# IS THERE AN INDISPENSABLE ROLE FOR GOVERNMENT DURING RECOVERY FROM AN EARTHQUAKE? A THEORETICAL ELABORATION

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Abstract

It is commonly argued that catastrophic effects of physical shocks are recovered consequentially due to internal adjustment mechanisms economies retain. The theoretical literature on growth implications of earthquakes relies on the same premise, by and large, putting relatively minor role on the shoulders of governments as an external source in recovering from catastrophic effects of an earthquake. This paper elaborates theoretically whether there is an indispensable role for government during recovery from the destructive effects of an earthquake. To this end, we employ a specific growth environment, namely AK framework, which imposes constant ratios on the quantities of the model from the start. It follows that, when a physical shock hits the economy, the model fails to restore these conditions automatically. The paper contributes to the literature in two ways. First, it shows that an indispensable role for government in restoring equilibrium after an earthquake is a theoretical possibility. Second, it advances our understanding on the procedure of restoring equilibrium when there are fixed ratios between quantities, an issue that is not known very much in the literature.

**Keywords**: Natural disasters, earthquakes, constancy conditions, economic growth

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# 1 Introduction

John Stuart Mill (1904, Book I, Chap.5) has noted long time ago that:

> " (…) what has so often excited wonder, the great rapidity with which countries recover from a state of devastation; the disappearance, in a short time, of all traces of the mischiefs done by earthquakes, floods, hurricanes, and the ravages of war. An enemy lays waste a country by fire and sword, and destroys or carries away nearly all the moveable wealth existing in it: all the inhabitants are ruined, and yet in a few years after, everything is much as it was before".

It would not be wrong to say that many economists, sharing Mill's observation, believe that an economic system would converge to its (long-run) equilibrium, whatever the magnitude of a physical shock on stock variables. One possible source of this common belief (bias?!) among economists is the prevalence of non-increasing returns to scale in overall production, which makes economic models essentially path-independent, and decreasing returns in specific production factors, which makes for rapid recovery from negative shocks. We think that a more inherent source of this belief owes to the conviction that "damages due to natural disasters are damages to stocks, whereas economists tend to think in terms of flows" (Tol and Leek, 1999, p.311). If flows are secured, it is natural to deduce that the unexpectedly shrunk stocks will be replenished through time.[1] The critical question that has not been discussed at a satisfactory level is whether the new equilibrium attained by the economy after a physical shock is the original (equivalently, optimal) equilibrium or not.

The unconditional recovery allegation has also been widely accepted/ argued in studies investigating the growth implications of earthquakes. For example, Oulton (1993) and Kepenek *et al.* (2001) argued that economies would (quickly) recover direct costs of earthquakes by relying on self-mechanisms. Some other studies like Albala-Bertrand (1993a, 1993b) and Selcuk and Yeldan (2001) assign some role to government in their studies. However, these studies (i) have not provided any legitimization on why government must shoulder a role, (ii) assign a secondary role to

[1] Tol and Leek (1999) note that some flow quantities like Gross Domestic Product (GDP), gross fixed capital formation, manufacturing, and public-sector spending grow after a natural disaster.

government during recovery in the sense that the government's role is limited to initiating/ accelerating growth. For example, Selcuk and Yeldan (2001) utilized an applied general equilibrium model to estimate the transition path of the Turkish economy to its new equilibrium after the devastating 17 August earthquake, and to obtain the market solution policy options to mitigate the negative effects of the earthquake. The government has two interrelated functions in the model: (i) to collect taxes, distribute transfer payments, purchase goods and services, (ii) to administer domestic public debt. Selcuk and Yeldan (2001) study four different assumptions via simulations: (i) no policy change; (ii) reliance on indirect taxes to finance the extra government expenditures for public investments to replenish the losses in the capital stock; (iii) endogenous adjustments on the existing indirect taxes to recover the loss in the capital stock; (iv) invigoration of foreign aid to recover the capital loss. They find that while a subsidy financed by foreign aid to individual sectors to recover the capital loss yields the best outcome (which is trivial), an indirect tax to finance the extra fiscal spending would result in an output loss, further deepening the impact of the earthquake on the economy (which contradicts with the initial aim of accelerating the adjustment). The study of Selcuk and Yeldan (2001) shows clearly that the intuition behind using the government as an external source of adjustment after an earthquake is to accelerate the adjustment. However, there is no theory in the literature backing why it is the government that must take on this role.

This paper contributes to the discussion made above in the following way. First, it demonstrates that an economic system may recover from the detrimental effects of a catastrophic shock without relying on external support, but the new equilibrium may not be the optimal one (*i.e.*, the original equilibrium). Second, it shows how government (the social planner) may take a role in restoring equilibrium. Hence, the paper concludes that there may be an indispensable role for the government in restoring optimal path.

We employ a very specific growth environment, namely the "$AK$ setup", in this paper. There are three reasons for using this set up in order to show the inevitable need for government involvement during restoring equilibrium. First, we argue that "automatic recovery" from physical shocks is basically due to diminishing marginal productivity assumption. A shock lowering the stock of an input (say, physical capital) implies increasing productivity of the input, which brings off convergence to steady state equilibrium in the long-run (a good example to this statement is the basic

Solovian framework, in which a shock on the physical capital is certainly recovered due to the neoclassical properties of the model). We need to remove this assumption if our aim is to assign an indispensable role for the government. Second, an interesting characteristic of "$AK$ models" (or patterns that are reduced to $AK$ models without generating transitional dynamics) is its enforcement of *constant ratios* among variables of the system *from the start*. Thus, if the path of one variable is known, then, necessarily, the time-paths of the rest are also known in these setups, given parameter values. What makes these models interesting from the viewpoint of shocks is that the constant ratios are *not tolerant* to disturbances. In other words, the conditions need to be restored as quickly as possible and preferably immediately, if an unexpected shock (*e.g.*, an earthquake) causes a deviation from these conditions because otherwise intertemporal maximization of the objective function cannot be accomplished. Noticeably, the aforementioned environment is a very special one, and the system is in need of social planner's *intervention* (*i.e.*, the market dynamics do not contain a self-sufficient mechanism that ensures convergence to the normal path). Third, our aim is to show that the need for government in restoring the optimality requirements is not a short run problem but a long-run one indeed. The $AK$ set up, which is a highly stylized and aggregated representation of long-run equilibrium from the start, provides an excellent environment in that respect.

This study can be seen an extension (and revision) of Chapter 5 of Barro and Sala-i-Martin (1995) from the viewpoint of solution procedure employed. In that chapter, Barro and Sala-i-Martin (henceforth BSM) discuss, in an extended $AK$ model, how to restore a constancy condition between physical capital and human capital after a physical shock on capital (*e.g.*, war) or on human capital (*e.g.*, epidemic). In their study, BSM argue that a temporary optimization policy that restricts the growth of the abundant quantity while letting the scarce variable grow after a shock is sufficient to restore constancy condition. We will follow the same intuition in our work, but offer a revised solution procedure. Hence, our contribution in this chapter lies also on proposing a more refined solution procedure as much as on discussing the role of the social planner on adjustment dynamics after a physical shock.[2]

The roadmap of the paper is as follows. We employ an augmented $AK$ model to derive fixed conditions among quantities of the model. We assume that the model-

[2] A more detailed critique of BSM's solution procedure can be found in Yetkiner (2003).

economy accumulates two stock variables, namely physical capital and housing in the form of foregone consumption. Hence, there is a competition between the housing and capital sectors for the forgone consumption. Our motivation for defining two types of stock quantities is the empirical regularity that an earthquake has different implications on the housing stock (residential buildings) and productive capital. The model derives a constant ratio between capital stock and housing that must be kept from the start if welfare is to be maximized. Next, we assume that an earthquake hits the housing sector while leaving the capital sector unaffected.[3] Clearly, it would not make qualitatively any difference to assume that the earthquake hits also the capital sector. Focusing on a single stock just helps us to put forward our argument in a simpler way. The problem of the social planner is how to restore the constancy conditions among the variables of the model after an unexpected earthquake. We show that adjustments to constancy conditions after a shock require the limitation of growth of undisturbed quantities of the model. The mechanism we propose, which is indeed substantially simple, restores the constancy ratios under a temporary optimization problem.

The organization of the paper is as follows. The second section studies the most basic $AK$ model for the purpose of making an introduction into the case of constancy conditions. The third section presents our model, which contributes to the literature in two ways. First, it demonstrates a refined solution procedure for restoring constancy conditions. Second, it shows the theoretical possibility that social planner may play an indispensable role in restoring these conditions. The last section is reserved for concluding remarks.

## 2 The Basics

Constancy conditions arise in $AK$ type models or in models that ultimately reduce to $AK$ form without generating transitional dynamics. The basic $AK$ model is the natural starting point for familiarizing with the condition. Define the overall utility as

[3] See Albala-Bertrand (1993a) on this.

$$U(C)=\int_0^\infty e^{-\rho t}\frac{C^{1-\theta}-1}{1-\theta}dt \qquad (1)$$

where $C$ is aggregate consumption, $\rho$ is the discount rate, and $\theta$ is the (absolute) value of elasticity of marginal utility. We assume that $\rho>0$ and $\theta>0$, and that the population is normalized to one and does not grow.

The production function is defined as

$$Y=AK \qquad (2)$$

where $Y$ is aggregate output, $A$ is the exogenous technology parameter, and $K$ is the aggregate physical capital stock. The model is closed by the macroeconomic budget constraint

$$\dot{K}=AK-C-\delta K \qquad (3)$$

where $\dot{K}$ is the instantaneous rate of change in the capital stock and $\delta$ is the rate of depreciation of capital. The solution of this problem is part of many textbooks (*e.g.*, BSM (1995)) and we will not elaborate it here. The system generates steady state growth without transitional dynamics:

$$g=\hat{C}=\hat{K}=\frac{A-\rho-\delta}{\theta}. \qquad (4)$$

In (4), $g$ is the rate of growth (a hat over a variable indicates the rate of change of the respective variable). A steady state growth without transitional dynamics entails also that variables of the system, namely consumption $C$ and physical capital $K$, hold a constant ratio between them from the start. In particular, it is straightforward to show that

$$\frac{C(t)}{K(t)}=A-\delta-g. \qquad (5)$$

Hence, there is a constant ratio between capital and consumption, starting from initial values $K(0)$ and $C(0)$. Consequently, consumption is not a free choice but a function of initial capital stock, given parameter values. This is called a "closed-form policy function" (see BSM, 1995, p.143, footnote 3). Furthermore, the condition is "binding" not only once-and-for-all but permanently, implying that the constant ratio between consumption and capital must be satisfied at all times. Finally, it is worth to note that a change on the right hand side of equation (5) does not violate the condition but just alters 'the rule' in accordance with the change. A violation arises if any of the quantities on the left-hand side (*i.e.*, physical quantities) is upset. BSM offered a solution procedure in chapter 5 of their 1995 book for restoring constancy conditions after a disturbance. We next look briefly at the solution procedure suggested by them before presenting our model and the procedure.

BSM (1995, pp. 172-9) discusses a two-sector growth model, which reduces into an $AK$ model without generating transitional dynamics. The familiar first order conditions of the maximization problem generate constancy conditions in the model. Next, BSM (1995) question what happens if one of the conditions is upset due to a physical shock. BSM (1995) state that constancy conditions dictate adjustments, *preferably instantaneously*, in the disturbed ratios. They add that instantaneous adjustment ("reversible investment") is not viable because "it depends on the possibility of an infinite positive rate of investment in one form of stock and an infinite negative rate of investment in the other form" (BSM, 1995, p.175). They argue that a more realistic assumption is to *limit* the growth of the abundant stock variable while the scarce stock variable is allowed to grow. Their interpretation is that the social planner realizes that the economy has too much of one of the stocks in relation to another stock, but since it is infeasible to have negative gross investment in the abundant stock, the practically feasible option is to force gross investment to zero. BSM argue that the temporary optimization problem will restore the condition in finite time and thereafter the system will return to original position (which is necessary in order to maximize the objective function).

We showed in Yetkiner (2003) that BSM's solution procedure has caveats though the intuition they developed is suitable. We will not discuss these caveats again in this paper but directly apply the solution procedure offered in Yetkiner (2003). This is done in the next section.

# 3 The Model

In this section, we develop a two-sector $AK$ model where one sector produces output and the other generates housing stock by using physical capital as input. Details of the model are as follows.[4] The overall utility is defined as

$$U(C,H) = e^{-\rho t} \frac{\left(C * H^{\gamma}\right)^{1-\theta} - 1}{1-\theta} \tag{6}$$

where $C$ is aggregate consumption, $H$ is the stock of accommodation units (houses), $\rho$ is the subjective rate of discount factor, $\gamma$ is the housing characterization parameter, and $\theta$ is the (absolute) value of elasticity of marginal utility. We assume that $\rho > 0$, $0 < \gamma < 1$, $\theta > 0$, and that population is normalized to one and does not grow. We also assume $\gamma(1-\theta) < 1$ to get diminishing marginal utility with respect to housing. The overall utility function has the following properties. First, elasticity of substitution between consumption and housing stock is one. Second, elasticities of marginal utility with respect to consumption and housing are constant ($\theta$ and $1-\gamma(1-\theta)$, respectively). Thus, $\theta > 1-\gamma(1-\theta)$ ($\theta < 1-\gamma(1-\theta)$) is guaranteed under $\theta > 1$ ($\theta < 1$), implying that, *ceteris paribus*, the intertemporal elasticity of substitution of consumption (housing) is greater than the intertemporal elasticity of substitution of housing (consumption). Hence, relatively speaking, the more rapid is the proportionate decline in marginal utility of consumption (housing) in response to increases in $C$ ($H$), and hence the households are less willing to accept deviations from a uniform pattern of $C$ ($H$) over time.

The production function is defined as

$$Y = AK \tag{7}$$

[4] See Smith, Rosen, and Fallis (1988, p.33) and Nielsen and Sørensen (1994) on how to introduce housing sector into a dynamic general equilibrium model.

where $Y$ is aggregate output, $A$ is exogenous technology parameter, and $K$ is aggregate physical capital stock.

In this model economy, part of resources is used for producing new houses. We conjecture that the net housing investment is captured by:

$$\dot{H} = I_H - \delta_H H \quad (8)$$

In Equation (8), $\dot{H}$ is the instantaneous change in the housing stock, $I_H$ is the gross investment for producing housing goods, and $\delta_H$ is the depreciation rate of houses. Note that we ignore completely housing quality for matter of focus.

The closure of the model is done by the macroeconomic budget equation. The constraint is

$$\dot{K} = AK - C - \delta_K K - I_H \quad (9)$$

where $\dot{K}$ is instantaneous rate of change in the capital stock and $\delta_K$ is the rate of depreciation of capital. Thus, we described the full properties of the model.

The complete solution procedure of the model is not very different than of the standard $AK$ model. For that reason, we shall skip it. It is straightforward to show that the steady state growth rate is

$$g = \hat{C} = \hat{H} = \hat{K} = \frac{A - \delta_K - \rho}{\theta - \gamma(1-\theta)}. \quad (10)$$

It is also easy to demonstrate that the two-sector AK model imposes constancy conditions on $C(t)/H(t)$ and $K(t)/H(t)$ for all $t$. In particular, we find these conditions as

$$\frac{C(t)}{H(t)} = \frac{A - \delta_K + \delta_H}{\gamma} \quad (11)$$

$$\frac{K(t)}{H(t)} = \frac{D}{A - \delta_K - g} \quad (12)$$

where $D = (g + \delta_H) + \frac{A - \delta_K + \delta_H}{\gamma}$. These conditions entail that all variables are interdependent and that we can trace the time paths of all variables from an initial condition of one variable, say, housing.

What is the importance of these constancy conditions from the viewpoint of physical shocks in our model? Suppose that a shock hits the housing stock at time $T_e$ and destructed a substantial size of it. Then, constancy conditions would be upset, and we need to restore them in the model. Intertemporal maximization demands adjustments (discrete or gradual). Discrete-adjustment, which includes infinite resource transfers between variables, is not appealing practically. Therefore, we need a scheme for gradual adjustments in order to attain maximization conditions. This can only be done by setting up a temporary maximization problem by the social planner. Let us first define the earthquake in the context of the model before switching to the solution procedure.

*The Definition of Earthquake*

In this paper, we define an earthquake a catastrophic event that destroys a significant amount of housing units. In particular, we assume that the housing stock is declined by some, say $\chi$, percentage due to an earthquake at time $T_e$:

$$H(T_e^+) = (1 - \chi) H(T_e^-) \tag{13}$$

where $T_e^-$ denotes time $T_e$ just before an earthquake, and $T_e^+$ represents the time immediately after an earthquake.[5]

*Simple response Policy*

In Yetkiner (2003) we discuss that there are infinite number of policy combinations that the government may follow in order to restore equilibrium. A rigorous selection must be based on a welfare comparison, which is not practically possible. Nonetheless, *intuition* suggests that a ‘good’ policy is immediate restriction of growth of undisturbed variables in the model until the required constancy conditions are restored, given that discrete adjustment is not possible. This is so because the later the equilibrium is restored, the higher the chance that the government is *not minimizing* the welfare loss. We call the policy of immediate restriction of growth of undisturbed variables as 'simple response policy' owing to the fact that the policy-maker follows a very simple scheme in order to restore constancy conditions. Noticeably, This is also the 'strategy' suggested in BSM (1995).

Before moving to the representation of solution, let us illustrate the impact of an earthquake on the time path of housing, and of restricting undisturbed variables. Figure 1 below does this.

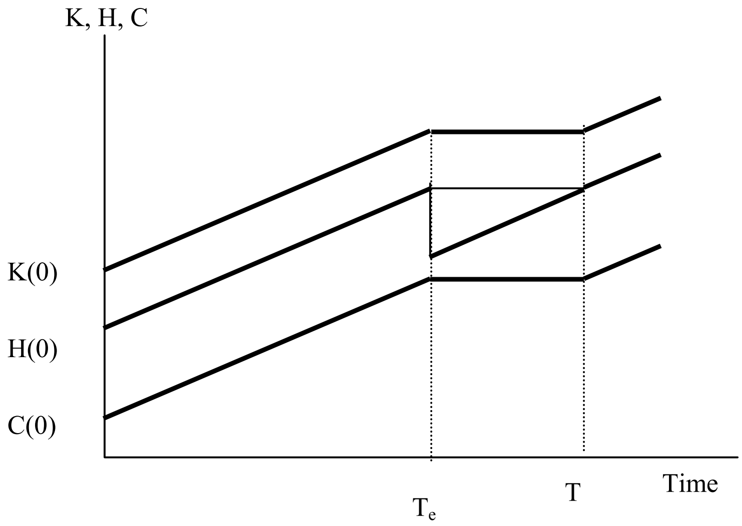


Figure 1. Restriction of undisturbed variables
(drawn linear for matter of presentation)

In figure 1, at time $T_e$, an earthquake hits the economy (the housing sector) and thus the constancy conditions between $K$ and $H$, and $C$ and $H$ are disturbed. Since there is more than one condition, it is *not* possible to restore them without constraining the growth of *all* undisturbed variables. As figure 1 shows, we must restrict then the growth of $K$ and $C$ immediately after the earthquake and release them to grow at the

[5] We will use $T_e$ and $T_e^-$ interchangeably whenever it is clear that time $t$ refers to just-before-earthquake.

point that $H$ reaches the pre-earthquake level. This is the requirement that an algebraic formulation of the problem should solve. We next turn to our example for technical representation of this scheme.

Suppose that the social planner agrees to restrict undisturbed variables immediately after the disturbance. The restriction implies setting up a temporary optimization problem, where the only unknowns are housing and 'restoration' time. The temporary problem starts at $T_e^+$ and ends at time $T$, in which the social planner maximizes

$$\begin{aligned} Max \quad & \int_{T_e^+}^{T} e^{-\rho t} \frac{\left(\overline{C} * H^{\gamma}\right)^{1-\theta} - 1}{1-\theta} dt \\ s.t. \quad & \dot{H} = I_H - \delta_H H \qquad (14) \\ & 0 = (A - \delta_K)\overline{K} - \overline{C} - I_H \end{aligned}$$

where initial value is $H(T_e^+) = (1-\chi)H(0)e^{gT_e}$, terminal value is $H(T) = H(0)e^{gT_e}$, terminal time $T$ is unknown, and $\overline{C} = C(0)e^{gT_e}$ and $\overline{K} = K(0)e^{gT_e}$. The problem specified in equation (14) is essentially a calculus of variations problem.[6] We can re-write the maximization problem after eliminating $H$ as follows:

$$Max \quad \int_{T_e^+}^{T} F(t, \dot{H}) dt \qquad (15)$$

where $F = e^{-\rho t} \frac{\overline{C}^{1-\theta}\left(\frac{I_H - \dot{H}}{\delta_H}\right)^{\gamma(1-\theta)} - 1}{1-\theta}$ and $I_H = (A - \delta_K)\overline{K} - \overline{C}$. The special form of $F(\cdot)$ implies that the Euler equation is

$$F_{\dot{H}\dot{H}} \ddot{H} + F_{t\dot{H}} = 0 . \qquad (16)$$

Together with fixed endpoint transversality condition $[F - F_{\dot{H}} \dot{H}]_{t=T} = 0$ and initial and terminal values, the Euler equation identifies the path of $H$.[7] Details of the

[6] Note that there is no need to use state-space constraint on the problem because, given that there is a single unknown in the model, the terminal time of the temporary problem is effectively the state-space constraint on the variable.
[7] See equation (2.19) for Euler equation and (3.11) for transversality condition in Chiang (1992).

solution are as follows.[8] First, applying the Euler equation formulation, we end up with a second order differential equation

$$\ddot{H} + \frac{\rho}{1-\gamma(1-\theta)}\dot{H} = \frac{\rho I_H}{1-\gamma(1-\theta)} \qquad (17)$$

Solving (17) yields that

$$H(s) = I_H \cdot (s - T_e^+) + c_1 e^{\frac{-\rho}{1-\gamma(1-\theta)}(s-T_e^+)} + c_2 \qquad (18)$$

where $s \in [T_e^+, T]$, and $c_1$ and $c_2$ are constants. Equation (18) indicates that housing stock increases as new investments are made. The three unknowns of (18) are $c_1$, $c_2$, and $T$. We also have three equations:

$$H(T_e^+) = c_1 + c_2 \equiv (1-\chi)H(0)e^{gT_e} \qquad (19)$$

$$H(T) = I_H \cdot (T - T_e^+) + c_1 e^{\frac{-\rho}{1-\gamma(1-\theta)}(T-T_e^+)} + c_2 \equiv H(0)e^{gT_e} \qquad (20)$$

$$\left[ e^{-\rho t}\left(\frac{\overline{C}^{1-\theta}}{1-\theta}\right)\left(\frac{I_H - \dot{H}}{\delta_H}\right)^{\gamma(1-\theta)-1} \right]_{t=T} * \left[ \frac{I_H - \dot{H}}{\delta_H} + \frac{\gamma(1-\theta)\dot{H}}{\delta_H} - \overline{C}^{-(1-\theta)}\left(\frac{I_H - \dot{H}}{\delta_H}\right)^{1-\gamma(1-\theta)} \right]_{t=T} = 0 \qquad (21)$$

Equation (19) and (20) are derived from the initial and terminal time conditions, respectively, and equation (21) is obtained from the transversality condition. Note from equation (20) (as well as from (18) at $s = T$) that

$$\dot{H}\Big|_{t=T} = I_H + \frac{c_1(-\rho)}{1-\gamma(1-\theta)} e^{\frac{-\rho}{1-\gamma(1-\theta)}(T-T_e^+)}. \qquad (22)$$

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[8] An alternative solution procedure is possible. Note that equation (16) implies $d/dt(F_{\dot{H}}) = 0$. Hence, $F_{\dot{H}} = c_1$, where $c_1$ is a constant. Starting from this observation, we can easily determine the housing path. Refer to Chiang (1992) for details.

Hence, the term $\left.\frac{I_H - \dot{H}}{\delta_H}\right|_{t=T}$ becomes $\frac{c_1\rho}{\delta_H(1-\gamma(1-\theta))} e^{\frac{-\rho}{1-\gamma(1-\theta)}(T-T_e^+)}$. In that case, non-trivial solution of equation (21) implies that the first component on the left-hand side of that equation *cannot* be zero and the second term must be zero. Hence, we derive from (21) that

$$\frac{c_1\rho}{\delta_H} e^{-\frac{\rho}{1-\gamma(1-\theta)}(T-T_e^+)} + \frac{\gamma(1-\theta)I_H}{\delta_H} = \overline{C}^{-(1-\theta)} \left( \frac{c_1\rho}{\delta_H(1-\gamma(1-\theta))} \right)^{1-\gamma(1-\theta)} e^{-\rho(T-T_e^+)} \qquad (23)$$

Unfortunately, it is not possible to solve analytically (19), (20) and (23) in order to find out explicit values of $c_1$, $c_2$, and $T$. We run a small experiment for a set of hypothetical parameter values just to check what these equations imply.[9] Our numerical experiment shows that it takes 2.334 'years' to recover a 50 percent reduction in the housing stock after an earthquake when $\theta = 0.8$ and 12.974 'years' when $\theta = 1.8$, where the earthquake hits the model economy at 'year' 80. These simple simulations approve our initial discussion that households are less willing to accept deviations from a uniform pattern of housing (relative to consumption) when $\theta < 1$. Since our aim is not to explore the exact time path of recovery, we consider it sufficient to run a single experiment. What we are sure is that the solution procedure will lead to a growing housing stock path while other quantities of the model are kept constant, and eventually the constancy conditions will be satisfied. Naturally, the temporary problem imposed by the social planner will be lifted at the time that the constancy conditions are attained. Finally, it is worth to mention that policy shocks (*e.g.*, consumption taxation) may be additionally used to accelerate the pace of restoring optimality conditions. Since they would not change the essential characteristics of the model, we skip them in this paper for matter of briefness.

*Discussion*

Physical shocks in general and earthquakes in specific can result in severe economic losses. The received view is that the economic impacts of earthquakes (and natural disasters) should be recoverable in time by relying purely on the internal dynamics of the economy. We show however that markets may sometimes fail to achieve efficient outcomes after natural disasters. The model poses an indispensable role for governments during recovery from natural shocks. In that respect, this study shows theoretically that government involvement during recovery from a shock might be Pareto-efficient in certain cases.

## 4 Conclusion

This paper has achieved two things. First, we showed that (i) a model economy might not necessarily return to optimal (*i.e.*, original) equilibrium after an earthquake by relying on internal dynamics, and (ii) the social planner's intervention might indeed be the only means for restoring constancy conditions. Hence, we showed that there might be an indispensable role for government involvement in restoring long-run equilibrium. Second, this study contributed to the literature by advancing our understanding on the solution procedure of restoring optimality conditions (within the limits of the example).

[9] The hypothetical parameter values are as follows: $\theta = 0.8$ or $\theta = 1.8$, $A = 0.07$, $\gamma = 0.8$, $\rho = 0.02$, $H(0) = 0.2$, $\chi = 0.5$, $Te = 80$, $\delta_K = 0.04$, and $\delta_H = 0.05$.

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