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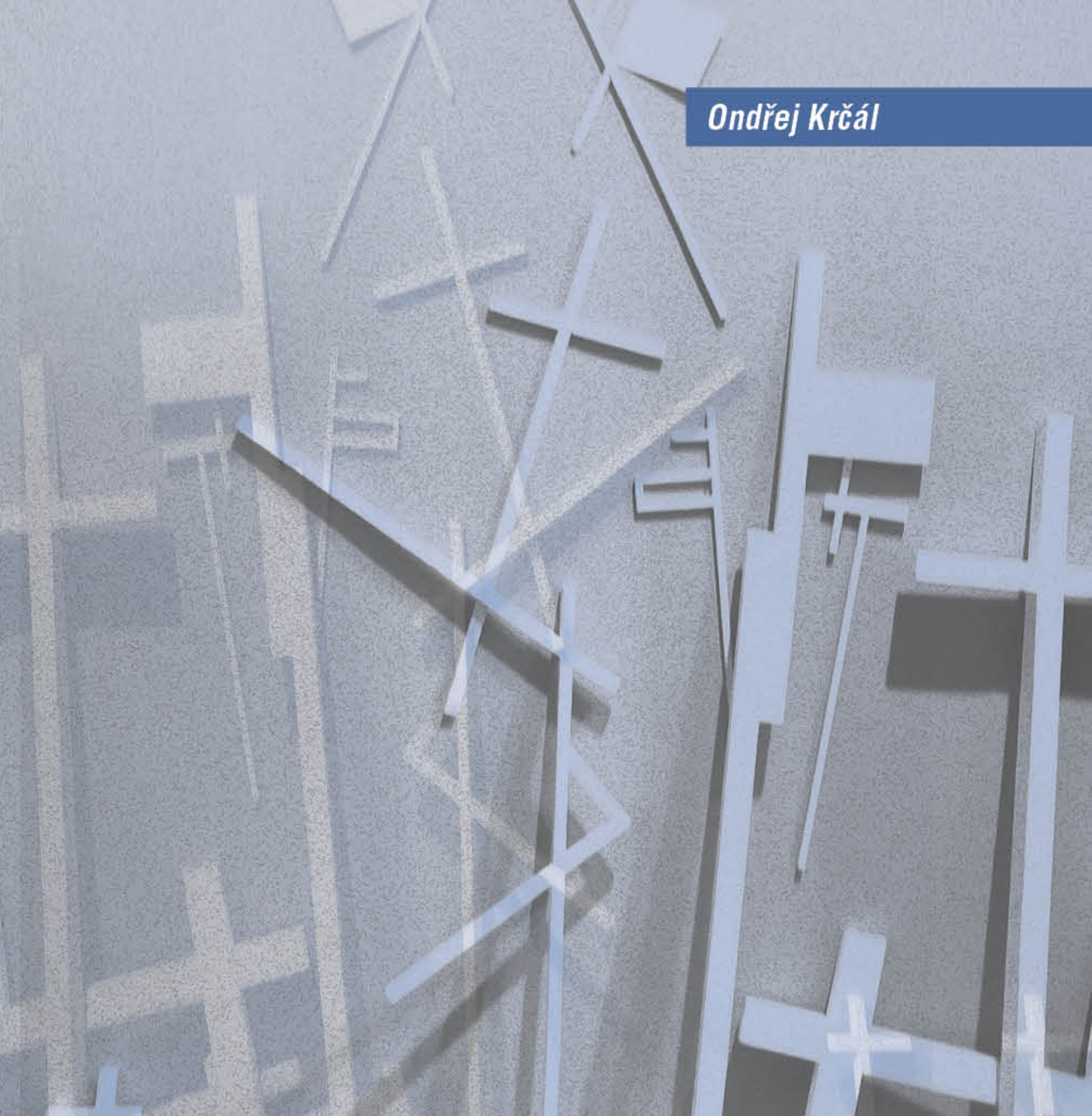
An Explanation of the Inverted-U Relationship between Profitability and Innovation

Ondřej Krčál



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Introduction

The literature on the relationship between competition and innovation has attracted the attention of the economic profession ever since the first publication of Schumpeter's *Capitalism, Socialism and Democracy* in 1942. In this work, Schumpeter argued that firms with market power might be more innovative than firms in competitive industries. Subsequently, many economists supported the Schumpeterian hypothesis that market power is good for innovation. Other important groups of economists argued that competition encourages innovation, or that innovation thrives at an intermediate level of competition.

The actual form of the relationship between innovation and competition, measured typically using profitability or concentration, is highly important for public policy, especially for competition policy, industrial policy and for the choice of the optimal intellectual property regime. For instance, if the Schumpeterian hypothesis is correct and competition reduces the innovative performance of firms, the goal of *competition policy* is unclear. By fostering competition, the authorities improve static efficiency because they reduce the dead-weight loss due to the market power of firms. But at the same time, they harm dynamic efficiency by reducing the innovative performance of firms. On the other hand, should market power discourage innovative activity, pro-competition policies would increase both the static and dynamic efficiency of markets. Similarly, if the goal of *industrial policy* is to create more innovative home industries, the optimal strategy also depends on the relationship between competition and innovation. Suppose that the Schumpeterian hypothesis is true and competition reduces innovation. Then it might be reasonable to use trade barriers to protect home industries from foreign competition. However, trade barriers will not be useful if competition stimulates innovation. Finally, the form of the relationship between competition and innovation is important for the choice of the optimal *intellectual property regime*. If Schumpeter's arguments are correct, a regime in which patents are assigned more easily and enforcement is stricter might be supported for two reasons. First, stronger patent protection increases the rents of the innovator and therefore the incentives to innovate. Second, stricter patent protection increases the market power of firms, which further enhances the innovative performance of the economy. On the other hand, if competition increases innovation, the possible positive effects due to stronger patent protection need to be weighed up against, among other factors, with the negative effects of less competitive environment on innovation.

Since Schumpeter's seminal discussion of the effect of market power on innovation, the relationship between competition and innovation has been widely studied in the empirical literature, mostly in the field of industrial organization, and the forces and effects behind the relationship have been discussed extensively in the theoretical literature. Unfortunately, neither the empirical nor the theoretical literature has provided clear support for the Schumpeterian hypothesis, or for the alternative hypothesis that competition encourages innovation. In the most influential recent contribution to the literature, Aghion *et al.* (2005) attempt to reconcile the opposing hypotheses. They find an inverted-U relationship between a profitability-based measure of competition and innovation and provide a natural explanation of the relationship that combines a positive and a negative effect of competition on innovation.

Following Aghion, Harris & Vickers (1997) and Aghion *et al.* (2001), Aghion *et al.* (2005) present a model of an economy consisting of a continuum of duopoly industries. Firms in these industries engage in step-by-step innovation. This means that a firm that has innovated moves exactly one technological step ahead, regardless of the technology used by the rival firm. Furthermore, the model sets the maximum possible difference between the technologies of the duopolists equal to one step. It means that firms one step ahead, called technological leaders, have no incentive to innovate. Hence the innovators are firms one technological step behind, called technological laggards, and firms at the same technological level, called neck-and-neck firms. The structure of product market competition is such that a rise in competition reduces innovation of laggard firms and increases innovation of neck-and-neck firms. The former effect of competition is called the *Schumpeterian effect* and the latter the *escape-competition effect*. The interplay of these two effects generates the inverted-U relationship between competition and innovation and two additional predictions, called Prediction B and Prediction C in this book. According to Prediction B, a rise in competition increases the share of unleveled industries with laggard and leader firms in the economy, which increases the average technological difference between the firms (called the *technology gap*). According to Prediction C, the peak of the inverted-U relationship is higher and occurs at higher levels of competition in an economy with a lower technology gap.

The predictions of the model of Aghion *et al.* (2005) have been tested in the recent empirical literature. While there is some support for the inverted-U relationship, the empirical evidence supporting the additional predictions is scarce. The lack of support for Prediction C is not so problematic because this prediction is not a necessary part of Aghion *et al.*'s explanation of the inverted-U relationship. On the other hand, Prediction B represents a necessary part of the explanation of the inverted U. According to this prediction, the proportion of neck-and-neck firms is relatively high in less competitive industries. Hence the escape-competition effect is likely to dominate the Schumpeterian effect, which means that a rise in competition increases the overall level of innovation. Conversely, the proportion of laggard and leader firms is relatively high in more competitive industries. In this case, the Schumpeterian effect is likely to dominate the escape-competition effect, which means that a rise in competition reduces innovation in the economy. The only two studies that find an inverted-U relationship between a profitability-based measure of competition and innovation and at the same time test for Prediction B are Aghion *et al.* (2005) and

Hashmi (2005). While the decreasing relationship between profitability and the technology gap found by Aghion *et al.* (2005) is consistent with their explanation, the flat and concave relationship in Hashmi (2005) is not compatible with Aghion *et al.*'s explanation of the inverted-U relationship. The empirical evidence, therefore, leaves room for an alternative explanation of the inverted-U relationship.

The goal of this book is to provide an alternative explanation of the inverted-U relationship between profitability and innovation that is able to reconcile the empirical findings of Aghion *et al.* (2005) and Hashmi (2005) related to Prediction B. More specifically, the book aims to provide realistically motivated models of the R&D decision-making of firms and test the predictions of the models using the empirical evidence of Aghion *et al.* (2005) and Hashmi (2005). The book should provide insights into possible causes of the relationship between the profitability of firms and innovation, which might prove useful for public policy.

In order to explain the empirical evidence, I introduce two models of innovation in this book: the basic model and the prospect-theory model of innovation. In the basic model, firms choose their R&D expenditures in order to maximize their expected profits within certain limitations. The aim of the model is to present a simple and general explanation of the empirical evidence. On the other hand, the prospect-theory model provides a more specific explanation, and predictions of the model correspond better to the empirical findings than predictions of the basic model. The prospect-theory model uses a behavioral theory of the decision-making process of managers. The R&D expenditures are chosen by managers of firms according to their preferences represented by the prospect-theory value function (Kahneman & Tversky 1979, Tversky & Kahneman 1992). Similarly to the model of Aghion *et al.* (2005), the size of innovation results from optimizing choices. On the other hand, the assumptions behind both models differ from Aghion *et al.*'s assumptions in several important aspects.

First, the model of Aghion *et al.* (2005) relates innovation to a theoretical measure of competition, which is shown to be increasing in the empirical profitability-based measure of competition (1−Lerner index). Thus their model is able to explain the empirical inverted-U relationship between profitability and innovation. The basic and prospect-theory models explain the empirical evidence directly by relating innovation to the profits of firms. This approach has two advantages. First, it avoids the problematic link between competition and profitability. As shown by Boone (2000, 2008), a rise in the level of competition may lead to both higher and lower industry profitability. Consequently, the predicted relationship between profitability and innovation might differ from the predicted relationship between competition and innovation. Second, it provides a more general explanation of the empirical evidence concerning the relationship between profitability and innovation because it covers all the possible factors responsible for variation in profitability, not only the intensity of competition like Aghion *et al.* (2005).

Second, the predictions of the model of Aghion *et al.* (2005) arise due to the assumption of step-by-step innovation and a specific structure of product market competition.

Thanks to these assumptions, competition has an opposite effect on innovation of laggard and neck-and-neck firms, which generates the inverted-U relationship and the related predictions. However, Aghion *et al.*'s explanation might not be valid in industries with a different mode of technological progress or different structure of product-market competition (see Subsection 1.3.2 for examples of such situations). In my explanation, all firms in an industry have the same incremental profit owing to innovation, which is either constant or decreasing in profits of firms. In this respect, my explanation is complementary to the explanation of Aghion *et al.* (2005). It is able to explain the empirical evidence even in the absence of either the Schumpeterian effect or both the Schumpeterian and escape-competition effects.

Third, there are important differences in the assumptions about the R&D process. In the model of Aghion *et al.* (2005), time is continuous. The intensity of innovative activity increases the probability that an innovation of a fixed size occurs at any moment in time. Furthermore, there are only two firms, which means that the innovative activity of one firm affects the optimal innovative effort of the other firm. On the other hand, time in my models is discrete. In each period, the R&D process generates an innovation with a certain probability. R&D expenditures influence the size of innovations. A rise in R&D expenditures increases the difference between the profits of the firm that succeeds or fails in generating an innovation. Finally, there are many firms in the industry, so that the size of R&D expenditures of one firm is assumed to have no effect on the innovative effort of other firms.

In this book, I provide several explanations of an inverted-U relationship between the profits and R&D expenditures of individual firms. The intuition behind all the explanations is similar. Starting at low levels of profits, a rise in profits tends to increase innovation because unprofitable firms, or their managers, are unable or unwilling to support high R&D expenditures. On the other hand, a rise in the profits of highly profitable firms reduces innovation because the benefits from an additional unit of R&D expenditure are decreasing in profits. The industry-level relationships between profits and R&D expenditures, called the *R&D function*, and profits and the technology gap, called the *technology-gap function*, depend on the distribution of profits in the industry. If all firms expect to earn similar profits, both R&D and technology-gap functions are likely to be inverse U- or V-shaped, which corresponds to the empirical findings of Hashmi (2005). On the other hand, if firms differ in profit earnings, the models are likely to predict an inverted-U or inverted-V R&D function and a decreasing technology-gap function, which corresponds to the findings of Aghion *et al.* (2005). In Aghion *et al.*'s model, Prediction B is a necessary component of the explanation of the inverted-U relationship. Hence the inverted-U relationship between competition and innovation emerges only if competition increases the technology gap in the industry. On the other hand, I provide a more flexible explanation of the inverted-U relationship between profits and innovation, in which the inverted-U R&D function is consistent with a concave or decreasing technology-gap function.

The rest of the book has the following structure: Chapter 1 presents a survey of literature related to the paper by Aghion *et al.* (2005). First, it presents the main assumptions and predictions of their model. Then it presents the recent empirical literature testing the predictions of their model, most importantly the empirical findings of Aghion *et al.* (2005) and Hashmi (2005). Finally, the chapter discusses the empirical evidence and some of the assumptions of the model of Aghion *et al.* and relates them to the alternative explanation presented in this book. Chapters 2 and 3 present the basic model and the prospect-theory model of innovation. Both chapters are organized in a similar way: they introduce the structure of the models first; then they present predictions of the models. More specifically: they relate firms' profits to their R&D expenditures; then they consider the relationship between profits and industry-level R&D expenditures; and finally they relate profits to the technology gap in the industry. Finally, both chapters show that for specific combinations of parameters, the predictions of the models correspond to the findings of Aghion *et al.* (2005) and Hashmi (2005). Chapter 4 discusses the robustness of the predictions to a variation in parameters. And finally, the last chapter sets down the conclusion.