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Conference Paper

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20th Biennial Conference of the International Telecommunications Society (ITS): "The Net and the Internet - Emerging Markets and Policies", Rio de Janeiro, Brazil, 30th-03rd December, 2014

Provided in Cooperation with:

International Telecommunications Society (ITS)

Suggested Citation: Ozu, Atsushi; Kasuga, Norihiro (2014) : The Economic Impact of Cloud Computing Diffusion in Japan, 20th Biennial Conference of the International Telecommunications Society (ITS): "The Net and the Internet - Emerging Markets and Policies", Rio de Janeiro, Brazil, 30th-03rd December, 2014, International Telecommunications Society (ITS), Calgary

This Version is available at:

<https://hdl.handle.net/10419/106885>

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The Economic Impact of Cloud Computing Diffusion in Japan*

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Abstract

The market for cloud computing is expected to rapidly expand and change the nature of ICT across all sectors; cloud computing transforms ICT from a tool dependent upon investment and physical ownership to one that can easily make use of outside resources. In this paper, the impact of the diffusion of cloud computing on Japanese macroeconomics was estimated and analyzed utilizing a DSGE (Dynamic Stochastic General Equilibrium) model-based simulation. Its academic contributions would be summarized as follows: (1) Assuming an endogenous market structure, a model that incorporates the effects of ICT capital and the ICT investment adjustment cost was built; (2) With that model, a DSGE simulation was conducted on a system comprised of a single sector of cloud computing and then the impact of the cloud computing diffusion on Japanese macroeconomics was estimated based on the relationship between that system and the whole Japanese economy; and (3) According to the simulation results, the diffusion of cloud computing use has a 0.10% GDP boosting effect for a fast adoption case scenario (one year to steady state) and a 0.059% GDP boosting effect for a slow adoption case scenario (five years to steady state).

* The views and opinions expressed in this article are those of the author only, and do not necessarily represent the views and opinions of Ministry of Internal Affairs and Communications (MIC), Institute for Information and Communications Policy (IICP) or any of their affiliates and employees. The author would like to thank Dr. Shota Moriwaki, Associate Professor of Osaka City University School of Economics, Dr. Toshihiko Takemura, Associate Professor of Saga University School of Economics and Dr. Ryo Hasumi, Economist of Japan Center for Economic Research for helpful comments and discussion. The author also would like to thank Dr. Federico Etro, Professor of Ca' Foscari University of Venice School of Economics for the useful discussion during his visit to Japan in March 2014.

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1. Introduction

1.1 Cloud Computing and its Market in Japan

In September 2011, the U.S. Department of Commerce's (U.S. DOC) National Institute of Standards and Technology (NIST) released "The NIST Definition of Cloud Computing" and characterized five important aspects of cloud computing, namely (1) On-demand self-service, (2) Broad network access, (3) Resource pooling, (4) Rapid elasticity, and (5) Measured service.¹

Given these characteristics, firms that choose to introduce cloud computing can operate on a platform provided by external cloud-service providers and accessed through digital networks. Because their operations were previously performed with their own hardware, software, and data, all of which were self-owned, operated, and maintained, an increase in efficiency is expected across all ICT-using sectors. As for cost, fixed costs, most of which have to be paid initially (initial cost), can be transformed to variable costs on a pay-as-you-go basis, and thus, financial efficiency is also expected to improve. In this respect, a firm that introduces cloud computing may save more, because if it procures its own system, it is likely that the specifications of that system would match the expected maximum workload in its product life of use rather than the specifications needed at the time of procurement. Moreover, because cloud computing lowers market entry costs, the number of market entrants is expected to increase.

Table 1 tabulates some of the published market forecasts related to cloud computing in Japan. The cloud computing market still occupies a small portion of the ICT market. However it is expected to grow rapidly in the near future. According to the MM Research Institute, from 2012 through 2017, the domestic cloud market is expected to grow at the annual compounded rate of 32%, while ICT investment is expected to remain at the same level.

Cloud computing is classified broadly into the two categories of public and private cloud computing. Public cloud computing is provided as a service by an external service provider, user firms paying on a pay-as-you-go basis, saving on initial costs. This is what the term "cloud computing" usually refers to. On the other hand, in private cloud computing, user firms build their own internal clouds, paying the initial costs. This improves productivity, among other things, through server virtualization, but its impact on macroeconomics may not dramatically exceed that of conventional ICT investment. Therefore, this paper focuses on public cloud computing.

¹ See "The NIST Definition of Cloud Computing" for details at <http://csrc.nist.gov/publications/nistpubs/800-145/SP800-145.pdf>

Table 1
Some Examples of Published Market Forecasts on Cloud Computing in Japan ^{*1}
(Unit: Billion JPY)

	2012	2013	2014	2015	2016	2017	2018
Domestic IT Market ^{*2} (IDC, Jan 2014)			14,158			14,397	
Domestic ICT Market ^{*2} (IDC, Jan 2014)			25,466			25,081	
ICT Investment of Domestic Corporations ^{*3} (MM Research Institute, Aug 2013)	25,000					25,000	
Domestic Cloud Service Market ^{*3} (MIC Research Institute ^{*4} , Dec 2013)	242 ^{*5}	273	301	328	355	382	
Domestic Cloud Market ^{*3} (MM Research Institute, Aug 2013)	510			1,256		2,041	
Domestic Public Cloud Service Market ^{*2} (IDC, Apr 2014)		130					385
Domestic Private Cloud Market ^{*2} (IDC, Aug 2013)		463				1,413	

^{*1} Tabulated based on press releases, which do not necessarily clearly define market, terms of use, or premises and assumptions used.

^{*2} Calendar year.

^{*3} Fiscal year. Japan's fiscal year starts in April and ends in March.

^{*4} MIC Research Institute (LTD) and Ministry of Internal Affairs and Communications share the same abbreviations of "MIC", however, they are not related to each other.

^{*5} Actual data.

1.2 Literature Review

Etro (2009) has quantitatively estimated the impact of the diffusion of cloud computing use based on DSGE (Dynamic Stochastic General Equilibrium)

simulations and demonstrated that it has a positive contribution to GDP, employment and business creation on 27 European countries.

DSGE is a sophisticated simulation tool employed to describe how macroeconomic variables collectively evolve as a result of shock (perturbation) applied to their steady state (equilibrium state) and converge to the original steady state or another steady state over time, by modeling the theory of microeconomics, and has been used primarily in the development of monetary and fiscal policies by academic researchers and policy makers, such as governments and international organizations.

Etro (2009) applied DSGE to the ICT field, using the theory of the endogenous market structure. His model can be summarized as follows: (1) Cloud computing reduces the ICT initial fixed costs of entry and production of all firms in all sectors, turning part of those fixed costs into variable costs; (2) The lowered barriers to entry result in an increase to the number of market entrants; (3) Competition in each market is enhanced and tends to reduce markups; and (4) As a GPT (General Purpose Technology), cloud computing does not directly augment TFP (Total Factor Productivity); however, there occurs gradual ICT capital accumulation over time.

1.3 The Scope and Purpose of the Research

In this research, I would like to estimate the impact of the advancement of cloud computing use on Japanese macroeconomics and provide data that can be used for policy formulation for the promotion and development of cloud computing. The main objectives of the research, rather than to ascertain its exact GDP growth rate contribution, are (1) To determine whether there is a (realistic) sustainable growth path of macroeconomic variables in Japan's case, under the certain conditions where the shock of the advancement of cloud computing use exists and (2) To illustrate the dynamic interaction of the macroeconomic variables.

To this end, (1) A model that incorporates the effect of ICT capital and the stickiness effect of ICT investment was built, assuming an endogenous market structure; (2) With this model, a DSGE simulation was conducted on a system comprised of a single sector of cloud computing; (3) Then the impact of the advancement of cloud computing use on Japanese macroeconomics was estimated based on the relationship between the system and whole Japanese economy; and (4) In order to calibrate the simulation's parameters and estimate the relationship between the system and whole Japanese economy, Japan's published macroeconomic statistics and a web-survey's results were used. The web-survey was conducted in March 2014, targeting businesspeople in Japan.

If evaluating the contributions of the cloud computing diffusion to GDP and productivity is the only objectives, an ordinary production function approach can be employed. However, a DSGE approach can measure not only GDP and productivity but also its influence on the total economy, including the impacts on households and the labor market. Also, the majority of researches on DSGE are on monetary and fiscal policies and the number of researches that DSGE is applied to other areas,

such as ICT, is small and limited.

The organization of this article is as follows. In Chapter 2, a model is presented and a simulation is conducted with the simulation parameters calibrated to the Japanese ICT market. In Chapter 3, the simulation results are applied to the whole Japanese economy and the impact of the advancement of cloud computing use on macroeconomics in Japan is estimated. Chapter 4 contains a final summary and analysis.

2. The Model and its Simulation Results

2.1 The Model

A system comprised of a single sector of cloud computing is considered and a model with an endogenous market structure is built for DSGE simulation. A number of models with endogenous market structure are introduced in several papers, such as Etro (2009), Colciago and Etro (2010), Bilbiie, Ghironi and Melitz (2012). Etro (2009) focuses on cloud computing and others deal with markets in general. Among models proposed by those papers, some equations are identical. However, this fact does not necessarily mean that the systems intended to be modeled are the same each as other, because a system is described by a set of simultaneous equations.

The model in this paper utilizes ICT capital, and the investment adjustment cost function is introduced in order to reflect the effect of the nature of stickiness (persistency) of investment. In this system, on the demand side many of the market participants may consume only cloud computing services and do not have to possess ICT hardware; however, on the supply side many of the market participants need to have facilities, such as data centers, to provide cloud computing services. Thus, ICT capital is employed in the model presented in this paper. Followings are the details of the model.

2.1.1 Households

The representative household supplies L_t hours of work and consumes C_t at time period t for the wage rate w_t . By assuming Constant Relative Risk Aversion (CRRA), the expected lifetime utility function of the representative household is described as

$$U(C_t, L_t) = E_0 \left[\sum_{t=0}^{\infty} \beta^t \left\{ \ln(C_t) - \chi \frac{L_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} \right\} \right], \text{ where } E_t[\cdot] \text{ denotes the mathematical}$$

expectation operator at time period t , β ($0 < \beta < 1$) represents the subjective discount factor, χ (> 0) represents the Frisch elasticity of labor supply to wages and φ (≥ 0) represents the Frisch intertemporal elasticity of substitution in labor supply.

This household's aggregate budget constraint holds that total expenditure that is comprised of consumption, investment of existing firms and investment of market

entrants should be equal to total income, and thus $C_t + IK_t + v_t ne_t = \pi_t n_{t-1} + r_t K_t + w_t L_t$, where IK_t represents ICT investment, v_t represents market entry cost, ne_t represents the number of market entrants, π_t represents the profit of the representative firm, n_t represents the number of existing firms, r_t represents the interest rate (cost of capital) and K_t represents the ICT capital.

The representative household maximizes U under the household's aggregate budget constraint. By applying the transition equation of the number of firms (5) and the transition equation of capital (8), both of which will be introduced later, we have the following equations of (1) to (4):

$$v_t = \beta(1 - \delta)E_t \left[\frac{C_t}{C_{t+1}} (v_{t+1} + \pi_{t+1}) \right] \quad (1)$$

$$L_t = \left(\frac{w_t}{\chi C_t} \right)^\varphi \quad (2)$$

$$g_t \beta \frac{C_t}{C_{t+1}} (1 - \delta^k) + \beta \frac{r_t}{c_t} = g_{t-1} \quad (3)$$

$$\frac{1}{c_t} = g_t \left\{ 1 - S \left[\frac{IK_t}{IK_{t-1}} \right] - \frac{IK_t}{IK_{t-1}} S' \left[\frac{IK_t}{IK_{t-1}} \right] \right\} + g_{t+1} \beta \left(\frac{IK_{t+1}}{IK_t} \right)^2 S' \left[\frac{IK_{t+1}}{IK_t} \right] \quad (4)$$

where δ represents the market exit rate of existing firms and market entrants during the time period of t , δ^k represents the physical depreciation rate, g_t is one of two Lagrange multipliers² in Lagrangian $\mathcal{L} = \sum_{t=0}^{\infty} \beta^t \left[\ln(C_t) - \chi \frac{L_t^{1+\frac{1}{\varphi}}}{1+\frac{1}{\varphi}} - f_t(C_t + IK_t + v_t ne_t - \pi_t n_{t-1} - r_t K_t - w_t L_t) - g_t \left\{ K_{t+1} - (1 - \delta^k)K_t - IK_t + S \left[\frac{IK_t}{IK_{t-1}} \right] IK_t \right\} \right]$ and $S \left[\frac{IK_t}{IK_{t-1}} \right]$ represents the investment adjustment cost function.

2.1.2 Firms and Market Clearing

Let us suppose that cloud computing goods have a variety of ω and that cloud computing goods are produced by capital and labor. By supposing that at time period of t , there are n_t existing firms and ne_t market entrants enter the market, and by the time period of $t+1$ some of the existing firms and new market entrants exit the market at the rate of δ , we have:

$$n_{t+1} = (1 - \delta)(n_t + ne_t) \quad (5)$$

We can divide the output Y_t into existing firm portion YC_t and new market

² The other Lagrange multiplier f_t turns out to be $f_t = 1/c_t$.

entrant portion ne_tv_t and divide the hours of work L_t into existing firm portion LC_t and new market entrant portion $ne_t \frac{v_t}{w_t}$:

$$Y_t = YC_t + ne_tv_t \quad (6)$$

$$L_t = LC_t + ne_t \frac{v_t}{w_t} \quad (7)$$

ICT capital K_t is accumulated as ICT investment IK_t is made. We have the following transition equation of capital:

$$K_{t+1} = (1 - \delta^k)K_t + IK_t - S\left[\frac{IK_t}{IK_{t-1}}\right]IK_t \quad (8)$$

In many cases, the transition equation of capital is described as $K_{t+1} = (1 - \delta^k)K_t + IK_t$; however, in order to reflect the sticky nature of investment (investment amount cannot be changed in the short term) and to avoid a situation in which investment amount jumps to its value in a steady state without a transition period, the investment adjustment cost function $S[x]$ is introduced. $S[x]$ satisfies the three following properties: (1) $S[x]$ has minimum value of 0 at $x=1$; (2) $S[x]$ has a minimal (local minimal) value of 0 at $x=1$; and (3) $S[x]$ is a downward-convex function. These properties are equivalent to $S[1] = S'[1] = 0$ and $S''[1] = \frac{1}{ss}$, where $ss (>0)$ is a constant that governs the degree of stickiness of investment adjustment cost. With these properties, $S[x]$ has the following two characteristics:

- (i) When IK_t is in a steady state, $IK_t = IK_{t-1}$ and thus $S\left[\frac{IK_t}{IK_{t-1}}\right] = S[1] = 0$.

Therefore, the equation (8) becomes $K_{t+1} = (1 - \delta^k)K_t + IK_t$.

- (ii) When IK_t is not in a steady state, $IK_t \neq IK_{t-1}$ and thus $S\left[\frac{IK_t}{IK_{t-1}}\right] > 0$.

However, the equation (8) and $K_{t+1} = (1 - \delta^k)K_t + IK_t$ are connected smoothly at $x=1$.

In this paper, the investment adjustment function is defined as

$$S[x] \equiv \frac{1}{2} \left\{ e^{\frac{1}{\sqrt{ss}}(x-1)} + e^{-\frac{1}{\sqrt{ss}}(x-1)} - 2 \right\} = \frac{1}{2} \left\{ e^{\frac{1}{2\sqrt{ss}}(x-1)} - e^{-\frac{1}{2\sqrt{ss}}(x-1)} \right\}^2 (\geq 0). \text{ Therefore, for any } x, S[x] \text{ is equal to or more than zero.}$$

Under the market clearing condition, we have:

$$YC_t = C_t + IK_t \quad (9)$$

By assuming a Cobb-Douglas production function, the production function of firm j ($j=1, 2, \dots, n_t$) at time period t can be described as $yc_{j,t} = A(lc_{j,t})^\alpha (k_{j,t})^{1-\alpha}$,

where $yc_{j,t}$ represents the output of firm j , $lc_{j,t}$ represents the hours of work of firm j , $k_{j,t}$ represents the ICT capital of firm j and A represents Total Factor Productivity (TFP), which is assumed constant in this paper, and α represents labor share. By multiplying n_t by both sides of the production function of firm j above, by assuming symmetry across firms of firm 1 to firm n_t , and by using the relationships of $YC_t = yc_{j,t}n_t$, $LC_t = lc_{j,t}n_t$, $K_t = k_{j,t}n_t$, we have the following equation:

$$YC_t = A \cdot (LC_t)^\alpha \cdot (K_t)^{1-\alpha} \quad (10)$$

Since TFP A and labor share α remain constant, the increase in output can be achieved by the increase in LC_t and K_t . This means that the contribution of cloud computing diffusion to output is modeled and achieved not by TFP but by GPT (General Purpose Technology).

By minimizing the total production cost of firms at the time period t ($r_t K_t + w_t LC_t$), we get the following equations:

$$w_t = \alpha \cdot \frac{YC_t}{LC_t} \cdot \frac{1}{\mu_t} \quad (11)$$

$$r_t = (1 - \alpha) \cdot \frac{YC_t}{K_t} \cdot \frac{1}{\mu_t} \quad (12)$$

where μ_t represents price markup in which $\mu_t = \frac{1}{mc_t}$, and where mc_t represents marginal cost.

In order to avoid extreme cases, such as a monopoly or perfectly competitive market, in which in a steady state both the profit of the representative firm and market entry cost equal zero, we introduce the Cournot Equilibrium. Under the Cournot Equilibrium, the number of firms in the market and the market structure are set endogenously and each firm decides on the amount of its production based on the given information of other firms' production amount. Since price markup μ_t holds $\mu_t = \frac{\theta}{\theta-1} \cdot \frac{n_t}{n_t-1}$, where θ represents the degree of substitutability across goods with a variety of ω , when $\theta \rightarrow \infty$, we can treat cloud computing goods as homogenous and we have:

$$\mu_t = \frac{n_t}{n_t - 1} \quad (13)$$

Under the Cournot Equilibrium, the profit of the firm j $\pi_{j,t}$ can be described as $\pi_{j,t} = \left(1 - \frac{1}{\mu_t}\right) \frac{yc_{j,t}}{n_t}$ and by assuming symmetry across firms and by using the relationships of $\mu_t = \frac{n_t}{n_t-1}$ and $YC_t = yc_{j,t}n_t$, we have:

$$\pi_t = \frac{YC_t}{n_t^2} \quad (14)$$

Since market entry cost v_t is expected to decrease with the advancement of cloud computing use, we assume the following equation:

$$v_t = \rho v_0 + (1 - \rho)v_{t-1} + e_t \quad (15)$$

where v_0 represents the steady-state value of the market entry cost, ρ represents the constant that governs the convergent speed of v_t ³ and e_t represents the market entry cost shock.

2.1.3 Summary of the Model

Now we have 15 endogenous variables of: output Y_t , consumption C_t , hours of work L_t , ICT capital K_t , ICT investment IK_t , output contributed by existing firms YC_t , hours of work of existing firms LC_t , wage rate w_t , interest rate r_t , number of firms n_t , number of market entrants ne_t , profit of the representative firm π_t , price markup μ_t , market entry cost v_t and Lagrange multiplier g_t . On the other hand, we also have a set of 15 simultaneous equations.

2.2 Calibration

Table 2 tabulates the parameters and calibrated values for the simulation.

³ At $\rho=1$ market entry cost v_t convergent to the steady-state value of the market entry cost v_0 at the quickest speed, because $v_t=v_0$ for any t .

Table 2
The Parameters and Calibrated Values for the Simulation

Parameter	Value
Labor share α	0.405
Discount factor β	0.998
TFP (Total Factor Productivity) A	1
Market exit rate of firms δ	0.00925
Physical depreciation rate δ^k	0.055
Steady-state value of the market entry cost v_0	1
Constant that governs the speed of market entry cost convergence ρ	0.629 (fast adoption case scenario) 0.180 (slow adoption case scenario)
Frisch elasticity of labor supply to wages χ	0.933*
Frisch intertemporal elasticity of substitution in labor supply φ	4
Constant that governs the degree of stickiness of investment adjustment cost ss	0.309

* χ varies depending on the simulation setting, because χ is set so that the steady-state value of the hours of work L_0 equals one.

The unit of time used is a quarter. The labor supply α is set to 0.405, because according to the 2013 Basic Survey on the Information and Communications Industry by the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Economy, Trade and Industry (METI), the labor share of the information and communications industry in FY2012 was 0.405. The discount factor β is set to 0.998⁴, which is equivalent to an annual rate of 1%, based on the recent yields of a newly issued 10-year Japanese Government Bond. Total Factor Productivity (TFP) A is normalized and set to one. The market exit rate of existing firms and new market entrants δ is set to 0.00925, which is equivalent to the annual rate of 3.7%, because according to the 2014 White Paper on Small and Medium Enterprises in Japan by METI, the exit rate of firms in FY2011 was 3.7%. The physical depreciation rate δ^k is set to 0.055, which is equivalent to the annual rate of 0.22, because according to a

⁴ Referring to other constants, two significant figures are enough for the discount factor. However, two significant figures make the discount factor equal to one, and that is inappropriate for this simulation. Therefore, 0.998 is used on purpose.

figure in Eden et al.(2014) the non-residential ICT annual depreciation rate is around 0.22, a number that was derived from the U.S. DOC Bureau of Economic Analysis' (BEA) fixed asset account. The steady-state value of the market entry cost v_0 is normalized and set to one.⁵ In the simulation two case scenarios are considered: (1) Fast adoption case scenario and (2) Slow adoption case scenario. In the fast adoption case scenario, the diffusion of cloud computing is more rapid, assuming that it takes a year (four quarters) for market entry cost to return to its steady state value after the shock is applied. On the other hand, in the slow adoption case scenario, the diffusion of cloud computing is more gradual, assuming that it takes five years (20 quarters) for market entry cost to return to its steady state value after the shock is applied. Accordingly, the constant that governs the speed of market entry cost convergence ρ is set to 0.629 for the fast adoption case scenario and 0.180 for the slow adoption case scenario.⁶ Frisch elasticity of labor supply to wages χ is set so that the steady-state value of the hours of work L_0 is normalized and equals one. Therefore, the value of χ varies depending on the simulation setting.⁷ Frisch intertemporal elasticity of substitution in labor supply ϕ is set to four, which is the value that Etro (2009), Colciago and Etro (2010), Bilbiie, Ghironi, Melitz (2012) commonly used. The constant that governs the degree of stickiness of investment adjustment cost ss is set to 0.309 (=1/3.24), because this is the value that Christiano et al. (2005) reported and that was utilized in many subsequent papers.

2.3 Simulation Premise and Results

2.3.1 Simulation Premise

In this paper, the model was built and the simulation was conducted with the assumption that the diffusion of cloud computing is reflected in the decrease of the market entry cost v . Since empirical data that describes the relationship between the diffusion of cloud computing and the decrease of market entry cost does not seem to be available, I assumed that the decrease of market entry cost is 5%, taking conservative estimate. The size of the shock applied to market entry cost e is set to 0.0526, because 5.26% of v_0 is 0.0526.⁸ In the simulation this shock is applied for the period of a quarter.

⁵ Etro (2009) pointed out that the combination of TFP A and the steady-state value of the market entry cost v_0 affects the endogenous level of market power and the number of market entrants ne_t . Based on the simulation results, it would be fair to conclude that the combination in this simulation falls within the proper range.

⁶ A 0.1% range of the steady-state value of the market entry cost v_0 was used to judge whether the entry cost reaches its steady state.

⁷ In many cases, the value of χ is slightly smaller than one.

⁸ $0.0526/(1+0.0526)=0.0500$

2.3.2 Simulation Results

Figure 1 and Figure 2 are the results of the simulation for the fast adoption case scenario (one year to steady state) and for the slow adoption case scenario (five years to steady state), respectively.

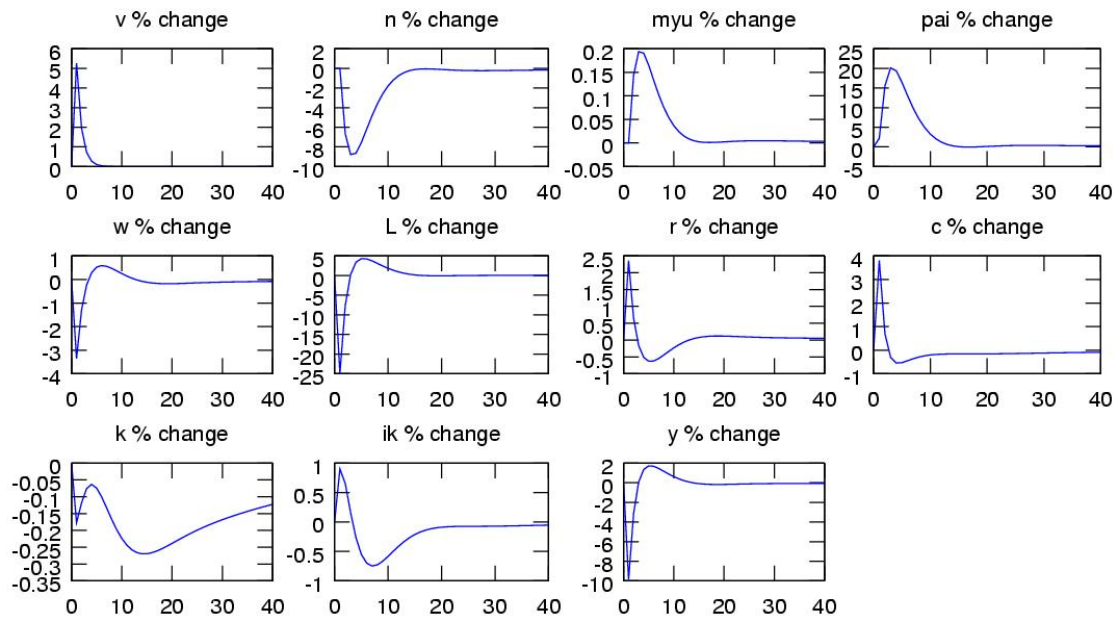


Figure 1
Simulation result - the fast adoption case scenario (one year to steady state)

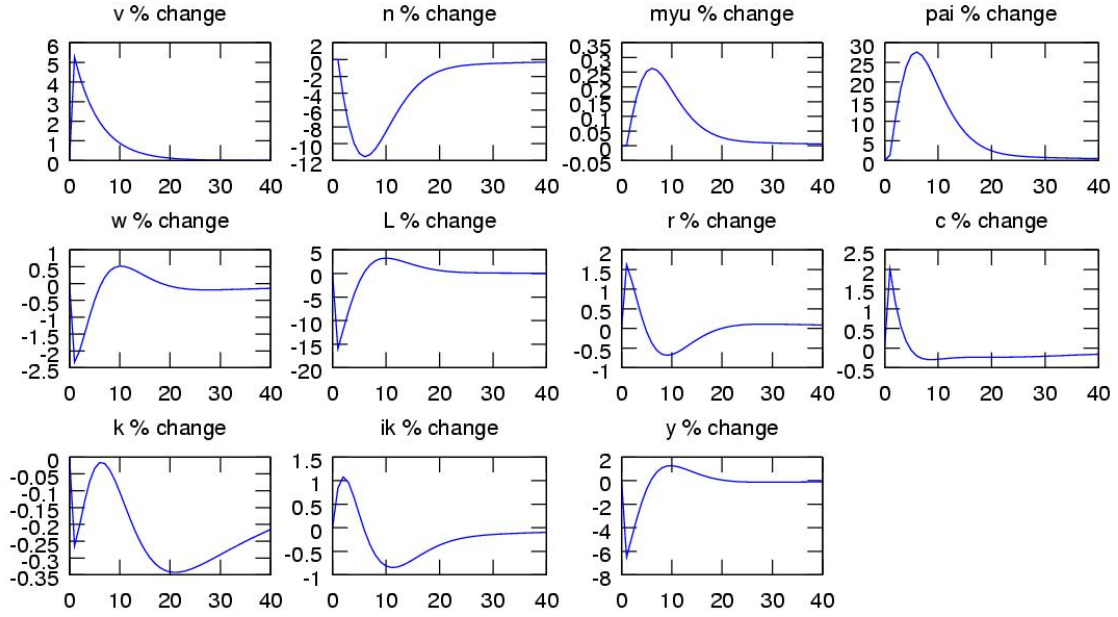


Figure 2
Simulation results - the slow adoption case scenario (five years to steady state)

The market entry cost v jumped sharply due to the shock applied and then gradually decreased 5% to its steady-state value (v_0) within the term of one year for the fast adoption case scenario or within the term of five years for the slow adoption case scenario. As a result of v increase, the number of firms n decreased at the early stage; however, it then gradually increased as v decreased. As n increased, price markup μ decreased to one and the profit of the representative firm π decreased. As μ decreased, wage rate w increased. Once π , n and the number of market entrants ne were known, output Y and hours of work L could then be calculated. It should be noted that as cloud computing use increases, both output Y and hours of work L increases.

In the simulation, the output Y increased 11.1% in the fast adoption case scenario and 6.94% in the slow adoption case scenario⁹, demonstrating that the impact of cloud computing diffusion positively impacted the output in a system

⁹ Comparison of the lowest value of Y after the shock was applied and Y_0 (the steady-state value of the output).

comprised of a single sector of cloud computing.¹⁰

3. The Relationship between Simulation Results and the Whole Japanese Economy

3.1 Current Cloud Computing Use in Japan

In Chapter 2 the simulation was conducted in a system comprised of a single sector of cloud computing and in Chapter 3, with several assumptions, an attempt is made to apply the simulation results to the whole Japanese economy based on Japan's published macroeconomic statistics and the results of a web-survey targeting businesspeople (conducted March 2014).

Table 3 tabulates the Percentage of firms using cloud computing service (Group A), Percentage of firms not using cloud computing service, but may use in the future (Group B), Percentage of firms not using cloud computing service and have no plans to in the future (Group C), Distribution of Sales (D); and Distribution of Added Value (E) for each of the six major industrial categories of (1) Construction, (2) Manufacturing, (3) Transport and Postal Activities, (4) Wholesale and Retail, (5) Finance and Insurance, and (6) Service and Other Industries.

Group A, Group B, and Group C are based on the data presented in the 2013 Communications Usage Trend Survey conducted by the MIC, but non-respondents were removed and recalculations were made. At the time of the survey, respondents were provided with five choices of (i) Used companywide, (ii) Used by some offices or divisions, (iii) Not used, but planning to use in the future, (iv) Not used and no plans to use in the future, and (v) Do not understand cloud services. Firms of respondents who answered (i) or (ii) were regarded as firms using cloud computing service. In this paper, Group A is derived from (i) and (ii), Group B from (iii) and (v), and Group C from (iv).

(D) and (E) are based on the data presented in the 2012 Economic Census for Business Activity conducted by the MIC and the METI, but recalculations were made to fit the six industrial categories.

The six industry categories are common between the 2013 Communications Usage Trend Survey and 2012 Economic Census for Business Activity, which are both based on the Japan Standard Industry Classification.¹¹

¹⁰ The impact of cloud computing diffusion positively impacts the hours of work as well in a system comprised of a single sector of cloud computing.

¹¹ There is a "Transport" category in the 2013 Communications Usage Trend Survey; however, of the values of the "Transport" categories in the 2013 Communications Usage Trend Survey and the "Transport and Postal Activities" category in the 2012 Economic Census for Business Activity are identical.

Table 3
Cloud Computing Using Groups, Sales and Added Value by Industrial Categories

Industrial Category	Percentage of firms using cloud computing service (Group A)	Percentage of firms not using cloud computing service, but may use in the future (Group B)	Percentage of firms not using cloud computing service and have no plans to use in the future (Group C)	Distribution of Sales (D)	Distribution of Added Value (E)
Construction	33.8%	33.8%	32.4%	6.2%	6.4%
Manufacturing	29.7%	29.8%	40.5%	25.7%	23.1%
Transport and Postal Activities	28.7%	34.4%	36.9%	4.1%	5.8%
Wholesale and Retail	33.4%	38.1%	28.5%	31.1%	18.6%
Finance and Insurance	43.5%	23.5%	33.0%	8.5%	7.6%
Service and Other Industries	36.7%	31.3%	32.0%	24.4%	38.5%
Total				100.0%	100.0%

* (Group A), (Group B), and (Group C): Author's computation based on the data presented in the 2013 Communications Usage Trend Survey by the Ministry of Internal Affairs and Communications (in Japanese).

* (D) and (E): Author's computation based on the data presented in the 2012 Economic Census for Business Activity by the Ministry of Internal Affairs and Communications and the Ministry of Economy, Trade and Industry.

Table 4 tabulated usage rate for each of major cloud computing services by industrial categories and the Weighted Average of usage rate for each of major cloud computing services by industrial categories.

Data was taken from the 2013 Communications Usage Trend Survey conducted by the MIC, but non-respondents were removed and recalculations were made.

Weighted Averages for each of major cloud computing services are calculated, using (E) in Table 3 as a weight for weighted average computation.

It is difficult to estimate the size of portion of cloud computing use in each firm's business activities and in firms of each industrial category's business activities; however, as the first approximation, simple average of all the major cloud computing services (including Other) is calculated for each industrial category: 16.0% is for Construction, 15.3% is for Manufacturing, 15.1% is for Transport and Postal Activities, 14.2% is for Wholesale and Retail, 14.6% is for Finance and Insurance, and 16.3% is for Service and Other Industries.

Table 4
Usage Rate for Each of the Major Cloud Computing Services by Industrial Category and the Weighted Average of Usage Rate for Each

Cloud Computing Service	Construction	Manufacturing	Transport and Postal Activities	Wholesale and Retail	Finance and Insurance	Service and Other Industries	Weighted Average
Server applications	30.4%	35.0%	43.0%	33.9%	30.8%	50.8%	40.7%
File storage / Data sharing	48.5%	51.0%	42.4%	36.3%	38.0%	47.5%	45.3%
Data Backups	15.1%	20.2%	21.3%	8.0%	8.6%	19.6%	16.6%
Internal information sharing / Portal	36.8%	24.8%	21.3%	34.6%	20.3%	36.4%	31.3%
E-mail	52.9%	53.8%	51.0%	50.5%	35.3%	47.0%	49.0%
Schedule sharing	39.2%	31.6%	25.2%	32.5%	23.5%	34.5%	32.4%
Project management	10.0%	4.7%	4.2%	7.1%	6.1%	6.1%	6.1%
Sharing information with business partners	11.2%	7.9%	5.6%	4.9%	11.4%	2.7%	5.7%
Sales support	8.6%	6.7%	2.9%	13.3%	29.7%	10.5%	11.0%
R&D related	0.0%	1.4%	0.0%	1.1%	0.0%	1.4%	1.1%
System development and website construction	1.7%	3.6%	4.1%	2.8%	5.5%	3.5%	3.5%
e-Learning	5.4%	5.8%	4.3%	3.7%	19.0%	3.7%	5.5%
Payroll / Financial accounting / HR	18.1%	13.5%	24.2%	12.2%	19.4%	20.7%	17.4%
Order taking and sales	2.6%	7.0%	2.1%	5.7%	1.3%	1.5%	3.7%
Purchasing	3.3%	9.2%	5.9%	4.4%	0.0%	3.8%	5.0%
Production management / Distribution management / Store management	3.0%	5.9%	13.4%	8.1%	2.0%	5.3%	6.0%
Billing and payment systems	1.6%	2.4%	3.9%	2.3%	2.6%	5.1%	3.5%
Authentication systems	1.0%	1.4%	2.9%	3.1%	4.1%	1.6%	2.1%
Other	13.9%	4.9%	8.8%	4.4%	20.6%	7.6%	7.8%
Average	16.0%	15.3%	15.1%	14.2%	14.6%	16.3%	15.4%

* Author's computation based on the data presented in the 2013 Communications Usage Trend Survey by the Ministry of Internal Affairs and Communications.

* (E) of Table 3 is used as a weight for weighted average computation.

Based on Table 3 and Table 4, the possible room for expansion of cloud computing use for each cloud computing user group (Group A to Group C in Table 3) is considered, with special attention given to (1) Business activities that employ cloud computing and (2) Business activities that do not employ cloud computing.

As for the Group A (those firms that are using cloud computing service), we suppose that (1) The percentage of business activities that employ cloud computing are represented by the Average in Table 4 (15.3% in the case of Manufacturing) and (2) The percentage of business activities that do not employ cloud computing is derived by subtracting the Average in Table 4 from 100.0% (84.7% in the case of Manufacturing). Then we also suppose that the only possible room for expansion of cloud computing use is found in (2). It is possible that there may be possible room for further expansion of cloud computing use in (1); however, in order to conservatively estimate the impact of the advancement of cloud computing use, we will set this possibility aside.

As for the Group B (those firms that are not using cloud computing service but may use in the future), we suppose that (1) The percentage of business activities that employ cloud computing is 0.0% and (2) The percentage of business activities that do not employ cloud computing is 100.0%. Therefore, we suppose that (2) contains all of the possible room for expansion of cloud computing use.

As for the Group C (those firms that are not using cloud computing service and have no plans to in the future), we suppose that (1) The percentage of business activities that employ cloud computing is 0.0% and (2) The percentage of business activities that do not employ cloud computing is 100.0%. However, based on the fact that Group C firms have already set business policy not to use cloud computing service, we, conservatively, suppose that there is no possible room for expansion of cloud computing use in Group C firms.

Figure 3 is a conceptual diagram of the possible room for expansion of cloud computing use for each cloud computing user group (Group A to Group C in Table 3).

For Each Industrial Category	[Total 100.0%]
Group A { Those firms that are using cloud computing services }	[29.7%]
{ (1) Business activities that employ cloud computing	(15.3% of 29.7%)
{ (2) <u>Business activities that do not employ cloud computing</u>	<u>(84.7% of 29.7%)</u>
Group B { Those firms that are not using cloud computing services but may in the future }	[29.8%]
{ (1) Business activities that employ cloud computing	(0.0% of 29.8%)
{ (2) <u>Business activities that do not employ cloud computing</u>	<u>(100.0% of 29.8%)</u>
Group C { Those firms that are not using cloud computing services and have no plans to in the future }	[40.5%]
{ (1) Business activities that employ cloud computing	(0.0% of 40.5%)
{ (2) Business activities that do not employ cloud computing	(100.0% of 40.5%)
* Manufacturing category numbers used.	
* Underlined is the element supposed to have possible room for expansion of cloud computing use.	

Figure 3
Conceptual Diagram of the Possible Room for Expansion of Cloud Computing Use for Each Cloud Computing User Group (Group A to Group C in Table 3)

3.2 Current Cloud Computing Investment in Japan

According to the InfoCom Research and Shinozaki (2014), ICT investment accounted for 25% of investment in Japan in FY2013.

Table 5 tabulates the breakdown of ICT Investment of Japanese firms in FY2013, taken from the web-survey results conducted by MIC in March 2014. The purpose of the web-survey was to understand the use trend of cloud computing and other new ICT services by Japanese firms, and it targeted businesspeople who have a position at their firms that involves screening and/or making final decisions on ICT investments, which include internal ICT system, network infrastructure, servers, and information securities, representing 34 industry segments. The number of total respondents was 1,527, with 762 responders representing firms that have introduced cloud computing and 765 responders representing firms that have not. The results of Table 5 were based on 659 responses out of those 762 responders from firms that have introduced cloud computing.

According to these results, 6.4% and 6.1% of ICT investment were used for private cloud computing and public cloud computing, respectively. As discussed in Chapter 1, this paper focuses on public cloud computing and this is in line with our conservative estimation.

Table 5
Breakdown of ICT Investment (FY2013)

Breakdown of ICT Investment	Percent
PC	34.4%
Software	24.0%
Servers	19.8%
Private Cloud	6.4%
Public Cloud	6.1%
Big Data related	6.0%
Other	3.2%
Total	100.0%

* Source: Web-survey conducted by the Ministry of Internal Affairs and Communications (MIC) in March 2014.

3.3 The Simulation Results and the Whole Japanese Economy

Based on the results above, the contribution of the impact of advancement of cloud computing to GDP is estimated.

Recalling that (1) in the simulation, the output Y increased 11.1% in the fast adoption case scenario and 6.94% in the slow adoption case scenario in a system comprised of a single sector of cloud computing; (2) for each of the six industrial categories, Group A firms are supposed to have possible room for expansion of cloud computing use for their business activities that do not employ cloud computing (the value of subtraction Average in Table 4 from 100.0%), Group B firms are supposed to have possible room for expansion of cloud computing use for 100.0% of their business activities, which do not currently employ cloud computing, and Group C firms are not supposed to have any possible room for expansion of cloud computing use; (3) ICT investment accounts for 25% of investment in Japan; (4) public cloud computing accounts for 6.1% of ICT investment in Japan; in the fast adoption case scenario, the contribution to GDP of Construction is 0.105%, that of Manufacturing is 0.093%¹², that of Transport and Postal Activities is 0.099%, that of Wholesale and Retail is 0.113%, that of Finance and Insurance is 0.103%, and that of Service and Other Industries is 0.105%. Therefore, applying (E) in Table 3 as a weight for a weighted average of these figures yields the contribution to GDP in the fast adoption case scenario, which is 0.103%. Similarly, the contribution to GDP in the slow adoption case scenario is 0.0589%.

¹² $11.1\% \times (0.847 \times 0.297 + 1.000 \times 0.298 + 0.000 \times 0.405) \times 0.25 \times 0.061 = 0.093\%$

4. Final Summary and Analysis

The impact of the advancement of cloud computing use on Japanese macroeconomics is analyzed and estimated utilizing a DSGE model-based simulation. It positively impacts GDP and hours of work in the system of a single sector of cloud computing; Under the fast adoption case scenario (one year to steady state), it has a 0.10% GDP boosting effect and under the slow adoption case scenario (five years to steady state), it has 0.059% GDP boosting effect.

Since there are several significant assumptions made when applying the DSGE simulation results to whole Japanese economy, it would be difficult to utilize these findings for policy formulation purposes instantly; however, in the modeling the effects of ICT capital and the ICT investment adjustment cost were considered, and through the simulation dynamic interaction of the macroeconomic variables in the endogenous market structure were illustrated.

Various further works are expected, including a more detailed analysis of cloud computing using firms' behavior that would make both the simulation and analysis of relationship between the simulation results and whole Japanese economy more accurate. Also, the web-survey results demonstrated that there exist several concerns (data security, privacy etc.) that hinder firms from introducing public cloud computing and prompt them to choose private cloud computing instead. Table 6 tabulates the web-survey results to the question "For each situation, to what degree do you think a shift from private to public cloud computing will occur?" For each situation about 40 to 50% of the respondents agreed that there will occur a shift from private to public cloud computing ("Big shift" and "Some shift"). Exploring possible measures to encourage the shift from private cloud computing to public cloud computing and the role of the government in the advancement of cloud computing use would be valuable agenda items to consider.

Table 6
Breakdown of ICT Investment (FY2013)

	Big shift	Some shift	No shift
Public cloud becomes popular.	10.0%	38.9%	51.1%
Advancement of data security is expected. For example, proper regulation is introduced or is harmonized internationally.	5.9%	42.0%	52.1%
Private cloud becomes popular.	8.8%	38.4%	52.8%
Data encryption technology is advanced and data access from unauthorized personnel is not expected.	6.5%	36.6%	56.9%
Advancement of personal data protection is expected. For example, proper regulation is introduced or is harmonized internationally.	5.3%	36.2%	58.5%
Cloud portability becomes popular.	6.1%	33.3%	60.6%

* Source: Web-survey conducted by the Ministry of Internal Affairs and Communications (MIC) in March 2014.

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