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Jens Rubart

The Employment Effects of Technological Change

Heterogenous Labor, Wage Inequality and Unemployment

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With 54 Figures and 21 Tables

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To my parents

Preface

The recent book has been prepared during my work as a research assistant at the Institute of Economics of the Darmstadt University of Technology, Germany. In July 2006 it was accepted as a Ph.D. thesis titled "Heterogeneous Labor, Wage Inequality and the Employment Effects of Technological Change – Theory and Empirical Evidence for the U.S. and Europe" at the Department of Law and Economics of the Darmstadt University of Technology.

In particular, I am indebted to my teachers Volker Caspari and Willi Semmler for giving me the advice and the opportunity to write this dissertation. My interest to work on the relationship between technological change and labor markets started during my studies at the University of Bielefeld where I participated in seminars on Economic Growth and Labor Markets held by Willi Semmler.

Early parts of this thesis and closely related research papers were presented at the ZEW Unemployment Workshop (Berlin, April 2001), the Zeuthen Workshop on Competition and Growth (Copenhagen, November 2001), the 7th Conference on Theories and Methods in Macroeconomics (Evry Val-d'Essone, June 2002), the 2003 Annual Meeting of the German Economic Association (Zürich, September 2003), the Economic Research Seminar at TU Darmstadt (June 2005), the Rhein-Main-Neckar Seminar on Labor Economics (Mannheim, November 2005), the 10th Conference on Theories and Methods in Macroeconomics (Toulouse, January 2006), the 12th International Conference on Computing in Economics and Finance (Limassol, June 2006), and the 2006 Annual Congress of the European Economic Association (Vienna, August 2006). It benefited from a variety of suggestions by, amongst others, Philippe Aghion, Ingo Barens, Pierre Cahuc,

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Oberursel, *Jens*
February 2007 *Rubart*

Contents

1

Introduction

[...] for while a capital is employed in this country it must create a demand for some labor; machinery cannot be worked without the assistance of men, it cannot be made but with the contribution of their labor
(D. Ricardo (1911))

1.1 Motivation

Through the centuries, the economic development of countries has been characterized by major technological revolutions, such as, for example, the introduction of the steam engine, electricity-based technologies, new production organizations such as the assembly lines devised by the Ford Motor Company, or the IT revolution in the 1990s.[1] In general, four important phases of economic development are considered: 1820-1913, 1913-1950, 1950-1973 and 1973 to the present, all characterized by the above-mentioned technological advances.[2] Meanwhile, it is evident that each shift in technology was followed by significant changes in the structure of employment. An interesting example of the effects of the steam engine for merchant shipping between 1865 and 1912 can be found in Chin, Juhn, and Thompson (2004). They show that the introduction of a new technology, the steam engine, created

[1] See, for example, Atkeson and Kehoe (2001) p. 6, or Landes (1999), ch. 18, for surveys of technological revolutions. Furthermore, the impact of the IT-Revolution is discussed in Greenwood and Yorukoglu (1997) and Gordon (2000).

[2] See Maddison (1991) p. 84 f.

a new demand for engineers whereby the demand for sailors declined. Furthermore, Chin, Juhn, and Thompson (2004) have found that the shift from sail to steam increased the 90/10 wage ratio[3] by 40%.

In general, the changes in wages and employment following a technological advance can be described as follows: some workers become obsolete, whereas those with a different skill set are needed for the production process. Due to the scarcity of workers with the required skill set the respective wages tend to increase. In recent times, since the mid-1990s IT revolution, economic researchers began to study the relationship between technological change and a heterogeneous labor force which differs in the skill set. This relationship has been the subject of a vast share of the recent economic literature and is subsumed under the concept of skill-biased technological change. In particular, the studies by Katz and Murphy (1992), Autor, Katz, and Krueger (1998), Goldin and Katz (1998, 1999), Katz and Autor (1999), and, in particular, Aghion, Caroli, and García-Peñalosa (1999) examined in detail the hypothesis of skill biased technological change.[4] The latter studies focus on the fact that in a period of major technological change the demand and wages for skilled workers increase. Although an increase in the supply of skilled workers should have led to a decline in the wages of skilled workers, induced technological advances lead to a further increase in demand for and wages of skilled workers (Acemoglu (1998)). A generally accepted indicator of skill biased technological change is

[3] Note that the 90/10 wage ratio describes the wage spread between the respective deciles of the wage distribution of an economy.

[4] It should be pointed out that the examination of "skill-biased technological change" is rather old. Examples of early studies that examine certain aspects of this hypothesis can be found in Reder (1955), Hansen (1961), or Tinbergen (1974).

the increasing gap between wages of skilled and unskilled workers during the last thirty years which is mainly observed in U.S. labor market data. Empirical evidence that support this technology-skill relationship include Fitzenberger (1999), Goldin and Katz (1999), Katz and Autor (1999), Card and DiNardo (2002), and Puhani (2005). Furthermore, in addition to the technology-skill relationship, the effect of capital-skill complementarity is also regarded as an explanation of the observed patterns of the wage spread and relative employment (see, for example, Skaksen and Sorensen (2005)). In particular, this approach lies in the focus of the work by Krusell, Ohanian, Ríos-Rull, and Violante (2000) and Lindquist (2004).

When surveying the existing literature on the technology-skill or the capital-skill bias, the literature is essentially subdivided into two main groups. The first group focuses on the long-run trend in inequality and relative employment. In general, this branch of the literature is built on endogenous growth models, such as Acemoglu (1998), Murphy, Riddel, and Romer (1998), Krusell, Ohanian, Ríos-Rull, and Violante (2000), Aghion (2002), and Greiner, Rubart, and Semmler (2004). However, as will be specified below, most of the theoretical studies do not examine labor market rigidities in detail, although empirical labor market studies point out the effects of labor market institutions. This second branch of literature focuses on the microeconomic evidence based on panel data studies as such as Fitzenberger (1999), Card and DiNardo (2002) and Puhani (2005). Furthermore, detailed empirical studies of the employment effects are presented by Layard, Jackman, Manacorda, and Petrongolo (1999) and Petrongolo and Manacorda (1999). However, most studies do not consider the time dimension of an technological

advance, i.e. it requires some time until the introduction of a new technology leads to observable changes on the labor market. In particular, Nickell and Bell (1995) emphasize that a detailed analysis of the consequences of shocks on the relative employment status is missing, *[...] it is essential to understand the consequences for unemployment relativities of a neutral shock [...]* .[5] Furthermore, as pointed out by Nickell and Bell (1995, 1996), there are time periods in which unemployment tends to increase for both high and low skilled workers. However, this observation is not consistent with skill biased technological change as the only source of the high unemployment rates of low-skilled workers.

Subsequently, the work of Acemoglu (1999), Mortensen and Pissarides (1999), Albrecht and Vroman (2002), and Gautier (2002), lead the literature to focus on the labor market effects of technological change. Whereas the study by Acemoglu (1999) focuses on the long-term perspective, the latter studies tend to consider employment effects at business cycle frequencies. Furthermore, this branch of literature provides evidence for the hypothesis of dual labor markets raised by Saint-Paul (1996). The dualism-approach recognizes that a market can be characterized by two different states at the same time, for example different unemployment rates of workers with different characteristics. This characterization coincides with the observation of different unemployment rates of high- and low-skilled workers. Although the labor market is characterized as the most important market when looking at the transmission of supply and demand side shocks, the obvious dualism is not taken into account.[6]

[5] Cf. Nickell and Bell (1995) p. 43.

[6] For example, elaborate studies of the importance of the labor market frictions in order to investigate the effects of monetary policy shocks can be found in Walsh (2003) or Trigari (2004).

In recent times, many studies (see e.g. Ljungqvist and Sargent (1998)) attempt to explain the high and persistent unemployment rate of continental European countries. However, their analysis is almost based on partial equilibrium models which focus on the labor market, only. In general, they conclude that rigid labor market institutions or high taxes explain the observed unemployment pattern. However, the relationship between structural changes and labor market institutions from an aggregate perspective is not in the center of the discussion. In addition, partial equilibrium models do not consider the relations between different markets such as goods and labor markets.

The seminal work of Mortensen and Pissarides (1999) introduced the effect of skill biased technology shocks under the presence of labor market imperfections into the macroeconomic literature. However, from a general equilibrium point of view, the studies by Mortensen and Pissarides (1999) and Gautier (2002) seem to be more partial equilibrium models that mainly focus on the labor market rather than on the whole economy. First attempts to incorporate skill-biased technology shocks into a fully specified dynamic general equilibrium framework were made by Pierrard and Sneessens (2003, 2004) as well as Lindquist (2004); the latter study focuses on the effects of capital-skill complementarity and, furthermore, neglects labor market imperfections. In particular, the work of Pierrard and Sneessens (2003, 2004) provides a reasonable explanation of the unemployment pattern of low skilled workers in continental European countries because of the assumption of rigid relative wages.

Although the assumption that technological advances occur stochastically, such as by Lindquist (2004), might be questionable, this ap-

proach is the standard one referred to in the recent macroeconomic literature. In general, theoretical explanations of technological change or structural change as a source of fluctuations were developed by Juglar in 1856, who focussed on cycles of a length of between three and eighteen years. Cycles of a longer period were analyzed by Kondratieff, Kuznets, Schumpeter and many others during the first quarter of the 20th century.[7] Although many explanations, such as Schumpeter's creative destruction concept, seem reasonable, the assumption of the existence of regular periodical waves of economic activity is not proven. According to Maddison (1991) economic fluctuations are due mainly to disturbances of an *ad hoc* character (cf. Maddison (1991): 108). The recent business cycle theory is particularly built on the *ad hoc* character of technological disturbances, the "Real Business Cycle" (RBC) theory. Mainly developed by Kydland and Prescott (1982) and King, Plosser, and Rebelo (1988), it analyzes the effect of stochastic disturbances of aggregate productivity within a framework of a neoclassical growth model with intertemporal optimizing agents. In order to explain both output and employment fluctuations, the RBC approach was extended by Hansen (1985), as well as Christiano and Eichenbaum (1992). However, the latter expansions of the RBC framework did not account for labor market imperfections or institutional settings. This was done by Danthine and Donaldson (1990) who introduced efficiency wages and, in particular, by Langot (1995), Merz (1995) and Andolfatto (1996) who introduced search and matching frictions on the labor market into a RBC framework. Another line of research is offered by Gong and Semmler (2000) and Ernst, Gong, Semmler, and Bukeviciute (2006)

[7] See Maddison (1991), Chapter 4 for further details.

who study disequilibrium phenomena on the labor market within the context of a RBC model. In particular, the latter model concentrates on the impacts of structural reforms on the labor market. They show that an increase in labor market flexibility, i.e. a reduction of the impact of labor market institutions, improves economic welfare but leads to higher employment risk for households. However, the search and matching framework builds the basic framework of the recent macroeconomic literature which studies output and employment fluctuations.

Up to now, a characterization detailing under which conditions technological change leads to positive or employment effects, or how technological advances diffuse over the labor market is still absent. This is particularly relevant to whether labor market rigidities are taken into account, which are obviously prevalent in continental European labor markets (as opposed to the U.S.). Furthermore, it is still unclear how labor market policies, such as minimum wages or dismissal protection legislation, which have been recently discussed in Germany, affect the employment rate of low-skilled workers in an economy which is in a state of non-stop technological change. Therefore, the aim of this thesis is to provide a theoretical framework in which the effects of technological change can be studied and which is, moreover, capable of accounting for the main empirical findings of leading OECD countries.

1.2 Outline

This thesis is structured as follows. In Chapter 2 the main empirical findings concerning employment and wages of different educational groups as well as important labor market characteristics are presented and discussed. Furthermore, this chapter provides a reduced-

form vector-autoregression (VAR) approach in which the effects of technological advances on the wage spread and the relative employment positions are studied empirically.

In chapter 3, the basic framework of search and matching frictions on the labor market is introduced. In addition, we discuss the effects of parameter variations by applying a calibration study to the obtained model solution which leads to a more detailed discussion of the effects of skill-biased technological change on employment and wage inequality, albeit within a rather static framework. There we can show that some of the cross-country variation in inequality can be reproduced by parameter variations of the model.

In chapter 4 the basic framework of a Stochastic Dynamic General Equilibrium (SDGE) model with heterogeneous labor is introduced and calibrated in accordance with empirical findings for the U.S. and Europe.

Subsequently, in chapters 5 and 6, the basic framework is extended by labor market frictions due to a search and matching approach as well as a wage-setting mechanism based on a Nash bargaining procedure. As in chapter 4, the model is calibrated in accordance with the empirical evidence. However, besides the search and matching frictions and wage bargaining, no other labor market institution or rigidity is assumed.

In Chapter 6 the search and matching approach is extended by two important labor market rigidities reported for continental European countries: rigid relative wages and employment protection mechanisms. In particular, the latter assumptions provide a theoretical and quantitative consideration of the outcomes of labor market policies. Fur-

thermore, besides the dynamic response of technological innovations, long-run as well as welfare effects of both policies are examined.

Chapter 7 surveys the results and concludes with a final outlook.

1.3 A Preview of Results

A comparison of labor market characteristics of the important OECD countries (see table 2.1 below) makes it obvious that, at least in France and Germany, the high and increasing unemployment rates are mainly driven by the increase in unemployment rates for low-skilled workers. However, the respective unemployment rates tend to remain stable or decrease for countries like the U.S. and the United Kingdom. The recent empirical literature, based mainly on microeconometric panel studies (see, for example, Fitzenberger (1999) and Puhani (2005)), explains this pattern in the context of the effects of skill-biased technological change. However, due to the rather static examinations, the dynamic effects of advances in new technologies on relative employment and wages are not taken into account. By applying a reduced form VAR approach, these dynamic effects are examined empirically. There, we find evidence for the hypothesis of skill-biased technology shocks for the U.S. and Germany. Furthermore, it becomes obvious that labor market institutions have significant effects on the wage spread and relative employment. In particular, the latter results bag for a detailed discussion of the effects of technological advances under labor market rigidities.

Based on this evidence, a comparative static analysis of a labor market with search and matching frictions and wage bargaining is developed. There we show that it is generally possible to discuss the observed cross-country variation of wage inequality and relative em-

ployment within a single theoretical framework. In addition, we will show that the complex relationships between the variables of interest require numerical calibrations for a detailed elaboration. The results show that it is generally possible to reproduce the aggregate evidence of the observed wage spreads across important OECD countries within one model framework by parameter variations.

By conveying the comparative static analysis of chapter 3 into a Dynamic General Equilibrium framework, we are able to give a detailed examination of the dynamic effects of technological change under several kinds of labor market institutions. By comparing the results of models which exhibit an increasing degree of rigidity, we show how these effects worsen the employment position of low-skilled workers. In particular, when rigid relative wages are considered, an unanticipated shock of skill-biased technology leads to an immediate decrease in low-skilled employment. Furthermore, we show that policies which increase dismissal protection do not have an enormous impact on the employment position. In addition, the examination of the long-run effects of both labor market policies shows that wage rigidities reduce steady state employment of both types of workers as well as total welfare. However, we find no such effects for employment protection mechanisms.

2

The Empirics of Inequality and Institutions

On the other hand, students of income distribution are in need of more precise information on the possibilities of substitution between various categories of labour, since this influence the demand structure of the labour market
(J. Tinbergen (1974))

2.1 Technological Change and Economic Fluctuations

Early quantitative work on the structure of wages and employment in the United States began in the 1930s and focussed almost entirely on occupational and industry-specific wage differentials. The "human capital" revolution in the 1960s and 1970s as well as the availability of new data sets on earnings and individual characteristics forced a shift of focus to educational wage and employment differentials.[1]

A recent survey of the evolution employment and wage differentials across important OECD countries since 1980 is given below in table 2.1. In accordance with the literature, it is shown that, although many industrialized countries such as the United Kingdom,[2] the United States, France and Germany were faced with a similar evolution of technology and industrialization and that the percentage of college graduates increased in the last 30 years, which indicates an overall increase in employment of skilled workers; we observe, however, different patterns

[1] See Katz and Autor (1999) for a detailed survey of the literature.
[2] A recent study of the rise of the U.K. wage differential is given by Prasad (2002).

of wage inequality across countries. In general, Anglo-Saxon economies such as the U.S. or U.K. show a growing wage spread, whereas in continental European countries like France or Germany wage inequality tends to be constant (see also Gottschalk and Smeeding (1997) or Acemoglu (2002)). The constancy of the wage spread accounts, in line with the hypothesis of skill-biased technological change, for the increase in unemployment of low skilled workers which is obvious for continental European countries. As reported by table 2.1 below, in Germany the unemployment rate of workers with lower secondary education exhibits a steady increase from 13 to above 20% between 1988 and 2004. On the other hand, the unemployment rate of low skilled workers declined from 13 to 6% in the U.K. or remained constant in the U.S.. For comparison, the unemployment rate of skilled workers remained either at constant levels between 3 and 5%. However, it is interesting to notice that the participation rate of low skilled workers in continental European countries exceeds the one of Anglo-Saxon countries.