4 Physical Shocks on Economic Structure: Earthquake and Growth†

4.1 Introduction

A strong earthquake is likely to cause large economic losses and death tolls. There are many instances of this. For example, the Kobe earthquake (17 January 1995) is estimated to have caused 131,500 million dollars of losses and 5,502 deaths.1 A recent earthquake that hit Turkey in 17 August 1999 killed about 20,000 people and leveled down more than 200 thousand buildings.2 Some experts argue that these costs tend to increase. For example, Berz (1994) argues that the next earthquake that will hit U.S. may

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1 This paper is joint work of I. Hakan Yetkiner and Adriaan van Zon. It has been conditionally accepted to Structural Change and Economic Dynamics.  
1 See Horwich (2000) for a detailed discussion of KOBE earthquake.  
2 Bibbee et al. (2000) discuss in detail possible macroeconomic impacts of the 17 August earthquake on the Turkish economy.
cause at least 40,000 million dollars, which doubles the costs of the Northridge, California earthquake of 1994.

One relevant literature that investigates the costs of an earthquake (and other natural disasters) is the natural hazards or disaster literature.\(^3\) This literature is concerned with the estimation of *momentary losses* of earthquakes at a detailed level.\(^4\) However, the disaster literature is not able to give rich insights in terms of *economic implications* of an earthquake as it lacks a theoretical economic framework. In that sense, predictions of natural hazard literature are not very valuable from an economic viewpoint.

The interest of economists in the impact of natural disasters in general and earthquakes in particular has remained relatively weak if one takes into account an earthquake’s costs in terms of casualties and dollars.\(^5\) There are only a handful studies investigating the economic implications of an earthquake with the help of economic modeling. One study is Albala-Bertrand (1993b). In a simple Keynesian multiplier-analysis framework, Albala-Bertrand (1993b) shows that capital loss is unlikely to have a significant effect in the long-run, and that a very moderate ‘response expenditure’ may be sufficient to prevent the growth rate of output from falling. Though Albala-Bertrand's (1993b) findings are intuitive, and albeit supported by casual observation, the paper uses the Keynesian multiplier analysis, lacking a general-equilibrium modeling approach. In that respect, his approach is insufficient for those who would like to understand the implications of an earthquake in most relevant dimensions.

\(^3\) See, for example, Alexander (1997) for a general overview of this field.
\(^4\) Chan *et al.* (1998) is a good example of such kind of approach.
\(^5\) This disinterest is conceivable to a certain extent given that these losses are one-time big losses, and therefore cannot have any significant effect in the long-run. Yet, rising costs and death tolls suggest that growth effects of earthquakes may be increasingly significant, especially for developing countries.
Another study is Oulton (1993), focusing solely on stock effects of an earthquake. This paper uses the standard Cass-Koopmans growth framework to determine how a reduction in the (initial) capital stock due to an earthquake is recovered in time. His calculations (via simulations) show that, given a standard Cass-Koopmans growth model, the adjustment to a 50% reduction in the initial capital stock is over 90% completed within a decade and almost totally completed within a generation. The weakness of Oulton (1993) is that he focuses solely on the direct effects of an earthquake by using a standard growth framework, which is, however, not suitable for an expanded analysis of impacts of an earthquake.

At the empirical level, a recent study is done by Selcuk and Yeldan (2001). They attempt to estimate the transition path of the Turkish economy to its new equilibrium after the devastating 17 August 1999 Izmit earthquake. Selcuk and Yeldan (2001) focus on the impact of an earthquake by looking at the macroeconomic implications of a 10 percent capital stock loss together with a 15 percent labor force loss. Their simulation results suggest that the initial impact of the earthquake on GDP may range from –4.5 percent to +0.8 percent conditional upon policies followed by policymakers and international donors.

An earthquake, however, is a lot more than death tolls and an abrupt depreciation of physical capital. One aspect that has received little attention is that an earthquake’s leveling effect on physical stock is asymmetric. In many instances, the economic loss of an earthquake on residential stock (we also call it accommodation units and unproductive capital throughout the

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6 Oulton (1993) also considers a labor-leisure choice in the Cass-Koopmans framework. Then, the recovery is even more rapid, being virtually complete within a decade.

7 Others are welfare implications of earthquakes and policy responses for restoring long-run equilibrium of an economy. The latter question is partially addressed in the fifth chapter of this manuscript.
study) is much larger than the loss on productive capital stock (*e.g.*, factories, machines, *etc.*).\(^8\) Perhaps the main reason why earthquakes have an asymmetric impact on capital is that the building quality is different between the two types of capital. In particular, this study builds on the assumption that building-quality for productive capital is higher than for unproductive capital.\(^9\) There may be several reasons for this. First, investment in productive capital is made to reap profits today and tomorrow. This can only be achieved by minimizing all calculable risks, including those of physical shocks, from the start. Thus, productive capital can be expected to have on average a better quality. Second, legal construction requirements may be more strictly controlled and followed in construction of productive capital than of unproductive capital. Third, productive capital may have links with foreign productive capital, also for developing countries, in the age of globalization. Production has been standardized across the world, and such standards are not limited to goods and services but cover in also the ‘production-environment’. Thus, higher building standards of developed countries are also imposed on manufacturing units of developing countries.

Instead, unproductive capital, especially housing units, may not always fulfill the required quality to stand earthquakes. This is especially true for developing countries. With financial markets underdeveloped, most

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\(^8\) Albala-Bertrand (1993a, p.47) supports our argument by saying “social sector and especially (...) housing is the most affected subcategory (...) of earthquakes”. A striking example to our argument is the recent 17 August 1999 Izmit earthquake of Turkey. A few days after the earthquake, all private businesses were able to recommence their manufacturing activities. It has become clear that the main destruction of the earthquake was on accommodation units and on public infrastructure.

\(^9\) An alternative way of abstraction is to consider that productive capital only consists of machines and free from risks of destructive effects of earthquake. In that case, all buildings ‘sheltering’ productive capital would also be counted in the category of unproductive
accommodation units are self-financed, and therefore, in order to minimize construction costs, constructed at lower quality levels. Building traditions also contribute to the low quality of accommodation units. Furthermore, policymakers, especially local authorities, seem to tolerate low quality housing units due to the low-income of these people. Construction regulations are simply overlooked by inhabitants, by local authorities, and even by governments.\(^\text{10}\)

If an earthquake hits the capital stock asymmetrically (based on the arguments raised above), then its implications must also be different from what the standard homogenous-capital models suggest. Such heterogeneity, for example, may cause shifts in the allocation of resources across the competing sectors after an earthquake, or other welfare implications. Similarly, the right policy suggestions can only be made if a model captures the most basic feature(s) of the problem. In short, when earthquakes hit capital stocks asymmetrically, which we argue it does, then we need to heterogenize capital in order to understand better its direct and indirect implications and to suggest the right policies.

In order to better understand the transitional dynamics and possible long-run implications of earthquakes, next we develop a dynamic general equilibrium model. More specifically, we extend the two-sector Uzawa model into a three-sector model by adding a housing sector (see Uzawa 1961 and 1963). The Uzavian framework helps us (i) to heterogenize the physical capital, and (ii) to skip intertemporal decision-making tradeoffs of consumers, that would complicate technical analysis. Our motivation in

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\(^\text{10}\) For example, in the recent experience of Turkey, it became clear that local authorities ‘closed their eyes’ to extra stories illegally built in the earthquake-risky area, the latter were one of the main reasons of the high death tolls and the large number of building collapsing.
employing the Uzawa model is its global stability property. In addition, the fact that our model has two state variables indicates that it would be extremely difficult to study transitional dynamics in any other approach. This makes the Uzavian approach also rather attractive for our research interests.

We would like to make three points clear about how we constructed the model. First, the Uzavian model, which is an extension of Solow setup, implies exogenous saving rates out of income that defines the allocation of income among alternative uses (i.e., how much is used as gross investment in housing sector, etc.). In particular, we focus on the short-run and long-run growth impacts of changes in these saving rates triggered by earthquakes. We argue that an exogenous savings assumption makes this model fit better to the case of a developing country in understanding the growth implications of an earthquake. Our intuition is as follows: we observe that capital markets are less developed in developing than in industrialized countries. Some asset-capital investment options may therefore be very risky, and shifting from one asset to another may therefore face higher transaction costs. Consequently, agents in developing countries may tend to allocate their savings among alternative uses at predetermined rates in order to hedge themselves against uncertainties. Evidently, real estate investment will often be used for this purpose. Thus, an exogenous saving-rate assumption may capture the precautionary behavior of households in developing countries.

Second, in the model we assume that an earthquake does not lead to any casualties. Otherwise, especially in case of heavy casualties, per capita housing stock would increase after an earthquake. As our focus of research is on the growth effects of an earthquake due to changes in physical capital,
we need to isolate them from other changes. Similarly, we ignore the hazardous effects of an earthquake on productive capital for the matter of focus. Hence, we interpret the asymmetric impact of earthquake on unproductive and productive capital at an extreme, assuming that the latter is free of any risk while the former is exposed to an earthquake at full risk. For the sake of illustration, we could think of two types of capital, each located in a different region.

Third, as Albala-Bertrand (1993a) and Bull (1994) advance, the economic impact of natural disasters will not be confined to its one-time physical damages only. Some other implications of (physical) shocks may appear later in time. For example, while damages to properties and casualties are among the initial implications of an earthquake, a reduction in activity of suppliers, in consumption, in tax revenues, as well as a rise in epidemics, in individual and family income imbalances, and in ecological changes will most likely appear in time. In the literature, it is common to group these effects under two headings, namely *direct effects* and *indirect effects*. The former one is used rather to mean the effect of an earthquake on *stock variables* (e.g., physical capital, labor stock). The latter refers to the impact of an earthquake on *flow variables*. Albala-Bertrand (1993a, p.19) explains the indirect effects as follows:

“(...) [The] indirect effects can be defined as the consequences of the disarticulation of social and economic frameworks brought about by the physical losses to base units and intermediating channels”.
In this chapter, we consider indirect effects as changes in flow variables after an earthquake.

As we argued above, our focus is more on the indirect effects of a devastating earthquake than on its direct effects. Given the global convergence character of the setup that we use, it is obvious that the model would return to its long-run equilibrium, independent of the intensity of the physical shock (direct effect). Indirect effects, on the other hand, which capture changes in flow variables, may lead to lower or higher short-run or long-run growth rates and income levels, depending on the direction and permanence of the change. Here, we capture indirect effects by changes in exogenous saving rates. The income is split between the consumption, investment, and housing sectors according to an exogenous rule. The shock is assumed to flatten out the housing stock substantially, while the population and capital stock are unchanged. Hence, economic agents start to revise their resource allocation decisions in terms of savings in order to accelerate the housing accumulation in the transitional period, and/or to increase their housing quality in the long-run. We call the former ‘response analysis’ and the latter ‘comparative statics’ in our study. We find that the economy experiences a fall in the growth rate and income level if the economic decision maker is short-sighted and prefers a quick recovery of the lost stock. By contrast, if the decision maker has a long-term vision, then accelerating the size of productive capital by increasing the corresponding saving rate will generate higher income and growth rates. The trade-off will regard the choice of time-span for rebuilding the housing stock, which is an argument of utility.

The organization of the chapter is as follows. In section two, we review what the standard Solow model entails about implications of an earthquake
for the sake of completeness. The third section presents that model. The fourth section discusses transitional and possible long-run implications of an earthquake. The contribution of this section is a further expansion of the literature towards understanding the indirect effects of an earthquake. An interesting finding of this section is that stimulating productive investment after an earthquake may be the superior policy to accelerate housing accumulation after an earthquake. We also show that an earthquake may have long-run implications if one would start to deal with building quality. The fifth section concludes the paper.

4.2 The Basics

It is very instructive to look at what one-sector Solow model tells us about the implications of an earthquake, because our model is basically an extension of the Solow (1956) model. The fundamental Solovian model says that an earthquake may have some temporary stock effects in the very short-run, but cannot have any significant effect on the long-run. To show this, let us take up the Solovian model at its most basic form.

Let us suppose that there is a one-sector economy, operating under the standard neoclassical paradigm. Assume that the production function is Cobb-Douglas and defined as

\[ Y = K^\alpha L^{1-\alpha} \]  

(4.1)

where \( Y \) is the aggregate composite output, \( K \) is the aggregate physical capital stock, \( L \) is the labor stock (population), and \( \alpha \) is the capital elasticity.
of output. As usual, suppose that the population grows at a constant rate \( n \) and the initial population level is normalized to one. Gross investment is defined as net investment, \( \dot{K} \), plus depreciation, \( \delta K \), where \( \dot{K} \) denotes the derivative of a variable with respect to an infinitesimal time change, \( dK/dt \), and \( \delta \) is the rate of depreciation. The gross savings are assumed to be equal to a constant fraction \( s \) of aggregate output (national income) in this closed-economy with no-government. Suppose that the savings-investment balance is satisfied at each time. Thus, we obtain the fundamental equation of (Solovian) growth, that is,

\[
\dot{k} = s \cdot k^\alpha - (n + \delta)k. \tag{4.2}
\]

Equation (4.2) is a differential equation where per capita capital, \( k \), is the dependent variable and time, \( t \), is the independent variable. Algebraically, it is easy to solve the first order nonlinear differential equation defined in Equation (4.2). The solution is

\[
k(t) = \left[ \frac{s}{n + \delta} + \left( k_0^{1-\alpha} - \frac{s}{n + \delta} \right) \cdot e^{-(1-\alpha)(s+\delta)t} \right]^{\frac{1}{1-\alpha}}. \tag{4.3}
\]

for a given \( k(0) = k_0 \). Recall that the steady state solution of equation (4.3) is the limit of that solution when time goes to infinity, that is,

\[
\lim_{t \to \infty} k(t) = \left[ \frac{s}{n + \delta} \right]^{\frac{1}{1-\alpha}}. \tag{4.4}
\]
Neither $k$ nor other unknowns of the model grow at steady state.

For investigating the growth implications of an earthquake in the transitional period, the best (indeed, the only) measure in this setup is the initial capital stock. This is so because the capital stock at any time but at infinity can be traced back to its initial value, i.e., there is a one-to-one correspondence between the capital stock and the initial capital stock in the transitional period. A simple calculation shows that $\frac{\partial k(t)}{\partial k_0} > 0$, i.e., the direction of change in capital per capita is positively related to a change in initial capital stock in the transitional period. This implies that a one-time decrease in the initial capital stock will be accompanied by an abrupt decrease in the capital per capita at time $t$, for $t \in (0, \infty)$. Thereafter, capital per capita will increase steadily and catch-up with the original path in the long-run.\footnote{To show these results more concretely, we also take specific parameter values and run equation (4.3) for 150 periods. We assume that $s=0.20$, $n=0.01$, $\delta=0.03$, $k(0)=1$, and $\alpha=0.30$. Let us call ‘normal path’ the undisturbed time path that the capital stock per capita will follow. When we run equation (4.3), we see that our hypothetical economy reaches 93% of the steady state in 100 periods. Next, we introduce a once-and-for-all shock into the model in terms of a 50% percent reduction in initial capital stock. This shock aims to capture the speed of absorption of stock effects of an earthquake by our hypothetical economy. Let us call the new path with initial capital reduction as the modified path. Our calculations show that the hypothetical economy will renew (accumulate) its capital stock at such a pace that it will catch-up up to 99% percent of the normal path-capital stock in}

The main drawback of the basic Solovian model from the viewpoint of our analysis is that it is a one-sector growth model. A one-sector growth model is a good approximation if the impact of a shock is symmetric across the economy. However, as we have discussed in the introduction, empirics show that earthquakes have a relatively strong impact on the housing stock. For example, it was estimated that in the 17 August 1999 earthquake in Turkey more than 200,000 accommodation units were leveled or damaged...
significantly, while there was only very minor damage on manufacturing units (productive capital). A one-sector model cannot explain the implications of such an earthquake. We need a non-uniform treatment of the capital stock in order to capture the asymmetric impact of an earthquake on an economy. Starting from this observation, we develop a three-sector version of Hirofumi Uzawa’s two-sector growth model in order to investigate the growth implications of an earthquake. The next section introduces the model.

4.3 A Three-Sector Growth Model

An (augmented) Uzavian framework provides us a perfect setting for cases where capital is treated non-uniformly. First, we are able to develop a better understanding of the direct effects of an earthquake. Second, an exogenous savings assumption allows us to investigate the indirect implications of an earthquake on the model economy. Third, the global stability property of the model assures that the system converges to its steady state irrespective of the degree of shock. The details of the model are as follows.

Consider an economic system consisting of investment-goods, $Y_I$, housing, $Y_H$, and consumption-goods, $Y_C$. Investment goods are needed to produce new goods (any type). Housing and consumption goods are argument of utility. The difference between the two is that the housing stock accumulates while consumption cannot, and households ‘consume’ the service generated by the stock. Suppose that production is subject to

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100 periods (i.e., 92% of steady state). Hence, an economy absorbs abrupt but non-continuous shocks.
constant returns to scale in all sectors and that marginal productivity of each factor is positive and diminishing, assumptions that are borrowed from one-sector neoclassical models. Our model, like Uzawa (1961, 1963) has two parts: a short-run analysis and a long-run analysis. Let us first look at the former one.

### 4.3.1 Short-Run Equilibrium

Under a perfectly competitive market assumption

\[ Y_i = F_i(K_i, L_i) \quad i = I, H, C \]  

\[ p_i \frac{\partial F_i}{\partial K_i} = r, \quad p_i \frac{\partial F_i}{\partial L_i} = w \]  

\[ K_I + K_H + K_C = K \quad L_I + L_H + L_C = L \]

where \( K_i \) and \( L_i \) are quantities of capital and labor employed in sector \( i \), \( p_i \) be the price in sector \( i \), \( r \) and \( w \) the returns to capital and the wage rate, \( K \) and \( L \) the aggregate quantities of capital and labor, and \( i = I, H, C \).

Equation (4.5) represents the production function of the \( i^{th} \) sector. Equation (4.6) is the familiar factor-employment condition. Equation (4.7) is the factor-constraint equation. Let \( y_i = Y_i / L_i \), \( k_i = K_i / L_i \), \( k = K / L \), \( \rho_i = L_i / L \), and \( \omega = w / r \). Equations (4.5)-(4.7) can be expressed as:

\[ y_i = f_i(k_i) \quad i = I, H, C \]
\[
\omega = \frac{f_i(k_i)}{f_i'(k_i)} - k_i \quad (4.9)
\]
\[
\sum_i \rho_i k_i = k \quad (4.10a)
\]
\[
\sum_i \rho_i = 1 \quad (4.10b)
\]

In order to proceed further, we need to define production functions. Let us suppose that production technologies are of the Cobb-Douglas type in all sectors. More specifically, suppose\(^{12}\)

\[
y_i = k_i^\alpha \quad y_H = k_H^\gamma \quad y_C = k_C^\beta.
\]  
\[
(4.11)
\]

Then, equation (4.9) becomes

\[
\omega = \left(\frac{1-\alpha}{\alpha}\right) k_i = \left(\frac{1-\gamma}{\gamma}\right) k_H = \left(\frac{1-\beta}{\beta}\right) k_C.
\]  
\[
(4.12)
\]

We can also deduce that (cf. equation (4.6))

\[
\frac{p_H}{p_C} = \left(\frac{1-\beta}{1-\gamma}\right) \left(\frac{y_C}{y_H}\right)
\]  
\[
(4.13)
\]
\[
\frac{p_I}{p_C} = \left(\frac{1-\beta}{1-\alpha}\right) \left(\frac{y_C}{y_I}\right).
\]  
\[
(4.14)
\]

\(^{12}\) The only assumption required is \(\beta > \gamma > \alpha\). This is a natural extension of the assumption made in original Uzawa models. It reads that the capital intensity of the consumption goods sector is higher than the capital intensity of the housing goods sector, which is higher than that of capital goods.
Equations (4.12)-(4.14) follow from the free movement of factor (across sectors) assumption.\(^\text{13}\)

Finally, we need to define the demand side of the model in order to find the short-run equilibrium. First, let us note that Gross Domestic Product (GDP), say, in consumption goods prices, is

\[
Y = Y_C + \frac{p_I}{p_C} Y_I + \frac{p_H}{p_C} Y_H
\] 

(4.15)

In an autarkic economy with no government, GDP in consumption-good prices (henceforth real GDP) is equal to real (national) income. The question that arises is how factor-income is allocated among alternative goods. We shall assume that the (short-run) demands for alternative uses of factor income are given exogenously by saving rates, as in Solow (1956) for a one-sector economy and as in Uzawa (1963) for a two-sector model.

Let us suppose that, at any moment of time,

\[
s_i Y = \frac{p_I}{p_C} Y_I
\] 

(4.16)

\[
s_H Y = \frac{p_H}{p_C} Y_H
\] 

(4.17)

where \(s_i\) and \(s_H\) are exogenous savings rates for investment goods and housing, respectively. Equation (4.16), for example, says that a certain

\(^{13}\text{Equations (4.13) and (4.14) follow from profit maximization with respect to labor. Obviously, we could do the same maximization with respect to capital. Then, in the subsequent analysis, we would have one more step to do to get the results.}\)
amount of income is spent on housing goods in terms of consumption goods prices. Obviously, the rest, \((1 - s_l - s_H)Y\), constitutes the demand for consumption goods. Consequently, we are equipped with the necessary equations to solve the short-run equilibrium of this model.

Let us start from equations (4.10) and (4.12), which, after some substitution, gives

\[
\left(\frac{\beta - \alpha}{\beta(1 - \alpha)}\right)k_C \rho_C + \frac{1 - \beta}{\beta} \frac{\alpha}{1 - \alpha} k_C + \frac{1 - \beta}{\beta} \left(\frac{\gamma}{1 - \gamma} - \frac{\alpha}{1 - \alpha}\right) k_C \rho_H = k
\]

(4.18)

To be able to express, for example, \(k_C\), in terms of given \(k\), we need to know \(\rho_C\) and \(\rho_H\). Equations (4.16) and (4.17) can be used to express these two unknowns in terms of \(k_C\). Note that the following is implied by these two equations:

\[
\frac{s_l}{1 - s_l - s_H} = \frac{Y_l}{Y_C} \frac{p_l}{p_C}
\]

(4.19)

\[
\frac{s_H}{1 - s_l - s_H} = \frac{Y_H}{Y_C} \frac{p_H}{p_C}
\]

(4.20)

Using equations (4.13) and (4.14) in (4.19) and (4.20) gives us

\[
\frac{s_l}{1 - s_l - s_H} = \frac{1 - \beta}{1 - \alpha} \frac{\rho_l}{\rho_C}
\]

(4.21)

\[
\frac{s_H}{1 - s_l - s_H} = \frac{1 - \beta}{1 - \gamma} \frac{\rho_H}{\rho_C}
\]

(4.22)
From equation (4.22), we can express $\rho_H$ in terms of $\rho_C$:

$$
\rho_H = \frac{s_H - \gamma}{1 - s_H - \frac{1}{1 - \beta}} \rho_C
$$

(4.23)

Substituting $\rho_I$ by $1 - \rho_C - \rho_H$ in equation (4.21) and also by using equation (4.23), we can solve $\rho_C$ (and thus others):

$$
\rho_C = \frac{(1 - \beta)(1 - s_I - s_H)}{(1 - \beta)(1 - s_I - s_H) + (1 - \alpha)s_I + (1 - \gamma)s_H}
$$

(4.24)

Let us for simplicity call the denominator in equation (4.24) $z_2 > 0$. Note that $z_2$ can be also expressed as $[(1 - \beta) + (\beta - \alpha)s_I + (\beta - \gamma)s_H]$. Substituting the solutions of $\rho_C$ and $\rho_H$ (not shown) in equation (4.18) gives us (after some algebra) an expression for $k_C$:

$$
k_C = \frac{\beta}{(1 - \beta)} \frac{z_2}{z_1} k
$$

(4.25)

where $z_1 = [\beta - (\beta - \alpha)s_I - (\beta - \gamma)s_H] > 0$. An interesting characteristic of $z_1$ and $z_2$ is that their summation is equal to unity. Equation (4.25) gives the short-run equilibrium of capital per capita in consumption goods for a given aggregate capital stock per capita. Then it is simply a matter of substitution to solve for other variables, like $k_I$ or $k_H$ in the short-run.
Thus, for example, the short-run equilibrium capital-labor ratio in the investment goods sector, by using (4.12), is

\[ k_i = \frac{\alpha z_2}{1 - \alpha} z_1 k. \]  

(4.26)

Note that equation (4.26) is an augmented version of the respective two-sector Uzavian solution.

### 4.3.2 Long-Run Equilibrium

In this augmented Uzavian model, we have two stocks, physical capital stock and housing. The critical difference between the two is that the former is both an output and a factor of production while the latter is only an output. In addition to this, we presume that housing goods, though accumulates, behaves very much like a consumption good in the model because of the assumption that a unit of housing stock is equal to a unit of housing service, an assumption that is frequently made in the housing literature.\(^{14}\) In that sense, housing goods are not different from consumption goods.

Let us suppose that the two stock variables grow according to the following rules:

\[ \dot{K} = Y_i - \delta_k K \]  

(4.27)

\[ \dot{H} = Y_{II} - \delta_H H \]  

(4.28)
It is worth to repeat here that there is a big qualitative difference between these two accumulation equations. While the former leads to accumulation of a factor of production, $K$, the latter results in accumulation of an output (or unproductive investment good). The trade-off in the model is obviously the allocation of physical capital stock and labor for alternative uses. Clearly, what we are after is the tradeoff between physical capital and housing accumulation.

We can determine the long-run equilibrium from the fundamental equation of (Solovian) growth expressed in per capita. The per capita version of equation (4.27) is:

$$\dot{k} = y_{ij} \cdot \rho_j - (n + \delta_k)k.$$  \hfill (4.29)

Since

$$\rho_j = \frac{(1-\alpha)s_{j}}{z_2},$$  \hfill (4.30)

using equations (4.11), (4.26) and (4.30) gives:

$$\dot{k} = \left(\frac{\alpha}{z_1}\right)^{\alpha} \left(\frac{1-\alpha}{z_2}\right)^{1-\alpha} s_{j} k^\alpha - (n + \delta_k)k.$$  \hfill (4.31)

Apparently, equation (4.31) is the augmented version of the standard one-sector fundamental equation of growth and therefore standard Solovian

\footnote{See, for instance, Smith, Rosen, and Fallis (1998).}
results apply. For example, steady state growth of capital per capita is zero
and the long-run equilibrium value of \( k \), \( \bar{k} \), is:

\[
\bar{k} = \left( \frac{\alpha}{z_1} \right)^{\alpha/(1-\alpha)} \left( \frac{1-\alpha}{z_2} \right) \left( \frac{s_I}{n + \delta_K} \right)^{1/(1-\alpha)}
\]  \hspace{1cm} (4.32)

Substituting back the long-run equilibrium value of \( k \) into short-run
equilibrium values of sector-specific capital yields the long-run equilibrium
values of these variables. For example, in the investment goods sector, the
long-run equilibrium of the capital-labor rate is

\[
\bar{k}_I = \left( \frac{\alpha}{z_1} \right)^{1/(1-\alpha)} \left( \frac{s_I}{n + \delta_K} \right)^{1/(1-\alpha)}
\]  \hspace{1cm} (4.33)

Finally, we can return to equation (4.28), which is of main interest to us.
First, let us express it in per capita terms:

\[
\dot{h} = y_H \rho_H - (n + \delta_H)h = \left( \frac{\gamma}{z_1} \right)^\gamma \left( \frac{1-\gamma}{z_2} \right)^{1-\gamma} s_H k^{\gamma} - (n + \delta_H)h
\]  \hspace{1cm} (4.34)

where \( h = H/L \) is per capita housing. It is easy to see that per capita
housing, like capital stock, does not grow at the steady state. The steady
state value of per capita housing is:

\[
\bar{h} = \left( \frac{\gamma}{z_1} \right)^\gamma \left( \frac{1-\gamma}{z_2} \right)^{1-\gamma} \frac{s_H}{n + \delta_H} k^{\gamma}
\]  \hspace{1cm} (4.35)
Apparently, per capita housing is a constant multiple of the per capita physical capital stock in the steady state. Putting it differently, the ratio of the stock of houses and apartment buildings to machines and other investment goods is constant in the steady state. This result is intuitive and expected given that the model does not generate endogenous growth and that there is global stability in the model, which is shown in the next subsection.

4.3.3 Stability Analysis

In this subsection we examine the stability properties of our model. Equations (4.31) and (4.34) determine the path of $k$ and $h$ for given values of $k(0)$ and $h(0)$. The phase diagram in Figure 4.1 below shows the nature of the dynamics.
Figure 4.1 Global stability in the augmented Uzawa model

The vertical line at $\bar{k}$ corresponds to the condition $\dot{k} = 0$ in equation (4.31). This equation also implies that $k$ is rising ($\dot{k} > 0$) for $k < \bar{k}$, and falling for $k > \bar{k}$. Thus arrows point right to the left of $\bar{k}$ and left to the right of $\bar{k}$, respectively. The solid curve in Figure 4.1 represents equation (4.34) for any $k$. This equation implies that $h$ is rising for values of $k$ below the solid curve and rising for values of $k$ above the curve. Thus, the system exhibits global stability. Whatever the destructive effect of a physical shock to the system, the economy will converge to the steady state. This property of our model fits in very well with the empirical regularity that economies recover from earthquake shocks.
4.3.4 More on the Transitional Dynamics\textsuperscript{15}

Productive Capital

The power of two-sector growth models with exogenous saving rates is that the dynamic stock functions allow for an algebraic treatment of transitional dynamics of stock variables. Note that equation (4.31) is a simple extension of equation (4.2). After replacing $s$ by $s' = \left(\alpha / z_1\right)^\alpha \left((1 - \alpha) / z_2\right)^{1 - \alpha} s_1$ in equation (4.2), solving the differential equation is straightforward, and it gives:

$$k(t) = \left[\frac{s'}{n + \delta_k} + \left(k_0^{1 - \alpha} - \frac{s'}{n + \delta_k}\right)e^{-(1 - \alpha)(n + \delta_k)t}\right]^{\frac{1}{1 - \alpha}}. \quad (4.36)$$

Now we have more tools (as much as more sectors) compared to a one-sector Solow-model. Not only once-and-for-all changes in initial values of stock variables, but also temporary or permanent changes in exogenous saving rates may be examined for understanding the implications of an earthquake.

A simulation of the capital path for a set of hypothetical parameter values reveals that the capital stock path starts from an initial value of one at time zero and, in about 225 periods, it converges to its steady state value, close to

\textsuperscript{15} In order to make our presentation clear and compact, we skip some illustrations but explain them briefly. These illustrations can be found in Kepenek et al. (2001).
6.73. Now, let us turn to the determination of the housing path of the model.

**Housing**

We need to solve the differential equation given in equation (4.34) in order to understand the dynamics of housing. First, note that we can re-write this equation as

\[
\dot{h} = s^s k^\gamma - (n + \delta_H)
\]  

(4.37)

where \( s^s = \left(\frac{\gamma}{z_1}\right)^\gamma \left(\frac{(1-\gamma)}{z_2}\right)^{1-\gamma} s_H \). We need to use the solution in equation (4.36) in equation (4.37), since the physical capital stock appears in the differential equation. The standard differential calculus brings us up to

\[
e^{(n+\delta_H) t} \cdot h(t) = s^s \cdot \int (k(t))^\gamma \cdot e^{(n+\delta_H) t} dt .
\]

(4.38)

Evidently, it is not possible to proceed further with a standard calculus. There are two possibilities. One is to assume that \( \gamma = 1 - \alpha \). In that case, it is easy to handle the integration because the non-linearity concerning the \( k \)-path in equation (4.38) disappears. Nevertheless, we shall refrain from undertaking any analysis under this special condition because \( \gamma = 1 - \alpha \) puts a ‘strong’ constraint on parameter values. More specifically, given the

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16 Parameter values are suggested as follows: \( n = 0.01 \), \( \delta_k = 0.03 \), \( \delta_H = 0.04 \), \( \alpha = 0.3 \), \( \gamma = 0.35 \), \( \beta = 0.4 \), \( s_f = 0.15 \), \( s_H = 0.15 \), \( k_0 = 1 \), and \( h_0 = 1 \). Note that our parameter assumptions satisfy the requirement that \( \beta > \gamma > \alpha \).
assumption of the model that \( \beta > \gamma > \alpha \), \( \gamma = 1 - \alpha \) implies that \( \beta > \gamma > 0.5 \) and \( \alpha < 0.5 \).

Given the general case \( \gamma \neq 1 - \alpha \), it is not possible to solve the integration in equation (4.38) via differential calculus due to the nonlinear form of \( k(t) \). We conjecture that

\[
\begin{align*}
    h(t) &= \left[ \frac{s''}{n + \delta_H} \right] \left[ \frac{s'}{n + \delta_K} \right]^{\gamma} \sum_{k=0}^{3} \frac{g}{g + \kappa} (-\gamma')_k y^k \left( \frac{1}{-a} \right)^k \left( \frac{1}{\kappa!} \right) + \\
    &\quad \left[ h_0 - \left( \frac{s''}{n + \delta_H} \right) \left( \frac{s'}{n + \delta_K} \right)^{\gamma} \sum_{k=0}^{3} \frac{g}{g + \kappa} (-\gamma')_k y^k \left( \frac{1}{-a} \right)^k \left( \frac{1}{\kappa!} \right) \right] e^{-(n + \delta_H)t} 
\end{align*}
\]

(4.39)

is the solution of equation (4.38). Using the same parameter values suggested above (cf. footnote 16) we find that the \( h(t) \) path converges to its steady state value in approximately 220 periods. We observe from the time path of the housing stock that, for the exploited parameter values, the behavior of the housing path is not much different from that of capital stock.

### 4.4 Implications of Catastrophic Earthquakes

In this section, we examine the implications of an earthquake. Before starting our analysis, we would like to clarify further several things. First, an earthquake may hit a model economy at its two different states, namely at

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17 See Annex D for the definition of variables and parameters, and derivations. We would like to thank C. Presura for his help with respect to the derivations.
its transitional period or at its steady state. Evidently, the model economy may react differently in these two states, and therefore the two must be analyzed separately.

Second, we conjecture that the savings rates exogenous to the system are ‘proper’ tools for gauging the indirect effects of an earthquake in our model. Actually, the exact use of savings rates is a matter of interpretation. If we interpret the model in the way that the decision-maker is an ‘undisclosed agent’ (i.e., if we refer to a market solution), then changes in saving rates represent ‘reactions’ of households and therefore can be safely classified under the category of indirect effects of an earthquake. On the other hand, as done usually, if we assume that a social planner is the decision-maker of the model-economy, then we may interpret these changes as policy tools of the social planner. In that case, after Albala-Bertrand (1993a, p.20), we may call these changes disaster responses.\(^{18}\) In our model, alternative interpretations do not make any difference, neither qualitatively nor quantitatively. We prefer to call our subsequent analysis response analysis.

Third, we ‘feel’ that the direct and indirect effects introduced by Albala-Bertrand can more easily be associated with the short-run. This led us not to use Albala-Bertrand’s terminology for analyzing the long-run implications of an earthquake, but to use the conventional growth terminology (i.e., comparative statics). The next subsection describes the direct and indirect implications of an earthquake in moderate detail when an economy is at its transitional state.

Last but not least, it is worth to remind that our results are constrained by the assumptions made. In that respect, had we assumed that an earthquake

\(^{18}\) He defines disaster responses as “a wide array of endogenous and exogenous reactions, measures, and policies to counteract, mitigate, and prevent disaster impacts and their effects”.

would also strike the population and/or productive capital, then that would have altered our results, especially the transitional ones.

4.4.1 Transitional Implications of an Earthquake on Housing

Direct Effects
Our analyses confirm that direct effects of an earthquake on housing are recovered ‘quickly’ by the model economy.\textsuperscript{19} Actually, given the global convergence property of our model, it is always true that any shock to any stock variable will be recovered in time. In that sense, it is less interesting to focus on the direct effects of an earthquake; more interesting results appear on its indirect effects.

Indirect Effects (Response Analysis)
Though convergence to the normal path is the main characteristic of our model, the social planner may prefer to accelerate the convergence process by transferring additional resources to be spent on housing after a catastrophic earthquake.\textsuperscript{20} More specifically, by enhancing investment in housing throughout increasing the saving rate out of national income at the cost of other sectors, the social planner may step up housing accumulation and thus the convergence of the modified to the normal path.

There are two saving rates that we can examine in order to understand the indirect implications of an earthquake. From the viewpoint of the social

\textsuperscript{19} For example, a 50 percent decline in the initial housing stock converges to 98 percent of the normal path value in 40 periods for the same set of parameter values defined above.

\textsuperscript{20} Non-response is an option but has not been common in general, especially on political grounds. Some level of policy response is always undertaken.
planner, while changing the saving rate for housing is a *direct tool* to overcome the negative effects of an earthquake on housing stock, a change in the saving rate for investment is an *indirect tool* for the same purpose. An increase in the saving rate for housing is direct in the sense that its impact is first and foremost on the stock of houses. On the other hand, say, a decrease in the saving rate for investment implies an increase in saving for housing as well as for consumption. Then, a decrease in saving for investment is an indirect tool of changing the path of housing. Here, we look at both effects in order to understand the implications of policy-maker responses during recovery from an earthquake.

Before starting to look at the indirect effects of an earthquake, it should be pointed out that in this and the next subsections, we shall use the idea of *marginal response path* in order to understand the response of the housing stock (and capital) to a shock. We define the ‘marginal response path’ as the path showing the *direction of response* of the *stock path* to changes in an exogenous variable/ parameter. That is, if, for example, the whole marginal response path has a positive value, then we infer that there is a positive relationship between the stock path and the variable under consideration at any time (*i.e.*, for any value). Hence, we get information about the response of a stock variable *over the full path* compared to the standard ‘one-time’ response analysis.

Figure 4.2 below illustrates the marginal response path of housing in response to a change in saving out of income for housing, $s_H$. 


The marginal response path of savings for housing is positive everywhere, which is in line with intuition. Thus, if, after an earthquake, the saving rate for housing increases temporarily, then this change would contribute positively to the housing stock. At low levels of housing stock, the $s_{H}$ elasticity of the housing stock is higher. Hence, the higher the stock, the higher the contribution of a unit change in $s_{H}$. Clearly, this contribution converges to a constant value because the housing stock itself converges to a constant level in the long-run.

Interestingly, the marginal response path of a change in the saving rate out of investment is also positive, given the parameter values. Figure 4.3 below illustrates this relationship.
This is an interesting result for two reasons. First, we may be inclined to believe that a decrease in the saving rate for investment may release some resources for extra housing. However, this is wrong. The investment sector is the engine of growth in the model. Therefore, any decrease in the productive capital not only leads to a decline in the investment goods sector but also to a decline everywhere else. Second, we will show in the subsequent section that a change in $s_I$ has ambiguous results on housing at the steady state, implying that the (strong) finding here may be an outcome of parameter values chosen or of being at a transitional state. The message to the policymakers from the analysis of this subsection is simple. Stimulating productive output via increasing $s_I$ may be the alternative way of advancing housing stock increases due to the fact that the productive
sector is the engine of the economy, \textit{i.e.}, causality runs from productive capital to housing. We advance this idea further in the next subsection. We will conjecture that our argument may be especially valuable for developing countries. However, let us first look at the impact of changes in $s_i$ and $s_H$ on productive capital.

\textit{The Impact of Changes in $s_i$ and $s_H$ on Productive Capital}

As we noted elsewhere in the text, our focus is on the implications of an earthquake on housing. Nevertheless, it is not possible to isolate the housing sector in our analysis because there is a ‘causality’ running from investment goods to housing, and hence all variables are interrelated.

If the social planner initiates a change in $s_i$ or $s_H$ for accelerating the accumulation of housing, she must also take into account the effect of these changes on capital accumulation. Simple algebra shows that $\frac{\partial k(t)}{\partial s_i} > 0$ and $\frac{\partial k(t)}{\partial s_H} < 0$. That is, an increase in the saving rate for capital raises the capital stock and a rise in the saving rate for housing lowers it. Hence, an increase in the savings for housing has a negative impact on the path of capital stock as a secondary effect.\textsuperscript{21} Thus, the indirect effects of an earthquake may be more intricate than it is thought at first.

\textit{Discussion}

Our analysis in the two subsections above makes it clear that a ‘rapid’ response after an earthquake in the sense of transferring more resources to
the housing sector (i.e., increasing $s_H$) may not always serve the goal aimed at. More specifically, increasing $s_H$ in response to losses in the housing stock due to an earthquake may trigger a slowdown in the growth path of productive capital, which may be costly to the economy. On the other hand, an increase in $s_I$ accelerates not only investment goods accumulation but also housing, though to a lesser extent (due to its indirect relationship). Hence, the result would depend on which of $\frac{\partial u(t)}{\partial s_H} = \frac{\partial y_C(t)}{\partial s_H} + \frac{\partial h(t)}{\partial s_H}$ and $\frac{\partial u(t)}{\partial s_I} = \frac{\partial y_C(t)}{\partial s_I} + \frac{\partial h(t)}{\partial s_I}$ is greater, under the assumption that the momentary utility function is defined as $u(t) = y_C(t) + h(t)$.$^{22}$ We note that $\frac{\partial u(t)}{\partial s_I} > 0$ but that $\frac{\partial u(t)}{\partial s_H}$ is ambiguous because the sign of $\frac{\partial y_C(t)}{\partial s_I}$ is unknown.$^{23}$ Hence, we may conclude that a direct response to housing losses by transferring additional resources to the housing sector may not really be a good policy in all cases, especially not in those cases where the duration of these transfers is long, e.g., 30 years. This finding leads us to argue that, after a catastrophic earthquake, undertaking policy changes supporting the productive sector, which has strong spillover effects on housing, may lead to ‘better’ results, especially in case of developing countries. Evidently, the immediate welfare implications of households may force policy-makers to

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$^{21}$ Our simulation analysis shows that the negative effect of an increase in the saving rate for housing on capital is rising but converging to a constant level. See Kepenek et al. (2001) for illustrations.

$^{22}$ Since we will not go further than pointing out the ultimate decision criteria, there is no need to extend the discussion into a more general utility function (e.g., CES type).

$^{23}$ Clearly, simulation analysis could be undertaken. We avoided this because results are highly dependent on how consumption goods and housing are weighted in the utility function. This brings additional complexity, and requires intertemporal modeling.
take immediate relief and recovery measures. We conjecture that international aid and foreign investment in housing may mitigate the pressure on the social planner, a point that will be emphasized again later in the text.

### 4.4.2 Long-Run Effects of an Earthquake

In this section, we analyze the hypothetical model’s predictions on the long-run implications of an earthquake. We argue that a permanent change in building-quality is a potential channel of long-run implications of an earthquake. In our model, this change can be captured by permanent changes in the exogenous saving rates. The argument goes as follows. Suppose that economic actors would decide to increase the building quality in response to the fact that their land is under the continuous threat of earthquakes (two good examples are Japan and Turkey). A better building quality implies either/both (i) higher expenditures out of income, and therefore an increase in the saving for housing at the cost of other rates, (ii) X-efficiency of buildings. The next issue is what the impact of such permanent changes on the long-run growth and income level would be. Below, we first look at the impact of permanent changes in the saving rates.

#### Changes in Saving Rates

The asymmetric impact of a strong earthquake on capital goods may lead to a permanent change in the saving rates of the model, capturing the behavioral change in an effort to increase the quality of housing. Such a behavioral change is probable after a large-scale earthquake. The social
planner/ households may start to be more concerned about the disastrous implications of earthquakes, and may start to channel larger part of their savings to housing at the cost of investment in productive capital and/ or spending on consumption. We show below that this may be a serious threat to the long-run performance of a (developing) economy, especially when such savings crowd out productive capital investment.

We undertake comparative-statics analysis in order to examine the long-run implications of such a shift. Clearly, we continue to use the well-known capital-intensities assumption that $\beta > \gamma > \alpha$. Table 4.1 below shows the results, where each column denotes the response of macro-variables to permanent changes in a particular saving rate in the steady state (for matter of completeness, we include real income per capita in the table).^{24}

In the table, the first column shows the response of per capita capital stock, housing, and income per capita to changes in the saving rate ‘out of income for investment goods’. In accordance with general intuition, such an increase in the saving rate increases the steady state level of the economy-wide capital stock per capita. The link is clear: when households increase their savings for investment goods, demand for productive capital rises. The induced demand is met by a rise in supply of investment goods. Thus, at each instant of time, more machines are produced and this positively contributes to the accumulation of productive capital stock. An unsettled result arises on the steady state level of housing, because of two countervailing factors. On the one hand, an increase in savings ‘out of national income for investment goods’ implies a reduction in resources for housing and therefore has inverse effects. On the other hand, such an increase in the stock of productive capital supports housing accumulation
due to availability of more resources. Hence, the ambiguity! Finally, an
increase in saving rate ‘out of national income for productive capital’
(investment goods) increases (national) income. This is in line with intuition
because capital is the engine of growth in our model.

<table>
<thead>
<tr>
<th></th>
<th>$S_I$</th>
<th>$S_H$</th>
</tr>
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<tbody>
<tr>
<td>$k$</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>$h$</td>
<td>?</td>
<td>+</td>
</tr>
<tr>
<td>$y$</td>
<td>+</td>
<td>?</td>
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</tbody>
</table>

In the table, the second column shows the response of economy-wide
capital, housing and income to changes in saving rate out of income for
housing. When households increase their savings out of national income for
housing, *ceteris paribus*, then the accumulation of capital is affected
negatively. This makes sense. A relative decrease in demand for investment
goods in equilibrium brings about a lower rate of capital accumulation.
Thus, the long-run steady state is affected negatively when housing demand
rises due to a rise in savings rate for housing.

Analogously, an increase in the saving rate out of national income for
housing goods increases the steady state level of economy-wide housing
stock per capita. However, an increase in savings out of national income for
housing has an ambiguous affect on the steady state level of income. Two

---

[24] We prefer not to present comparative-statics of sector-specific capital stock intensities to
offsetting factors work in this case. On the one hand, an increase in resources for housing lowers productive capital accumulation and thus availability of resources for further production in all sectors. On the other hand, housing production is itself an income-generating activity and therefore increases output and income.

We argue that our finding that changes in $s_H$ has negative effects on capital per capita may be valuable especially for policy-makers. The analyses suggest that permanent changes in quality preferences of households for housing may lead to a permanent decrease in capital per capita. Hence, we may conclude that a change to higher-quality housing may not always be the first-best strategy, especially in case of developing countries. This finding lead us to conjecture that a housing strategy, including opening the housing market to international investment in order to prevent permanent (as well as temporary) swings in investments from productive capital to housing, may be a wiser strategy from the viewpoint of long-run growth performance. In that way, both the quality of housing can be improved and a poverty-trap avoided.

**Changes in Depreciation Rates**

In this subsection, we analyze the implications of quality changes with an alternative parameter that we label X-efficiency of buildings. Quality improvements are not always achieved by higher expenditures. For example, using steel and wooden instead of concrete materials in building construction improves earthquake-resistance of buildings seriously. Or, keeping residential neighborhoods away from fault lines is also a simple but effective safety measure against hazardous effects of earthquakes. In those changes in saving rates, which is a straightforward extension.
cases, assuming a decrease in the rate of depreciation can capture the economic implications of such quality improvement, including those of one-time big shocks. Table 4.2 below shows the economic implications of an increase in X-efficiency of building construction. Again, we include capital and income in the table for matters of completeness.

Table 4.2 Implications of Quality Improvements in Housing
(measured via changes in the depreciation rate)

<table>
<thead>
<tr>
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<th>$\delta_K$</th>
<th>$\delta_H$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$k$</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>$h$</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>$y$</td>
<td>-</td>
<td>0</td>
</tr>
</tbody>
</table>

First, any increase in the quality of productive capital is of the utmost important for an economy, and has positive effects on the steady state value of productive capital, housing capital and income. Second, a quality improvement in housing has no effect on productive capital or in income, but only on housing (and thus implicitly on welfare). The reason for getting this ‘isolated’ result is that in our model causality is running from productive to unproductive capital. We conclude that policy-maker’s X-efficiency also contributes to overcoming adverse effects of earthquakes.
4.5 Conclusion

In this chapter, a three-sector growth model was developed in order to better understand the growth implications of an earthquake. An interesting characteristic of an earthquake is that it may be ‘selective’ in its impact on capital goods. This feature arises from the fact that the quality of capital varies significantly in its two different uses. While productive capital is built up according to the ‘modern’ norms of construction, housing buildings are constructed at low quality, by and large. This observation is especially true for developing countries, where households/governments try to reduce housing costs due to low-income. Thus, an earthquake becomes selective in the sense that it hits capital goods asymmetrically.

We first discussed the implications of an earthquake in the standard growth framework, and concluded that standard growth models suggest that an earthquake cannot have long-run implications on an economy. The weakness of standard models is that they only measure the direct effects of earthquakes.

Next, an augmented two-sector growth model was developed, where capital goods are heterogenized. This set-up is especially relevant for developing countries because these economies, relatively speaking, lack intertemporal choices. The model developed provided richer transitional dynamics and comparative statics analyses because it enabled to analyze both the direct and the indirect effects (response effects) of an earthquake.

Our transitional dynamics analyses showed that stimulating productive capital investment might be a good alternative domestic policy for stimulating rebuilding the housing stock after an earthquake, and concluded that foreign investment in housing (induced via providing market incentives
to these investors), instead, could be used in order to mitigate immediate welfare implications of homelessness.

Our long-run analyses were based on the premise that an earthquake can have long-run implications if housing-quality preferences change permanently. We used two tools in order to understand these possible long-run effects. First, changes in building-quality can be captured by changes in savings allocations. We showed that such changes, however, might have negative implications on the economy. Second, these changes can be analyzed by using a depreciation parameter. This part of our analysis showed the positive impact of higher building-quality on long-run performance (at least in the sense of accounting). Our long-run comparative statics analyses supported the argument that swings in savings from productive investment to housing may not be good for an economy, especially not for a developing one. We argued that opening the housing market to international investment might therefore be a good alternative strategy, because it might allow for better building quality without incurring large swings in domestic savings allocation.

The above model still may need improvement. First, welfare implications have not been explored explicitly. Homelessness has significant welfare implications and policymakers must take this into account. Second, human losses have not been considered. Human capital is an important argument of positive growth. When an earthquake hits a region, the human capital stock may ‘depreciate’ severely due to deaths, injuries, and migration, and this may not only lead to massive human suffering, but, may also have rigorous implications on the growth performance of an economy. Third, an earthquake itself is a stochastic event given the indeterminacy of its timing.
Therefore, a stochastic modeling approach may produce additional information. We leave these and further research areas to the future.