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Recovery from natural disaster: A numerical investigation based on the convergence approach

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ABSTRACT

This article employs a simple growth model, using government-funded public infrastructure and external effects to examine how the 2011 Great East Japan Earthquake and Tsunami affected economic recovery in the post-disaster period. By examining the recovery period following the disaster, we concretely consider the recovery process from various angles. Our main finding is that the speed of convergence decreases slightly, from about 5.7% to about 5.4%, after the disaster. In the disaster area, many people have concerns about the length of the recovery period. In considering the recovery progress, we also examine several economic and social policies that might help to shorten the recovery period.

These studies should in no way be read as an argument that minimizes the costs of war. And as long as war and the threat of war persist, the negative economic consequences appear to be large. However, the research suggests that economies (and people) are surprisingly *robust*. Once wars are completely ended, economies can at least sometimes recover from massive destruction over the course of a *single generation*.

[C. I. Jones, *Macroeconomics*, 3rd ed. (2014, p. 120)]

1. Introduction

The analytical target of this paper is the 2011 Great East Japan Earthquake and Tsunami (hereinafter, GEJET), which occurred at 2:46 PM Japan Standard Time (JST) on 11 March 2011. Using the well-known convergence analysis method, we examine the long-run process of recovery from a massive natural disaster, in particular the GEJET, by employing an endogenous growth model with public infrastructure (capital). More specifically, the effects of the disaster on the length of the recovery period are investigated. It seems likely that the length of the transitional period will differ before and after the GEJET.

Massive disasters cause widespread human and physical damage and thereby result in significant economic and social impacts. These broad damages should have some sort of influence on the length of the recovery period. In our model, it is conceivable that the simulated value for the length of the post-disaster transition period corresponds to the length of the actual recovery process. In this respect, by comparing the results in this paper with the actual recovery status, we are able to evaluate the overall levels of recovery achieved at each stage.

In addition to being an important and interesting numerical analysis, we also seek to clarify what policies are effective for speeding up the recovery process through the use of a rigorous economic model. This is a meaningful exploration for improving critical issues in the disaster-affected area.

Before giving the details of our study, we provide an overview of the existing research. Although convergence analysis itself is a well-known method in growth theory (e.g., Barro and Sala-i Martin, 1992; Barro et al., 1995; Ortigueira and Santos, 1997; Turnovsky, 2002), as far as we know, academic research on the recovery process from massive disaster that employs a convergence approach has

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been rarely conducted at the international level.[1] Given this state of research, Shioji (2012) is a pioneering paper that took the GEJET into consideration. Based on a specific real business-cycle model with the Stone Geary preference, he showed that the impacts of public investment differ in the vicinity of massive disasters. However, Shioji (2012) did not discuss the length of the recovery period, which is our focus in this paper.

Some empirical studies on disaster research are of interest. It seems that the bulk of empirical studies covering the GEJET have not yet come, but Yamamura (2012) made a valuable contribution by investigating how the experience of the GEJET with the severe nuclear accident in Fukushima affects individual beliefs about the risks of nuclear accidents. In addition, Naoi et al. (2012) employ unique survey data to examine how consumers reacted to the GEJET. Most recently, Kajitani and Tatano (2014) estimated production capacity losses due to the GEJET, and Lazzaroni and van Bergeijk (2014) presented a comprehensive meta-analysis of macroeconometric studies on the effects of natural disasters. However, the scarcity of research on disaster, not only the GEJET, means that little attention has been given to the empirical relationship between natural disasters and economic development generally. Skidmore and Toya (2002) make an early and valuable contribution in this area. Moreover, Toya and Skidmore (2007) and Loayza et al. (2012) are recent leading studies on the relationship between disasters and economic development.

Now we briefly explain the traits of the model developed in this paper. First, the stock of public infrastructure has a positive influence on activities relating to the production of goods. This is an extremely general observation in the recent literature on growth theory, including on endogenous growth models (e.g., Futagami et al., 1993; Agénor, 2010). Second, public infrastructure is mainly accumulated through public investment of funds received through proportional income taxes levied on private agents. Public infrastructure is also affected by certain external effects. Such externalities, on which we expand later, can be interpreted as an effect where raising living standards further induces public capital accumulation; this seems to be empirically supported.[2] In any case, infrastructure is viewed as having a vital role in the present study, with the external effects of infrastructure provision being of particular importance in the model for creating a situation in which *investment drives further investment* in the disaster-affected area. The strength of these effects certainly exerts an influence on the speed of recovery. It seems that, in the accumulation of public infrastructure, public spending is borne entirely by the *public* sector, whereas the external effects are largely dependent on the vitality of the *private* sector. Regardless, the specification for generation of infrastructure constitutes a key part in this paper.

After presenting and developing a theoretical model, we conduct a numerical simulation for the model. In the numerical examination, first of all, certain indicators, including the convergence rate, are identified as pre-disaster benchmarks. Then, by using precise estimates of actual capital destruction by the GEJET, we recalculate the previous benchmark indicators. Thus, the rate of convergence to a steady state totally governs, in a theoretical sense, the transition dynamics during the post-disaster period. Moreover, for given levels of capital destruction, the time between destruction and recovery to a specified level can be calculated. This yields *quantitative* implications for the recovery process. Finally, we confirm the model s behavior through changes in important parameters and identify some policies that could act to accelerate the process of recovery. In this last part, *qualitative* implications are indicated.

The rest of the paper is organized as follows. Section 2 presents a basic model and derives a theoretical speed of convergence. In addition, the properties of the dynamical system are clarified. Section 3 develops extensive numerical analyses on the recovery process from the GEJET and attempts to suggest beneficial recovery policies. In Section 4, we provide concluding remarks.

2. The model

2.1. Basic framework

In this section, we present a simple endogenous growth model with special attention given to the impacts of natural disasters. The present model basically follows the second model in Hosoya (2005), with both models being characterized by the inclusion of public factors. In Hosoya (2005), as an interesting feature, the evolution of public health stock (or public health infrastructure) is determined by the two *external* factors for agents: government health expenditure and external effects. We adopt this specification.

For models studying the relationship between natural disasters and economic growth, it is important to consider social infrastructure, including public capital. Natural disasters not only damage large amounts of private physical capital and cause loss of life (which affects the labor force) but also severely damage public infrastructure. Therefore, a suitable model for examining the present issue should include these factors. Moreover, we consider an externality that affects the provision of infrastructure. It appears that the pace of recovery from disasters reflects the degree of the externality. Since a strong and close relationship between infrastructure and living standards together with the production environment is apparent, we would like to introduce this relationship externality into the framework. Accordingly, public infrastructure promoted by the externality is indispensable in the present investigation. In a later numerical analysis, when taking capital destruction into consideration, we focus attention on the ratio of private capital to public infrastructure. This ratio is a basic index for evaluating economic performance.

In a general context, as in Raurich (2003), Agénor (2008), and others, public infrastructure seems to affect both utility and production. In the present setting, however, infrastructure is simply introduced into the structure. Specifically, it affects *only* individual labor productivity in the production of goods. Such a specification is also generally applicable in an endogenous growth model, and is considered to be valid for practical use (see, for instance, Futagami et al., 2008; Agénor, 2010).

In the following, we focus on the case of a *decentralized* economy. The pattern of agent behavior in this case is briefly summarized as follows: a representative household chooses its consumption path so as to maximize the lifetime utility for a given stock of public infrastructure and the fiscal variable (here, the tax rate on income). Let us begin a detailed investigation.[3] Formally, the household maximizes Eq. (1) under the constraints (2) (4):

$$\max_{C(t)} \int_0^{+\infty} \frac{C(t)^{1-\theta}-1}{1-\theta} e^{-\rho t} dt, \quad \theta > 0, \ \theta \neq 1, \ \rho > 0, \tag{1}$$

[1] Using the Solow model, the Japan Research Institute (2011) has developed a numerical simulation of the impact of the GEJET. That research takes a different approach than ours does; however, their study shares some traits with the present study. For the overall impact of disasters, see, for instance, Mimura et al. (2011) and Esteban et al. (2013). Tatano et al. (2004) and Ikefuji and Horii (2012) theoretically analyze the general relationships between massive natural disasters and economic growth. In Barro and Sala-i Martin (2003, Ch. 5), the economic impacts of losses of physical and human capital are examined.

[2] A simple empirical test conducted in Hosoya (2014), though its scope is limited, supports this type of externality.

[3] The description in this section basically follows that in Hosoya (2005, 2014).