z_0, z_1) = (0.16, 15.4) \quad (49)$$

$$\text{with } t_{student} = (1.189, 2.258) \quad \text{and } R^2 = 0.9752$$

The total direct investment abroad also on two components, on the total existent capital, represented by the variable “*Assets*” in the equation, and a second component, the profit rate of direct investment $\rho_w^E - \rho^E$, where ρ_w^E is the expected profit rate on production activities in the rest of the world, and ρ^E is the expected profit rate in the productive activities in Japan. The estimated coefficients are as follows.

$$(d_0, d_1) = (0.008, 5.25) \quad (50)$$

$$\text{with } t_{student} = (2.719, 2.671) \quad \text{and } R^2 = 0.9697$$

Data respect to inflows and outflows of capital and the stock of assets of Japan in the rest of the world as well and of the rest of the world in Japan can be obtained from the Japan’s Balance of Payment Statistics (historical data) of the Ministry of Finance. International interest rates and interest rates in Japan can be obtained from the central banks database systems.

8.7. Total Fertility Rate function

The equation of the TFR is a linear function has two parameters f_0 and f_1 which we have estimated using OLS using data for the period 1990 to 2010.

$$TFR = f_0(1 + \text{wage change rate}) - f_1(1 + \Delta \text{education costs}) \quad (51)$$

Long term data on the TFR is from the Survey on Population Dynamics of the Ministry of Health, Labor and Welfare. The “wage change rate” is the annual change rate of the real wage rate which we have estimated using the information provided by e-Stat of the Monthly Survey on wages and hours worked (“Maitsuki Kinrou Chosa”) performed by the Ministry of Welfare and Labor. The “education cost change” is the annual change rate of the ratio education costs to the consumer price index. Therefore represents the “real” change rate of the costs of education. The information about costs of education used is the price index of education included in the consumer price index. The information about the consumer price index can also be obtained from e-Stat. The estimated parameters are highly significant at a 95% level.

$$(f_0, f_1) = (2.63, 1.28) \quad (52)$$

$$\text{with } t_{\text{student}} = (10.37, 4.92) \text{ and } R^2 = 0.9999$$

8.8. Demand for money

The parameters of the real demand for money, k_1, k_2 (equation (30)) were estimated using the OLS method using data from 1980 to 2009. The estimated values are highly significant at a 95% level:

$$(k_1, k_2) = (1.06, 0.423) \quad (53)$$

$$\text{with } t_{\text{student}} = (363.5, 5.7866) \text{ and } R^2 = 0.9999$$

8.9. Wage adjustment

The nominal wage rate is adjusted every year according to the wage negotiations explained in section 6. We specified the following linear function to compute the annual change rate in nominal wages.

$$\frac{\Delta w_t}{w} = \omega_0 \chi + \omega_1 \text{sticky} \pi_{t-1} + \omega_2 (u_{t-1} - u_N) + \omega_3 \left(\frac{Inv_{t-1}}{Inv_{t-2}} - 1 \right) \quad (54)$$

Wages adjust upwards with technological change, χ , with inflation π_{t-1} and with the increase in the volume of investment $Inv_{t-1} \div Inv_{t-2} - 1$ of the previous year. On the other hand wages will tend to fall when the unemployment rate u_t is above the natural rate of unemployment u_N . Our estimations confirmed the direction of the effects of these variables and results of the OLS method estimation are as follows.

$$(\omega_0, \omega_1, \omega_2, \omega_3) = (0.4, 1.296, -0.81, 5.1) \quad (55)$$

$$\text{with } t_{\text{student}} = (1.55, 6.21, -4.47, 2.565) \quad \text{and } R^2 = 0.9642$$

“sticky” is a dummy variable which is $\text{sticky} = 0.1$ when $\pi_{t-1} < 0$ and $\text{sticky} = 0.4$ when $\pi_{t-1} > 0$. This indicate that wages are downward sticky: when inflation is negative wages tend to fall but not that much; when inflation is positive, wages adjust upward quicker than when inflation is negative.

Data about the inflation rate π_t was estimated using the Consumer Price Index, Ministry of Internal Affairs and Communications, Statistics Bureau. The unemployment rate u_t comes from the Survey on Labor Force of the same source. The nominal wage rate was computed from the National Account Statistics. The variable Inv_t is a proxy for the level of profits companies expand equipment and machinery when profits are rising.

8.10. Tax rates and government expenditure

In this section we summarize the exogenous variables related to the general government, that is tax rates, expenditures, investment, social security expenses, debt, etc.. The data used in the simulations corresponds to the year 2010 and a summary of the values used are as follows.

a) Tax rates:

Consumption tax rate = 5% (only 72% of consumption is taxed)

Other taxes levied on consumption (tobacco, alcohol, gasoline, etc.) = 3.4%

Social security contributions rate = 26%

Income tax rate = 14.4% (average income tax rate = 4.4%, inhabitant tax rate = 10% with 80% of income as taxable)

Corporate tax rate = 33% (50% of total profits are deductibles)

Asset tax rate = 0.5%

Inheritance tax rate = 60%

Import tariff = 7%

Tax rates were obtained from the information about tax collection from (Tax System and Financial Situation of the Government) the Ministry of Finance of Japan and the National Tax Agency (Tax Collection Database) and the National Account Statistics.

b) Government expenditures:

Consumption of the government = ¥42 trillion.

Investment of the government = ¥16 trillion.

Subsidies to enterprises = 3.7 trillion yens

Unemployment benefits = 12% of the non-received waged by the unemployed.

Pensions = ¥50 trillion.

Health transfers = 86% of total health consumption of the nation (¥40 trillion \times 0.86)

Care of the elderly = ¥6.5 trillion.

Child support = ¥13000 per month per child below 15 years old.

Cost of free high school program = ¥0.4 trillion

Other transfers to the household and welfare costs = ¥32 trillion

Information on the government expenditures can be found on the National Account Statistics.

In our simulations, all expenditures are adjusted by inflation of the period.

c) Debt of the Government

Gross debt of the government = ¥1120 trillion

Net debt of the government = ¥576 trillion.

Holding of the debt by the Bank of Japan = 7%

Holding of the debt by foreign investors = 5%

Holding of the debt by national investors = 88%

Long term debt = 80% (maturity 2 or more years later)

Average interest rate of the debt of the government = 0.7%.

Foreign Assets of the Government = 1.1 trillion USD.

Depreciation rate of the fixed assets of the government = 4.5%.

Information on the debt of the government was obtained from the Ministry of Finance of Japan (Tax System and Financial Situation of the Government). The depreciation rate of the fixed assets of the government can be computed from the National Account.

d) Bank of Japan

The central bank of Japan, the Bank of Japan controls the monetary base through the open market operations (purchases of assets like bonds and commercial paper in the secondary market) and also fixes the deposit requirement rate and the discount rate.

Monetary base = ¥100 trillion.

Discount rate = 0.3%

Average deposit requirement ratio = 0.8%

Target inflation rate = 2%

The deposit requirement ratio in Japan is 0.8% but the technical or voluntary reserves held by banks is higher and close to 4%.

e) Rest of the world

The exogenous variables related to the rest of the world are the following.

- 1) GDP of the rest of the world at Purchasing Power Parity (PPP) in 2010 = \$70 trillion

Data source: IMF, World Economic Outlook Database

- 2) World Population growth rate = 1%

World Population growth rate change = - 0.1%

Data source: World Population Prospects of the United Nations

- 3) International prices index of imported goods in USD = 0.02

International price of exported goods in USD = 0.012

Data source: BOJ

- 4) international interest rates: 5.7% (computed on USD)

Data source: Central Banks of several countries.

The international interest rate is financial profit rate on a basket of the main destinations of the Japanese investment abroad (United States, Europe, United Kingdom, China, Singapore, Singapore, Australia Thailand, etc.). Interest rates and exchange rates were obtained from the database of the central bank of each country. The profit rate is higher than the basket of the interest rates because of the higher returns of investment in stocks and bonds which is higher than the deposits rates.

- 5) Total foreign financial private net assets and direct investment: stock of private direct investment: ¥50 trillion, stock of financial private net assets: ¥120 trillion.

Data source: JETRO, Database

f) Assumptions and estimation results of the parameters of the model

In this section we present our estimation for the values of the parameters before the disaster of March 11th. In a later chapter we explain how the values changed because of the earthquake.

1) Technological change: χ

According to Pietro, et al (2009) the average total factor productivity in Japan during 1981 ~ 2004 was 1.8% per year for tradable sector, and 1.7% for non-tradable sector of production. Our calculations using data between 1980 and 2010 are consistent with those estimations: TFP for the whole economy must have been between 1% to 1.5% but closer to 1.0% in 2010, our benchmark year. In the future, this benchmark rate of technological progress is assumed to rise further or slow down depending on the materialized achievements of recent innovation which in turn depends on the general economic conditions and the capacity of companies to generate profits. As we have estimated, the technological change rate depends on the change rate in profits in the most recent past, following the equation below

$$\chi = 1.0\% + 0.13 \frac{\Delta \Pi_t}{\Pi_t} \quad (56)$$

Information about profits and the TFP can be obtained from the National Account Statistics using the growth accounting equation as an hypothesis for the computation. The two coefficients of the above equations were estimated using OLS and are significant at a 95% level with t-student values of 7.66 and 5.349. R2 is 0.81.

2) Expected growth of the Japanese economy

Economic agents expect the economic growth rate to move in a certain interval centered in 2% which is close to the potential growth. One way to obtain this value is to use the growth accounting equation which has been represented below. This equation says that the growth rate of the GPD is addition of three components: 1) technological progress rate (χ), 2) labor input growth $\frac{\Delta N}{N}$ multiplied by the share of salaries on total GDP (α) and 3) the capital accumulation growth rate $\frac{\Delta K}{K}$ multiplied by the share of profits on GDP (β).

$$g_E = \chi + \alpha \frac{\Delta N}{N} + \beta \frac{\Delta K}{K} \quad \text{with } \alpha + \beta = 1 \quad (57)$$

This equation is valid for the economy in the long run, and under the assumption of perfect competition and full employment of resources, but can be used to obtain a benchmark for expectations about the future average growth rate for the long run. As explained in the previous section, $\chi \rightarrow 1\%$. No positive contribution is expected from labor because the labor force is expected to fall with $\frac{\Delta N}{N} \rightarrow -0.3$. Finally, as $\beta = 0.45$ and $\frac{\Delta K}{K} \rightarrow 2.3\%$ the contribution of capital accumulation would be close to 1%. Expected growth would be centered in this potential growth of 2%, but the effective value could be above or below depending on the economic conditions during the cycle. We represent this cycle effect by : $\Delta g_{\text{expected}}$

$$g_E = 2\% + \Delta g_{\text{expected}} \quad (58)$$

The formation of expectations about the change in the growth rate $\Delta g_{\text{expected}}$ is assumed to depend on both supply and demand factors. Supply factors include any change in labor and capital and technology. Demand factors include expected changes in consumption, exports, investment and government expenditures. For example, expected consumption growth $\frac{\Delta C}{C}$ is assumed to depend on the average expected growth of population and salaries. The expected growth in exports $\frac{\Delta EX}{EX}$ depends on the expected growth of the world economy and the expected change in the real exchange rate. Investment growth $\frac{\Delta I}{I}$ is assumed to depend on the increase in profits. Accordingly, the total expansion of the expected growth rate will be the weighted average of growth rates of each component as follows

$$\Delta g_{\text{expected}} = a_c \frac{\Delta C}{C} + a_i \frac{\Delta I}{I} + a_g \frac{\Delta G}{G} + a_{EX} \frac{\Delta EX}{EX} - a_\sigma \frac{\Delta \sigma}{\sigma} + \text{Radom} \quad (59)$$

a_c, a_i, a_g, a_{EX} are the participation of each component of demand (consumption, investment, government expenditures and exports) on the total GDP. Finally,

$\frac{\Delta\sigma}{\sigma}$ is the expected change in the risk rate of the economy, and a_σ is a coefficient which reflects the incidence of risk on growth. $\frac{\Delta C}{C}, \frac{\Delta I}{I}, \frac{\Delta G}{G}, \frac{\Delta EX}{EX}$

were estimated using a adaptive expectation approach, which assumes economic agents use the most recent past information to form their expectations. All the variables of the above equation are generated endogenously, and each year is recomputed to adjust expectations. The variable “*Random*” is an infinitesimal random number $|Random| < 10^{-4}$ which measures a certain set of unpredictable events that may cancel with each other giving a positive or negative very small effect.

3) Risk of investment

The risk involved in investment depends on the capacity of the economy to reproduce and expand in the future. The risk rate is not observable but it can be inferred from the valuation of assets of the nation as the net present value of the future profits. Considering an infinite horizon, the value of assets, V can be estimated as follows

$$V = B_E \frac{1 + g_E}{r_E + \sigma - g_E} \quad (60)$$

Here, B_E is an estimation of the permanent expected profits, g_E is the expected growth of the economy, r_E the expected real interest rate and σ the implicit risk rate. Then we use the information provided by the National Accounts: as December 2009, the total value of fixed assets is ¥2,300 trillion, the value of net profits ¥115 (before paying taxes). As explained in the previous section, the expected growth rate of the economy is close to 2% and a similar value for the real interest rate. Finally, the resultant risk rate is very close to 4.8%. As we explain later, the basic risk rate must have increased because of the disaster.

Some factors would be affecting this benchmark risk rate. For example, in the future we think that the risk rate may increase if the size of the gov-

ernment debt is not contained, relative to the same ratio in other developed countries. The idea behind this hypothesis is that when the government debt grows too much, investors may believe that the government will be in trouble of paying its debt. Investors may stop lending to the government and may send their funds to other countries. Most of lenders to the government are local investors, but there is no reason to believe they will avoid sending their funds to other countries if returns are much higher. One more factor that may increase the risk of investment is the possibility of the formation of future assets bubbles derived from expansionary monetary.

$$\sigma_E = 4.8\% + \gamma_1 \left(\frac{Debt}{GDP} \right)_{Japan} - \frac{Debt}{GDP} \Big|_{Row} \Big) + \gamma_2 bubble \quad (61)$$

$\gamma_1, \gamma_2 > 0$ are small coefficients for which we have made the hypothesis $\gamma_1 = \gamma_2 = 0.1$. We will make the experiment of a sensitivity analysis to observe the stability of the results. The variable *bubble* is measured as the price of assets relative to the GDP deflator. As the real value of assets rises, the risk of asset bubble increases and vice versa.

4) World GDP, international interest rates and international prices.

The growth rate of the world economy GDP (PPP) after 2010 g_t^w is expected to fluctuate 3.8% per year. This value is obtained using the assumptions of the growth accounting equation, by which the growth rate is the addition of technological progress, the contribution of labor expansion and the contribution of capital expansion. The growth rate of the GDP of the rest of the world was specified as a linear equation as follows

$$g_t^w = 3.8 + \Delta g_t^w \quad (62)$$

Δg_t^w is any change in the growth rate due to several reasons. For example, growth may go more rapidly as more advanced technologies are applied, but this may be compensated by a reduction in the population growth rate. Besides, capital accumulation may go faster, but this depends on the international interest rates. Increases in the interest rates may slow down growth. As many several unpredictable changes may occur, we included an infinitesimal random variable to represent it. The potential increase in the growth rate, Δg_t^w

$$\Delta g_t^w = \text{Random} - 0.68\Delta i_{t-1}^w \quad |\text{Random}| < 10^{-4} \quad (63)$$

The world inflation is expected to keep in step with the growth rate and accelerate if the economy growth picks ups.

$$\pi_t^w = 0.6g_t^w + 0.4\Delta g_{t+1}^w \quad (64)$$

The above coefficients were estimated using OLS to data on growth, inflation and interest rates for several countries, with the t-student coefficient significant. Data used corresponds to the database of the IMF and the OECD.

9. Simulations Results

Our simulations work has three objectives. The first objective of task is to use the estimated parameters of the equations of the model to reproduce the equilibrium in the “benchmark year” which is the year 2010. The second task consists in computing what we call the “benchmark path” which is the most probable future path of the Japanese economy under certain assumptions about the international economy and without policy changes by the Japanese authorities. Although very recent, and the available information is insufficient with respect to several issues, we also attempt to have a preliminary assessment of the impact of the March 11th disaster. In the following sections the assumptions and limitations of our simulations will be explained, and results will be presented. All simulations were performed using the Mathematica software and the program can be provided if requested. The third objective is to compare the “benchmark path” (before the disaster) with the expected path after the disaster.

9.1. The equilibrium in 2010

The first important task of the simulations is to reproduce the initial or benchmark equilibrium which corresponds to the year 2010. Although we estimated all parameters using econometric methods applied to independent data, some of them were adjusted and set to reproduce as closest as possible the benchmark equilibrium. The initial price level was set to the unity and the in-

ternational price level of both imported and exported goods were chosen to reproduce consistently the levels of exports and imports in 2010.

Using our model, we compute the equilibrium in 2010, and the values obtained are very close to the really observed values, and we think the suggest that the model could be used to observe the evolution of the economy in the following years and well as to assess the impact of different economic policies. However, more than the absolute value of the different values, the direction of the changes is what matter to us. First of all, we here present a summary of the main macroeconomic variables as we obtained from the computation of the equilibrium. Then we display the path of the economy without any policy changes.

Main endogenous variables according to the model (benchmark 2010):

Inflation rate = -2.1%
 Unemployment rate = 5.0%
 Nominal interest rate = 0.73%
 Real interest rate = 2.9%
 Exchange rate = 1 USD = ¥87.1
 GDP = ¥469 trillion
 Salaries = ¥246 trillion
 Consumption of the Households = ¥338 trillion
 Private Investment = ¥70 trillion
 Exports = ¥73 trillion
 Imports = ¥69 trillion
 Government consumption and investment = ¥57 trillion
 Deficit of the Government = ¥52 trillion (11% of the GDP)

All other variables, like consumption, investment, tax collection, labor supply and demand etc. are available and can be provided if requested. Most variables are quite close to the observed values.

9.2. The before earthquake “benchmark path”

We here describe the results of the simulations of “benchmark path” which is the expected path for the economy in the next 15 year before the March 11th disaster. The first assumption of the computations is that no big disrup-

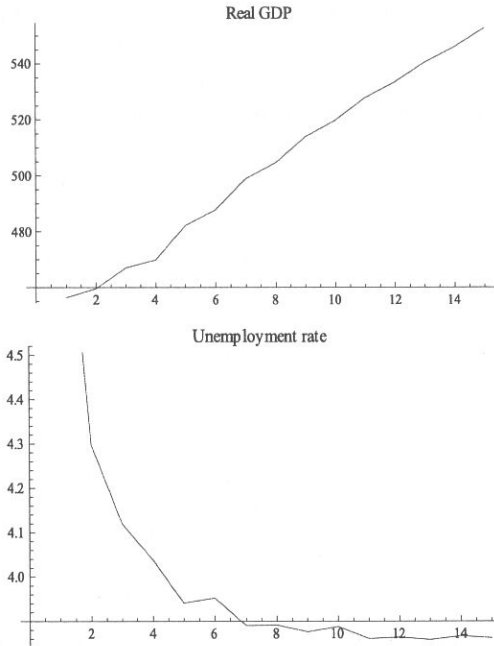
tions in the world economy are expected and with global growth as described before. The second assumption is related to the economic policy in Japan: in the benchmark path, it is assumed that there are no policy changes. This means that the government would keep its tax rates unchanged, and that government expenditure would only be adjusted according to the inflation rate. On the other side, the BOJ would keep its monetary policy unchanged. We also assumed that the hidden interventions on the foreign exchange market by the government would continue as in the past, purchasing foreign currency to avoid sudden appreciations of the yen. Finally, the demographic structure of Japan would follow the patterns described in previous chapters.

In what follows we describe the main results of our simulations, main figures will be display here, but figures with all the rest of the graph have been compiled in the appendices. For each of the following figures, the horizontal axis represents “time”, with the initial point corresponding to the equilibrium in 2010.

What was the most probable scenario for the Japanese economy before the earthquake, the tsunami and the nuclear disaster? First of all, after growing 3.9% in 2010, in the year 2011, we expected the economy to experiment almost zero growth. The main drag on the economy would have been consumption because as most of the economic stimulus (tax credits and subsidies to efficient cars purchases, subsidies to electric appliances purchases) have expired, consumption of the working household was cooling down. As consumption of the retired household is less dependent on the above mentioned consumption subsidies, performance would have been better. However, as the world economy would have allowed for strong growth in exports, the unutilized capital would have fallen fast. Then, companies would have been more willing to invest in new equipment and machinery. The government would have not contributed to the economic growth in 2011.

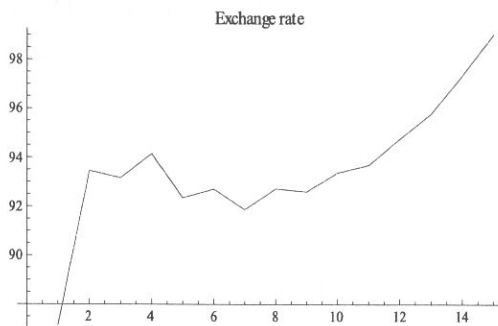
Even in the absence of stimulatory policies, since 2012 the economy would have taken a healthier path with production growing between 2%~1.3%. This would have been achieved supported by all components of private demand: consumption, investment and exports. The unemployment rate will have fallen and approach to the level of the natural rate of unemployment, which is estimated to be close to 3.8%. Though the inflation rate would have return to

positive territory after 5 or 6 years, it would have been lower than the target inflation rate of the BOJ, which at the moment is 2%. The next two graphs represent the expected path for the GDP and the unemployment rate.

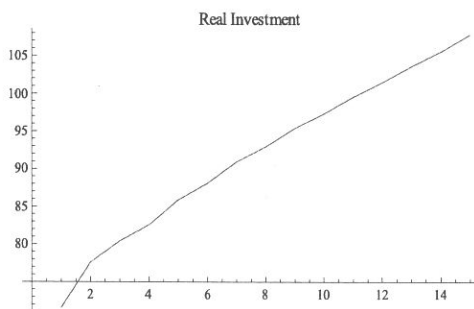


It is interesting that the economy would have managed to grow, even in the context of a shrinking population. First of all, as the world economy expands, international interest rates would have increased above the unusual present low levels. Moreover, as the profit rates in the developing countries and in the United States were expected to improve, the flow of capital to the rest of the world would have increased faster. As investors choose to reallocate their portfolio buying foreign assets, the demand for foreign currency would have probably increased and the yen would have fallen with respect to the main currencies. This, in turn would have helped the export activities. The next figure represents the path of the nominal exchange rate.

The Japanese economy after the March 11th, 2011 disaster

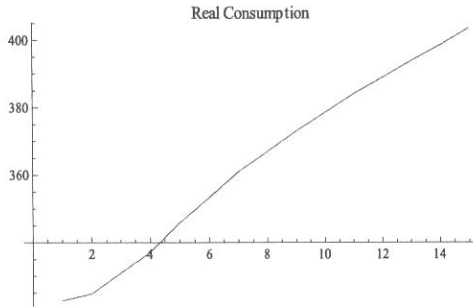


Investment was expected to rise continuously as the unutilized capital stock gradually disappears and as more optimistic enterprises attempt to buy new and more efficient machinery and equipment to increase production either to export or to sell in the domestic market in the future. According to our simulations, as the economy picks up and deflation comes to an end, the real interest rate falls what would have also stimulated the volume of investment. The real interest rate would have fallen from its high initial levels of 2.7% to almost zero and even turn negative later in the cycle. Negative interest rates also constitute an additional stimulus to investment as shown in the following graph.



The simulations results also show that the labor market would have become relative tight because of a falling labor supply and higher labor demand. This would have increased the bargaining power of workers and real wages would have risen too. Besides, the labor demand was expected to be shifting to the right due to technological progress and capital accumulation. All this would

have made the economy approach to full employment. Under the assumption of no tax increases, strong wages will allow consumption growth, even with a falling population.



On the other hand, improvements in the fiscal position of the general government (central government plus, local governments and plus social security) would have become visible as the economic expansion would have brought higher tax collection to the government. The deficit could have fallen even without any tax increases. The ratio deficit/GDP would have fallen continuously too. However, rapid increases in the social security expenditures and growing interest payments, would have not allowed the government achieve a surplus in its accounts in the forecasted period. Therefore, the government net debt would have continued growing in absolute terms.

Even if the economic recovery would have made the TFR rise, it may not have reached the population reposition level 2.1 quick enough to avoid a fall in population, which would have retracted at 0.3% annual rate. By 2025 population would be close to 122 million.

9.3. The Tohoku Kanto earthquake shock

The above predictions for the Japanese economy have to be changes drastically because of the events of March 11th. The magnitude-9 earthquake and the tsunami that triggered ended up in a nuclear meltdown in at least three of the reactors of the Fukushima Dai-Ichi nuclear plant. The disaster will have a significant impact on the Japanese economy, which may not be transitory and will be far beyond the economy of the most affected prefectures of Miyagi,

Iwate and Fukushima. It is difficult to make predictions as at the moment of writing this report only 4 months have passed since the disaster and information is still insufficient. For this reason, predictions should be taken with caution, and more than the precise numerical changes we have computed, we would like to focus on the *direction* the economy take.

Figures comparing the two benchmark path and the path after the earthquake appear in the appendices. Due to space restrictions, we included in the appendices the graphs of only the most important macroeconomic variables, like the GDP, interest rates, inflation rates, wage rates, unemployment, etc. However, more detailed results or results respect to other variables can be provided if requested. In the figures there displayed, the graph with a complete line represents the expected path for each variable before the earthquake. The graph with a dotted line represents the expected path after the earthquake. The starting point corresponds to the economy at the year 2010. First, let us present some genera remarks about how the economy is expected to evolve, then, we will present a more detailed description about how the parameters and exogenous variables have changed because of the disaster.

a) Economic trends of the economy post-disaster.

We expect the economy to contract about 2.3% in at least the first quarters after the disaster, but it will recover in 2012 helped by the reconstruction efforts, the slowly but improving consumer confidence and also supported by the expansion in the world economy. The path for the GDP can be observed in Figure 1 of the appendices. The unemployment rate may rise after the disaster but will fall rapidly later the following year (see figure 2, app). The reduction in the unemployment rate may be the result both supply and demand side factors. First, although our simulations show a sudden increase in the unemployment rate, it may soon fall because of supply side effects. As workers become discouraged from looking for a job, labor supply may fall, which causes a reduction in the unemployment rate. Later, demand of labor would start picking up with the reconstruction efforts. Real wages (figure 3, app, left) would fall but will recover since the second year.

The contraction in the GDP in the following quarters of 2011 will be mainly

the result of a reduction in the volume of consumption (graph 4, app.) and very weak investment (figure 5, app). Even if the world economy continues recovering from the world crisis of 2008, exports growth will have difficulty to keep a positive growth, because of the disruptions that the disaster may generate in the supply chain. The government will compensate the victims of the disaster, and also will increase public investment to rebuild the destroyed infrastructure. However, most of the work is expected to take place in 2012, then it may not contribute much to the economic growth of 2011. As a consequence of these unexpected public expenses, and as we expect the government will avoid any immediate tax increase, the deficit of the general government will soar to almost 16% adding to the already very high public debt.

Because of the disaster, population will fall faster than expected (figure 6, app, left) and it will be more difficult for the government to improve its finances. The main reason is that a lower path for the real wages will push the fertility rate downwards (figure 6, app, right) and then number of birth will remain low. Besides, as population ages, the increase in the social security expenditure, will continue rising and the government will have to borrow increasing amounts of money to pay its bills or may even have to sell some of its assets. The ratio of the net debt of the government to the GDP will continue rising for the foreseeable future (figure 9, app), but this situation will not be sustainable and the government will have to raise taxes. Furthermore, the BOJ will allow the interest rate increase to cool down the economy as we will explain later.

Although the economy will recover, it will remain below the economic path expected before the disaster: both the level of production and consumption will be lower. As we observed the retired household may probably manage better than the working household.

In two main fronts the long term path of the economy will differ drastically respect to the expected path before the disaster: inflation rate and the exchange rate. We expect Japan to return to positive inflation rate by the end of 2011 or in 2012 (figure 3, app, right). The inflation spike is not only the result of the supply side disruptions which contain production of goods and services, but it is also related to the depreciation in the yen later in 2012. Although the yen may rise temporarily in immediate following month of the

disaster because of capital repatriation by Japanese companies to finance the recovery and also because of uncertainties in the world economy, the value of the yen will start weakening later on what will make the cost of imported goods higher (figure 8, app). The weakening of the yen will be the result of an increase in imports and also due to a renewed capital outflows which will probably start by the end of 2012. With respect to the path of the yen our prediction differ drastically from the forecast by the Economist Intelligence Unit which expect the yen to remain relatively strong in the coming years close to 1 USD=82 JPY. Our simulations show the yen may even fall to 1 USD=100 JPN if energy restrictions remain, contamination of food is not resolved and the world economy continues recovering at the present rate.

Next we explain with more detail how the disaster has changed general scenario under which the economy has been developing. We describe how the parameters and exogenous variables were changed because of it. As mentioned before, the results should be taken with caution and are only meant to provide an indication about the direction the economy may take because of the combined disaster.

b) About how the disaster changed the parameters and exogenous variables.

Several negative shocks which have affected the area of the disaster like human losses, homes and infrastructure destruction, uncertainty about the future, food poisoning by nuclear materials, and much more have already started to make its ripple effects throughout the economy: disruption in the circulation of goods and services, the difficulties about how to pay the cost of the reconstruction under the very delicate present fiscal situation, then the uncertainty about the future of the role of nuclear plants in the energy strategy, According to the Japan National Police Agency, by July 20, there are 20,662 persons either dead or missing and 5,694 injured. More 170,000 persons have been living in some shelters during this period and the damage on housing and infrastructure is huge: more than 235,377 homes were totally or partially destroyed, burned ore swept away by the tsunami. There are 3,559 damaged roads, 77 damaged bridges and 29 damaged railways. The public works required to clear all the rubble is expected to take several months. Total cost of the reconstruction is estimated to be in the range of

¥20 to ¥30 trillion which is more than 5% of the GDP and more than twice the total for the 1995 Kobe earthquake. The most affected area corresponds to the prefectures of Miyagi, Iwate, Fukushima, Ibaraki and Aomori which represent a combined 7% of the GDP of Japan. However, the damage extends well beyond this area affecting Chiba, Tochigi, Gunma and Saitama as well.

Human losses though very regrettable, are not the biggest disruption to the economy as a whole. From the point of view of the macroeconomic performance, the biggest challenges are the disruptions caused by the uncertainty of the resolution of the nuclear crisis, the contamination of food and water and the disruption in the chain of production of several important products.

First of all, an important negative supply side impact is related to the destruction of assets and the disruptions in the circulation of inputs and the supply of raw materials and parts between different companies. We reflect this in our model with a down grade in the variable λ of the production process which includes the level of capital, technology of production and of circulation of goods and services. We estimate the total cost of reconstruction of destroyed housing and other private property to be close to ¥10 trillion, reparations of infrastructure above ¥10 trillion too. We estimated that capital stock could have fallen about 1.0%~1.5%. The reduction in the technological level due to supply chain or energy disruptions may be close to 1%. In any case these figures should be adjusted as more official information becomes available.

A second negative impact is related to several disruptions to export activities. The still ongoing crisis in the Fukushima nuclear plants is causing severe disruptions to the agricultural local sector because of the detected contamination of several products like vegetables, milk and beef. Exports of Japanese food from the affected area has been restricted by other countries, and commercialization inside Japan banned. The government will have to compensate food producers by for example purchasing the contaminated products. However, exports of food are not higher than 1% of total exports, and exports of food from the affected region are negligible. The biggest negative impact on the export activities will come from the disruptions in production in important factories located in the area or which are indirectly connected to

them by the supply chain and also due to energy restrictions. Although the world economy is expected to grow faster than in 2010, several Japanese exporters may not be able to respond smoothly to the external demand. Several big export companies like Toyota, Honda, Nissan, Sony and other have had to halt production at least temporally. We think that there will be a temporary disruption in the volume of exports which we have estimated to be close to 10%. In spite of this negative shock we do not expect a fall in the total value of exports in 2011.

A third, and probably more important impact is related to the supply of energy and more specifically the direction the nuclear energy strategy may have in the future. According to the Nuclear and Industrial Safety Agency the government ordered safety upgrades at all existing nuclear plants of Japan which may suggest a no backing away for the current national strategy of nuclear electricity expansion. However, the Prime Minister Kan said he wanted to see Japan free from nuclear power. We believe that responding to public pressure, the planned expansion to the nuclear energy production will end up being halted at least for the next decade. This will imply a higher import bill of fossil fuels like oil and natural gas. Besides, in the short run, disruption in the local production will mean that the imports of other raw materials will increase too. In mathematical terms, all this translates in a higher marginal propensity to import inputs, the parameter m of the import function which will become higher. Imports of food and water will probably increase too at least in the medium term. The parameter m_0 the propensity to import consumption goods of the import function will increase too. The increase in the marginal propensity to import is the main cause of the weaker yen and the inflation cost process that we observed with our simulations.

The forth negative impact is on the risk rate of investment, σ which will increase because of the uncertainties about the resolution of the nuclear crisis. This will not allow private investment recover as fast as expected even if the government embarks in a bold recover project. The rise in the risk of financial investment will rise too and then capital will flow out of the country in higher proportions than normal. Although companies are expected to repatriate capital from abroad to finance the recover, the yen may not continue rising as expected because the increase in the value of imports will make the demand for foreign currency higher. This will have important implications for stability

of prices in the future. As we have seen, there might be a spike of inflation in 2012 caused by a combination of several factors which are the higher demand from the government for the reparation efforts, an increase in the cost of gasoline and all the other imported products due to the weaker yen. As an unintended consequence, a weaker yen may help export companies in the longer run as long as the supply chain disruptions and energy restrictions are lifted. As a result of our simulation exports will rise faster because of this phenomenon. We think the risk rate may increase from 4.8% to 4.9%

Consumer confidence will fall too, not only because of the uncertainties of the event related to the spread of radiation on food and tap water but also as the costs of rebuilding the area will be burdened mostly by the government, the household will expect taxes to rise in not a very distant future. We have assigned a 4% fall in the consumer confidence in 2011, because although the most affected region represent a 7% of the GDP, uncertainty and disruption in job creation go well beyond the area. However, we think confidence will improve in 2012.

We expect the government to avoid immediate tax increases, and also postpone the planned consumption tax hike. In our simulations we assumed the government will increase public expenses in about 15 trillion in 2011 and 2012. The bank of Japan will continue an expansionary monetary policy. The immediate response of the monetary authorities was an expansion of the monetary base which in 3 weeks has increased about ¥20 trillion. In the long run the economy will recover but sooner than later the government will have to start repairing its finances. As inflation accumulates, the BOJ will also have to start tightening the monetary policy. We will a detail analysis of these policies for a future report.

10. Concluding Remarks

This paper presents the preliminary results of our predictions about the future path of the Japanese economy after the triple disaster earthquake-tsunami-nuclear crisis of March 11th 2011. We estimate a dynamic open macroeconomic model which also includes the basic features of the population dynamics of Japan. Most of the parameters of the model, (production function, the con-

sumption function, the investment function, export function and import functions) were estimated using econometric methods. Other parameters were calibrated using as a benchmark the year 2010. The calibration technique differs from the econometric method in that it uses only one observation point to make the estimation.

First of all, as our simulations focus on the effects of the disaster, we assume the world economy would be increasing at a 3%~4% without very big disruptions or financial crisis. As the world economy continues recovering from the 2008 financial crisis, international prices of raw materials will be rising as described in previous chapters. Interest rates are expected to rise too. However, with respect to the international scenario our simulations do not include the most recent international events related to for example the possibility of a downgrading of the government debt by credit rating agencies of some European countries like Greece, Ireland and probably Portugal, Spain and Italy. We do not consider either the increase in the uncertainty caused by the still unsolved problem of the increase in the debt ceiling of the debt of the government of the United States. The potential failure to increase it will most probably trigger “the unthinkable” downgrade of the triple-A grade causing a wave of higher uncertainty in the international financial markets, probably pushing interest rates up. Although all these events are very important to predict the future growth of the world economy and therefore the demand for Japanese products, as well as the international price of energy and raw material, we have kept our optimistic view that the Washington politicians will come to an agreement. Similarly, we assume the European Union will be able to manage the debt problem of the troubled countries and no bigger financial disruptions will occur.

Considering the above, as we have found from our simulations the economy will follow a very different path because of the disaster. The loss of life the disruption to the normal life of the population of the Tohoku Kanto area, especially Miyagi, Iwate and Fukushima are incalculable. Uncertainty about the resolution of the nuclear crisis and the release of radiation materials to the environment will loom for a long period. As the planned expansion of production of nuclear energy will be stopped, the energy strategy of the country will shift the energy mixt to the traditional fossil fuels like oil, natural gas, and even the environmentally damaging coal, at least in the near term. Eolic,

geothermal, solar and other renewable sources may be encouraged by the government, but it will take longer to be adopted as investment costs are high.

We think the yen may remain high probably for some months because of the world recent uncertainties, and also because to repatriation of capital by Japanese companies to finance the recovery. However, sooner or later the yen will start weakening as a response of the increase in the value of imports and therefore in the demand for foreign currency. This will be the result of both higher volumes of imports of fossil fuels, other raw materials and food. The rising trend in the international prices of those products will make the import bill even higher. Also a faster than Japan growing world economy will make the differential interest rate between the rest of the world and Japan increase. This will induce an outflow of capital which will also push the yen downwards. We also expect several companies to continue shifting production to other countries where the profit rate is higher.

After a period of economic contraction, the economy will start recovering as a result of the reconstruction efforts by the government and also supported by a more favorable international economic environment lead by developing countries like China, Brazil, and the ASEAN countries. The weaker yen will also make exports activities more profitable. Soon, the economy will return to a growth path between 1.3~2%, though low for international standards, respectable for Japan, especially in the context of a falling population. Employment will also improve and the unemployment rate may even fall closer to the natural rate of unemployment which includes frictional and structural unemployment and is thought to be 3.8% for Japan. Deflation is expected to end, first due to rising costs of energy and food, then later, the core inflation rate which includes all goods and services excluding energy and food, will start rising too.

As our simulations show, the while the economy growth, the public debt continues rising due to exploding social security obligations, then, sooner than later the government will have to raise taxes to pay the exploding public debt. The bank of Japan will also have to reduce the monetary base to raise interest rate and avoid the formation of future bubbles.

We have left for future further analysis of several aspects of our model. First of all, we would like to actualize the simulations about the effects of the earthquake as more precise information becomes available, especially about how the costs of the disaster will be distributed among the population. It is also important to review our computations as soon as the government defines its energy strategy to compensate for the reduction in the nuclear energy supply. Also important is to consider how the international scenario changes with the still unfolding events with respect to the debt problem in the United States, the possibility of a hard landing in China if the real estate bubble is not well managed and also the effect of the instability in the Middle East in the price of oil.

With respect to the estimations of the parameters and exogenous variables of the model we would also like to perform a sensitivity analysis as result may vary as the value of those parameters change. The future dynamics of the Japanese economy will be very different depending on drastic changes in government policy. For example, in our estimation of Japan's demographic dynamics we have assumed an unchanged pattern of immigration, but a very different pattern of growth would emerge if immigration laws were relaxed. Also we have assumed Japan does not engage in any important trade liberalization agreement. However as Japan's future growth is becoming more and more dependent of trade growth, a different path may also be achieved if for example Japan joined the Trans Pacific Partnership Agreement (TPP), which creates a free trade zone in the Pacific region. One more aspect that requires further analysis are redistribution of income and wealth that is expected to occur and which are either resultant of the economic policy changes or through variations in the price level. One more interesting factor to include in the model is the analysis of the housing market. The housing bubble in Japan which occurred during the last five years to the 1980s is already 20 years distant in the past. As more and more houses built during that period will be depreciating in the coming years, and then it becomes more relevant to study how a falling population may be interact with a falling stock of homes and the effect it may have on home prices.

Acknowledgments

I extend my sympathy to all the families living in the area of the earthquake and tsunami of March 11th, 2011, who may have lost their loved ones, their jobs or property. I hope this paper can contribute to the implementation of positive policies to their relief, especially to help them reengage quickly into the labor force. I am grateful to the Osaka University of Economics and Law for the financial support it gave me to pursue the research of this paper. I am responsible of any error of this paper. I will work hard to correct them.

Main bibliography and data source

- 1) BOJ Time-Series Data Search, Bank of Japan
- 2) Tax System and Financial Situation of the Government (on line report), Ministry of Finance of Japan.
- 3) Tax Collection Database, National Tax Agency
- 4) Trade and Investment database, Japan External Trade Organization.
- 5) World Economic Outlook Database, International Monetary Fund (IMF).
- 6) Organization for Economic Cooperation (OECD) Statistics.
- 7) World Population Prospects: The 2008 Revision Population Database, United Nations, Department of Economic and Social Affairs, Population Division, Population Estimates and Projections Section.
- 8) Kakei Chousa, Consumer Price Index, Survey on the Labor Force: Ministry of Internal Affairs and Communications, Statistics Bureau.
- 9) National Accounts, Economic and Social Research Institute of the Cabinet Office, Government of Japan.
- 10) Kokumin Seikatsu Kiso Chousa, Ministry of Labor
- 11) Capital Utilization Survey, Ministry of Economy, Trade and Industry.
- 12) Japan's Balance of Payment Statistics (historical data), Ministry of Finance.
- 13) Exchange rates, interest rates, Central Banks: Central Bank of the Philippines, Reserve Bank of Australia, Federal Reserve of the United States, People's Bank of China, Bank of England, European Central Bank, Bank of Thailand, Central Bank of Indonesia. Central Bank of Brazil, Bank Negara Malaysia, The Bank of Korea.
- 14) Survey on Population Dynamics, Ministry of Health, Labor and Welfare. Available in e-Stat, Ministry of Internal Affairs and Communications. Statistic Bureau.
- 15) Country Report, Japan, China and the United States, 2007~2011, The Economist Intelligence Unit.
- 16) Pietro, C. Pisani M., Baini N. and Rebucchi A. (2009). "Global Imbalances: The Role of Non-Tradable Total Factor Productivity in Advanced Economies", International Monetary Fund Working Paper, WP/09/63
- 17) Counter measures for 2011 Tohoku district, Japan National Police Agency
- 18) Nuclear and Industrial Safety Agency, NISA.

Appendices: The Japanese economy after the March 11th 2011 disaster

Simulations results (main graphs)

In the graphs displayed below, the complete line represents the expected path for each variable before the earthquake. The dotted line represents the expected path after the earthquake. The horizontal axis represents the passage of time, with the starting point corresponds to the economy at the year 2010. Most variables like the GDP, consumption etc., are expressed in trillion JPY, other variables like the inflation rate, the unemployment rate, the interest rate are expressed in %. The exchange rate is the value of the dollar (for example, 1 USD = 87 yens in 2010). The price level is a price index, equal to 1 in 2010.

Figure 1

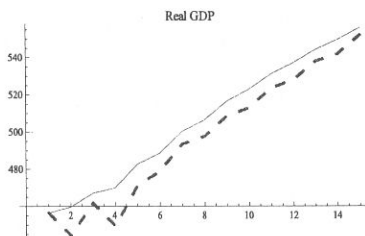


Figure 2

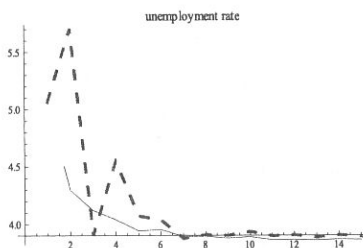


Figure 3

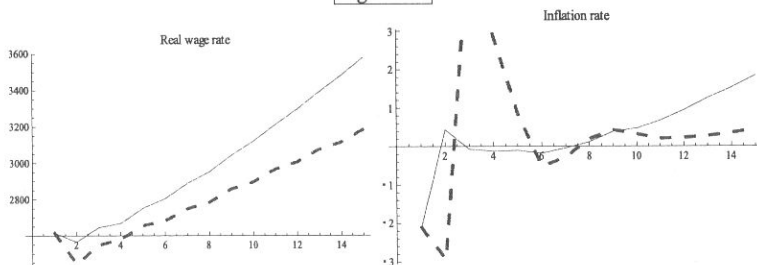


Figure 4

The Japanese economy after the March 11th, 2011 disaster

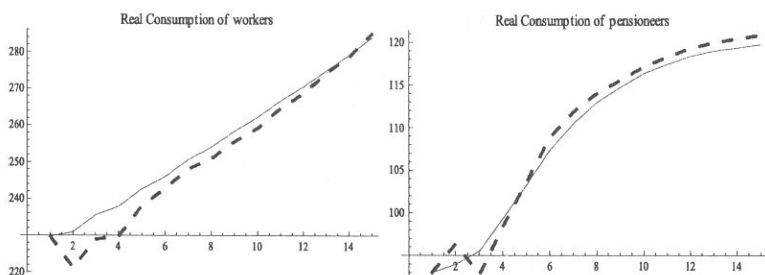


Figure 5

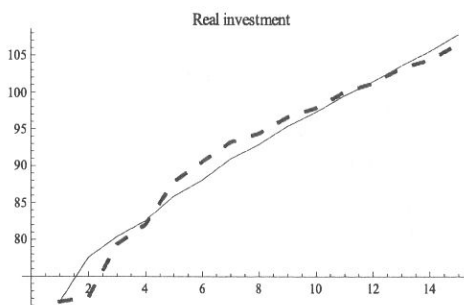


Figure 6

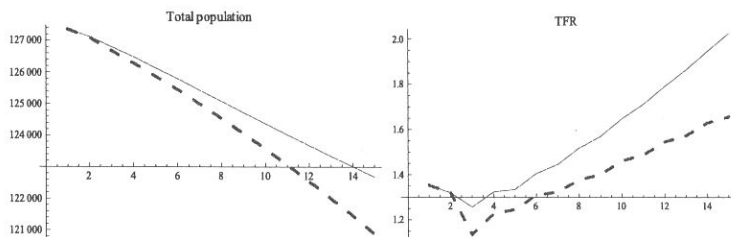


Figure 7

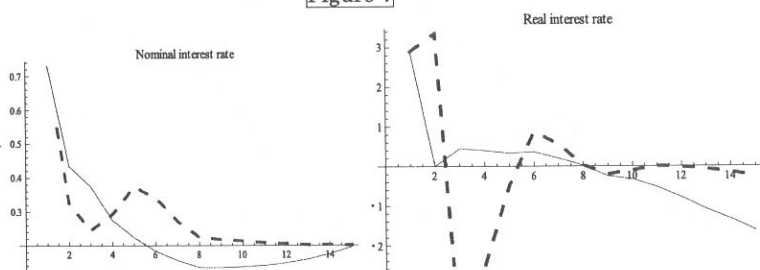


Figure 8

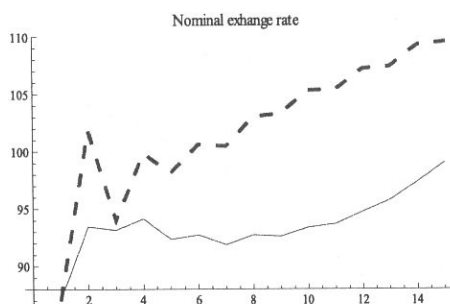


Figure 9

