6 Epilogue

6.1 Introduction

This dissertation consists of a number of essays on shocks in deterministic growth models. We aimed at two things in this dissertation. First, to sharpen our understanding on the growth impact of drastic changes such as market shocks, natural shocks, and policy shocks. A better understanding of the role of shocks in growth processes helped us to identify (and hopefully to fill-up) gaps in the field of economic modeling and to use these findings to raise new questions. Second, we intended to initiate background work for analyzing the growth implications of shocks in a taxonomy. The issue of shocks has clearly not been analyzed sufficiently and systematically in the (deterministic) growth literature, even if many studies used some notion of shocks in their analysis in one way or another. This dissertation intends to provide a more systematic treatment of shocks in deterministic growth models.

In order to achieve that, each paper was designed to sharpen in one way or another our understanding of the growth impact of market shocks (input
prices and technology), policy shocks (taxes), and natural shocks (earthquake), and to systematically connect shocks with growth modeling.

This epilogue is organized as follows. First, a summary of our findings is presented in the next section. The next section hints a research agenda that can be drawn from our analysis.

### 6.2 A Summary of Findings

This dissertation contains five essays. The first one reviews the place of drastic changes in economic growth literature; each of the four subsequent chapters examines a particular shock and its consequences in a deterministic growth framework. The contribution of this thesis is threefold. First, it presents a new interpretation to the existing growth literature by placing some of the most basic growth literature in a taxonomy of shocks. We believe that this may in itself initiate further research on the growth impact of drastic changes. Second, the four core essays cover the issue of shocks with a wide variety of frameworks and techniques from the growth literature, ranging from the two-sector Uzavian growth model to the endogenous technological change framework. Third, we analyze the three types of shocks defined by our taxonomy. In two essays, we look at market and policy shocks, whereas in the other two essays, physical shocks are the focus. Hence, we discuss the growth impact of shocks in various frameworks. Next we will summarize the basic findings of each chapter.

The first chapter reviewed the growth literature from the viewpoint of shocks. We first gave a taxonomy of shocks, and pointed out that classifications of shocks are useful but that it would be more fruitful to stick
to one of them as the reference taxonomy. We argued that grouping shocks according to their sources was the best choice, because it allowed for a more detailed sub-grouping. Next, we reviewed basic contribution in the field of growth literature according to this taxonomy. The novelty of our effort was that, for the first time, to our knowledge, the growth literature has been reviewed according to a taxonomy of shocks. Our conclusion was that many growth-modeling work could be (re-) interpreted in terms of growth impacts of shocks, but that few of them really touched this issue explicitly. There seems to be plenty of room for further research on the growth implications of shocks.

The second chapter (the first of essays) was an extension of the Romer (1990) endogenous technological model in two ways. First, we included energy consumption of intermediates. Second, intermediates were made heterogeneous by assuming endogenous energy saving technical change. We analyzed market shocks (energy price shocks) and policy shocks (taxes on the intermediates) within this framework. Energy price shocks were exogenous in the model. We showed that a continuous energy-price rise would have negative effects on the growth rate of economy within our endogenous technological change framework due to the following mechanism. Increasing real energy prices led to corresponding rises in the user costs of intermediates and hence to a fall in profits on those intermediates. This diminished the incentive to produce newer, more productive intermediates (though the fall in this incentive was cushioned to some extent by the substitution possibilities between raw capital and energy implied by the Cobb-Douglas function). Hence, there would be less growth when an economy experienced negative real energy price shocks. The
contribution of this model to the literature was its success to show the negative growth impact of energy price shocks in a rigorous way.

Next, within the same framework, we examined whether research incentives subsidized by taxes (policy shocks) could diminish the negative growth effects of energy price shocks. We studied two policy changes that might stimulate further R&D in the model. In particular, we investigated the impact of an energy tax, with and without recycling in the form of an R&D subsidy. The former might be called the (pure) induced technological change case and the latter might be labeled a directed induced technological change. Nevertheless, we found that (additional) taxation on energy use did not generate induced technological change. Indeed, the mechanism worked in the reverse order. We found that introducing a tax would change the profitability of producing intermediates. Changes in profitability would influence the allocation of labor over its two uses: R&D and final output generation. This would change the steady state growth rate, apart from having level effects as well. We showed that growth would be negatively affected and a reallocation of labor from R&D towards final output would be observed in case of non-recycling taxes. In contrast, when taxes were recycled towards R&D sector, we observed that the introduction of an energy tax would raise the growth rate of output, while the tax would not work for a high share of R&D employment in total employment. In conclusion, we found that increasing input prices (with or without taxation) was not enough by itself to induce R&D efforts, which could have compensated the rising energy prices. Finally, we deduced that an energy-specific R&D sector had to be introduced into such models in order to denote induced technological change.
The third chapter (the second essay) investigated why drastic technological changes were introduced in clusters and what was the impact of such technology shocks on long-run output growth. We showed that drastic technological changes were cyclical because basic R&D was carried out only at times when entrepreneurial profits for incremental technologies of the prevailing technological paradigm fell close to zero. We also showed that drastic technological changes were the ‘genuine’ engine of growth in the long-run.

The chapter was relevant to shocks for several reasons. First, the model generated technology shocks. Interestingly, these technology shocks were cyclical, alternating between applied technologies and drastic technologies. The model showed that declining profit opportunities for incremental technologies of the prevailing technological paradigm were the source of cycles. Second, the shocks (cycles) were endogenous, which is rarely studied in the growth literature. The falling profits character of the complementary sector was not due to an assumption but a property that the model generated endogenously. Third, we found that shocks on R&D labor at levels could indeed be a good (and intuitive) source of ‘growth push’, contrary to the argument based on the ‘scale effects’ critique. This was because R&D labor could work on basic R&D only cyclically, so that it was not justified to raise the scale effects critique on such models. We concluded that a technology shock has a positive impact on the long-run to the extent that it is accompanied by the positive growth (shocks!!?) of complementary inputs.

The fourth chapter (the third essay) was an example of showing the possible impact of natural (physical) shocks on the transitional and long-run growth performance of an economy. On the one hand, strong, large-scale
earthquakes might cause substantial costs of life and capital. On the other hand, casual observation showed us that economies seem to recover from catastrophic earthquakes relatively quickly. This paper opened the black box concerning the growth implications of an earthquake. In the paper, we assumed that a catastrophic earthquake (a one-time permanent shock) hit housing stock. We studied the direct and indirect impacts of shocks at transitional and steady state levels. First, it was shown that the direct effects of an earthquake on housing were quickly recovered in a neoclassical economy. Second, we studied the indirect effects of earthquakes in the transitional period. We found that indirect effects of an earthquake in terms of changes in saving rates might have serious negative effects in the short-run. We demonstrated that it might be more beneficial to increase savings in favor of the capital good sector rather than of the housing sector after an earthquake, because investment into the productive sector implied more output in the future, even if the immediate welfare implications of housing loss could be high. We thus showed that a physical shock creates a trade-off between short-run and long-run welfare, where policymakers have to make a decision. Third, we examined the indirect effects of earthquakes in the long-run. We interpreted permanent changes in saving rates or in depreciation rates (X-efficiency of buildings) as an indicator of structural changes in the housing sector (e.g., an increase in building quality). We showed that permanent changes in saving rates and depreciation rates might have strong implications on the long-run values of variables in the model. For example, we showed that increases in savings out of national income for housing decreased the long-run capital stock. We concluded from this study that physical shocks may have serious impacts on an economy, not only
because of their direct effects, but also and particularly because of its indirect effects.

The fifth chapter questioned the belief that “all physical shocks would be recovered unconditionally, at least in the long-run”. Recall that the fourth chapter showed that economies converge to their normal path, at least in the long-run. The very source of this finding was the diminishing marginal productivity of ‘capital’ (capital is used as a generic word, referring to any input in production technology). So, we studied what would happen when the diminishing marginal productivity of capital assumption was removed from the production technology. To this end, we employed a specific technology, namely AK technology. We first showed that an AK technology produces constancy conditions among variables, implying a fixed ratio among quantities. The latter property distinguishes these types of growth models from conventional growth studies because the ‘natural convergence’ property as discussed in the first and used in the fourth chapter would work no longer after physical shocks. Next, we elaborated theoretically on feasible adjustment policies to recapture constancy conditions after a one-time permanent shock, as market forces were not able to restore equilibrium automatically. This raised the issue of the role for the government in recovering from a shock. We indicated that in the AK-modeling the role of a social planner is essential when there are constancy conditions among quantities, because market solution cannot really restore them (even if that would be socially optimal). The contribution of this chapter was to demonstrate (indirectly) that governments have to play a critical role after a natural disaster, and to offer a solution procedure for how to deal with shocks under constancy conditions.
6.3 Hints for Future Research

In his dissertation, Dietzenbacher (1984, p.266) states: “answers raise new questions, solutions define new problems, results call for a generalization or a sharpening, assumptions for a relaxation, gaps need to be filled up, and loose ends are to be tied up” (Dietzenbacher, 1984, p.267). This observation also holds for the present research. Below, we hint on prospective issues in general and in specific questions that could follow up our contributions.

This manuscript clearly is not a complete work on the growth effects of shocks, but rather an initiation towards a more systematic work. In that respect, we were unable (i) to touch on many growth setups that could be analyzed from the viewpoint of shocks, (ii) to give an answer to all shocks-specific research questions that were brought forward in the introduction. Any research on these lines will contribute significantly to the further understanding of the growth effects of shocks.

Our research would also suggest follow-up research on a number of specific issues. First, a weakness in the model of the second chapter (on energy-price shocks) was the exogenous energy supply assumption. Two interrelated extensions of this work are possible from the perspective of growth effects of shocks. Firstly, if energy is interpreted as a carbon-based (nonrenewable) energy stock, than the most natural next question is the growth effect of ending energy supply shocks. We are aware that assuming increasing energy-prices refers to the same problem from the other side (duality!) in the sense that Hotelling’s rule states very clearly that increasing prices is a salient feature of deteriorating stocks. Nonetheless, the two are not the same at all times because a smooth deterioration of the stocks cannot
be secured in an endogenously growing economy. In particular, if energy consumption is foreseen as a function of technology and the growth rate, then (i) the more the economy grows, the more we need energy, (ii) the more technology advances, the more we can potentially save on energy resources. Subsequently, (endogenous) energy consumption can hardly follow a smooth path and we need to know more on the interrelationship between technology, endogenous growth and nonrenewable energy stocks.

Secondly, technological advance not only saves the use of nonrenewable energy but also brings into stage alternative energy resources. Hence, the growth effects of introducing alternative energy resource shocks have to be understood as well. The growth effect of such shocks would not necessarily be positive because, say, a switch from carbon-based energy resources to non-carbon based energy resources can raise costs, at least at the time of switch, especially if adjustment costs of capital from the former to the latter are high.

Second, physical shocks in general and natural shocks specifically have been rarely studied in the growth literature. A reflection of that disinterest can be observed from a handful studies on the growth implications of earthquakes, a frequent and destructive natural shock observed across the globe. Our work is a pioneering attempt in that direction, but contains still many weaknesses. One is that we do not consider quality of housing construction in our model. Such a consideration leads to either replacement of old or renewal of existing buildings. We only examined the case that destructive effects of earthquakes cause a change in saving rates. Another reflection of earthquakes could be a change in preferences towards a higher quality in housing, however our model has not touched the latter issue, but
such an extension would contribute to our understanding of the indirect effects of earthquakes.

Third, heuristically speaking, the issue of the optimality ratio seems to be totally ignored in the economics literature. This issue, however, might well be more important than it seems at first sight because fixed ratios seem to be a regular fact of economic life. We therefore argue that further work both on the properties and application of constancy conditions is necessary, and could contribute significantly to our understanding of the implications of shocks in several contexts.