INSTITUTIONALIZED INCENTIVES FOR INGENUITY – PATENT VALUE AND THE GERMAN EMPLOYEES' INVENTIONS ACT

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Institutionalized Incentives for Ingenuity – Patent Value and the German Employees' Inventions Act

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Abstract

Germany is one of few countries in which the monetary compensation for inventors is not only determined by negotiations between employer and employee-inventor, but also by relatively precise legal provisions. In this paper, we describe the characteristics of the German Employees' Inventions Act (GEIA) and discuss which incentives it creates. We rely on responses from a recent survey of 3,350 German inventors to test hypotheses regarding this institution. We conclude from our data that the law creates substantial monetary rewards for productive inventors. The qualitative responses from our survey confirm this view, but also point to a number of dysfunctional effects.

Keywords: Employee-Inventor; Inventor Compensation; Patent Value; Productivity

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1 Introduction

In 2001, the EU15 countries invested a total of € 175.5 billion in research and development activities. Approximately two thirds of this amount were R&D expenditures made by business enterprises, the remainder shared by publicly financed research institutions and academia. Almost 70 percent of these investments are expenditures for R&D personnel. Yet, it is surprising how little attention is given to the transformational process behind these numbers. Clearly, the development of ideas and new concepts is financed by the funds just summarized. But the actual work is done by inventors, either in corporate labs, in publicly financed research institutions or in academic research, and their motivation and incentives should matter greatly for Europe's chances of becoming more successful in global technology markets.

While the innovation literature in the early 50s and 60s contributed a large number of insights into invention processes[1], much of the subsequent work in this field turned away from the individual inventors to consider the overall design of processes and organization. The underlying paper does not follow this trend, but seeks to return to a topic that is probably a highly neglected one in contemporary innovation studies – the motivation and performance of individual inventors. Using a novel dataset with extensive information on the context of invention processes, the value of inventions, and the biography and mobility of inventors, we describe a rather unique institutional setting in which the compensation of inventors is determined by law. The backdrop of our study is the German Employees' Inventions Act (GEIA), once hailed as progress towards giving inventors a fair share of the benefits that they produce in creative work, and nowadays criticized as heavy-handed government intervention in processes public administrators should better not meddle in.

There are few processes that go unregulated in Germany. The compensation for employee-inventors is one of the processes which many countries have left to be negotiated between the parties involved, the inventors and the corporations. Only very few countries have embedded rules and provisions in the civil code or in legal provisions. There has been a long-standing debate in Germany (but also in other countries) whether such regulation really creates proper incentives for ingenuity and inventions. Some authors have pointed out that the regulation may actually be counterproductive in that it induces strategic behavior among inventors and firms which may be harmful to innovation incentives.

Since much of the potential behavior cannot be observed easily, we use inventor responses from a large-scale survey to explore some of these issues. We find that inventor compensation in Germany allocates some returns to inventors – in a few cases exceeding gross salaries by a factor of two and more. But in most cases, the compensation appears quite moderate from the inventor's perspective. In our survey data, we measure the inventor's compensation as the compensation received for a particular patent (or all patents to which the inventor contributed) divided by the gross salary without inventor compensation. The extent to which inventors profit from their inventions can be shown to depend most strongly on the invention's value and quality. Second, the number of inventors has a very plausible impact which appears to be largely in accordance with the legal provisions. Variables associated with the inventor's rank in the organization also impact significantly on the compensation share variable, which is again consistent with the legal provisions. While inventor productivity (the average annual

[1] Consider for example the work in Ritti (1971) and Allen (1977).

number of inventions made over the inventor's active career) contributes positively to patent value, it has a negative coefficient in our compensation regressions. Similarly, educational attainment is negatively associated with the compensation share variable. These results presumably reflect the legal rule that individuals higher up in the organization will profit less from a service invention – simply since contributing to such inventions is part of their normal job for which they are compensated by relatively high salaries. Taken these and other results together, it appears that the mechanism is basically meritocratic in nature, and that it follows the legal provisions quite closely.

Our survey responses also yield qualitative insights into the functioning of the compensation schemes. Most inventors (59.5 percent) view the legal regulation positively, largely because of its financial effect in their favor. Others emphasize the fact that the risk and costs of patenting are born by the employer. Among the 28.3 percent who view the compensation rules largely negative, two opinions are dominant – that the compensation is not large enough, and that the compensation scheme lacks transparency. A criticism frequently encountered in the literature concerns the tendency that superiors appear among the inventors although they have not contributed to the invention. Inventors may accommodate such requests (or even suggest an inclusion of other decision-makers) in order to maximize the chance of having an invention being protected by patents. We do not find much evidence of such strategic behavior – only 1.8 percent of the respondents mention it. These results support a cautious positive assessment of the German Employees' Inventions Act, but we cannot compare the compensation rules to a setting in which bonuses would be negotiated bilaterally between employer and employee-inventor.

The remainder of the paper proceeds as follows. In section 2, we describe the history and provisions of the German Employees' Inventions Act. We also summarize the results from previous studies that have analyzed this nexus. In section 3, we discuss our research questions in more detail and specify the hypotheses to be tested later. Section 4 presents the data and discusses the key variables that we have devised for the multivariate analysis. In section 5, we present some descriptive evidence bearing on our main question, while the multivariate results are presented in section 6. The final section provides a brief discussion of our results and concludes.

2 Invention Processes and the German Employees' Inventions Act

2.1 Salient Features of Invention Processes

To assess the efficacy of institutionalized incentives for inventors, it is helpful to consider the salient features of invention processes first. We do not attempt to draw a real-life picture of such processes here, but a basic understanding of their features is important to understand the basic incentive problems. We make three observations on inventions and patents: first, productivity among inventors appears to be very heterogeneous in the sense that few inventors produce the lion's share of inventions within an R&D department; second, the value of individual patent rights follows a highly skew distribution which can be approximated quite well using a log-normal distribution function; third, inventions are often made by or within teams. Thus, the dynamics of R&D teams is highly relevant for our study. We discuss these points in turn.

The productivity of inventors is quite heterogeneously distributed. An early study of this issue was undertaken by Lotka (1926). Lotka analyzed the publication output of scientists. His research resulted in the following equation, often referred to as *Lotka's Law* - the number of scientists producing exactly n papers is proportional to $1/n^2$. Hence, when 100 scientists publish exactly one paper per time period, it would be a share of $1/2^2$, i.e. 25 who would produce two papers in that time period, about 11 ($1/3^2$) with three publications, and so on. One may argue that such differences in productivity may merely be a function of experience (and age). Allison/Steward (1974) undertook a study to distinguish between time-invariant effects associated with the individual inventor, and experience effects due to the cumulative advantage of scientists. Cumulative advantage means that scientists become more productive during their professional life. As a measure of productivity, the authors used the number of citations received by scientific articles of US scientists in university departments. Results showed that both, pre-existing differences and cumulative advantage affect differences in scientists' productivity. Note that in this study, output is measured using the quantity of output, not its quality. But as it turns out, the relatively good performance in terms of publication numbers is not achieved by trading quantity off against quality. Ernst et al. (2000) conducted a survey on inventors of 43 German firms and show that highly productive inventors are frequently responsible for the most valuable patents. Narin/Breitzman (1995) extended Lotka's findings on patented inventions in the semiconductor industry. As a result, they find that output is even more concentrated than Lotka's Law suggests.

A multitude of attempts have been made to measure patent value using value indicators drawn from patent documents available in patent databases of national or regional patent offices. Indicators used are e.g., the number of citations received (Trajtenberg 1990, Harhoff et al. 1999, Lanjouw/Schankerman 1999), the number of claims (Lanjouw/Schankerman 1999 and 2001), the incidence of an opposition or litigation (Lanjouw/Schankerman 1999, Harhoff/Reitzig 2001, Harhoff/Hall 2003), or patent renewal data (Pakes 1986, Schankerman/Pakes 1986, Lanjouw et al. 1998). Results of most of these approaches have one element in common: they provide evidence for a highly skewed distribution of patent value (i.e., Harhoff et al. 1999, Scherer et al. 2000). Scherer et al. (2000) show that the top decile of German patents in 1977 accounted for 88 percent of the total value.

Giummo (2003) analyzes the time profile of returns to patented inventions, as well as its cumulative value. In his analysis, information on patent value was gained from compensation records of German inventors of six major German companies (the variable we are analyzing later on). Calculation of the amount of compensation requires valuation of the surveyed invention. Therefore, compensation records are often considered a good proxy for patent value (up to a factor of proportionality). Building on this assumption, Giummo confirms previous findings concerning the skewness of the distribution of patent value.

The third characteristic of modern invention processes is team production. In our data, only 24 percent of the inventions covered by our survey were made by individual employee-inventors. Inventor teams consist on average of 2.5 inventors. Incentive systems need to take this characteristic into account by coming up with a sharing rule for inventor compensation. While the negotiations between co-inventors can be acrimonious, even more complex cases arise in the context of sequential inventions. Suppose that team A has made a basic invention upon which the inventions of several other inventor teams are based. If subsequent inventions replace the original one in the marketplace, the earlier inventors may see their compensation erode because too little emphasis is given to the pioneering nature of their contribution. In our survey responses, some of these conflicts will turn out to be important.

2.2 Institutionalized Compensation Schemes in Various Countries

In Germany, the rights and liabilities within an employer–employee-inventor relationship are governed by a specific legal institution. Comparable legal regulations only exist in Denmark, Finland, Norway and Sweden. We briefly consider a few features of these systems before turning to the German institutions.

The Swedish Employees' Invention Act is of dispositive nature, i.e., the legal provisions may be amended by the employer or the employee as long as the employee’s basic right to compensation is not affected. Basically, the Swedish Employees' Invention Act distinguishes between two types of employee inventions: the work-related invention and the invention arising outside the context of employment. The rights on work-related inventions are fully transferred to the employer. For the second type, the rights to the invention remain with the employee. The employee may apply for a patent before reporting the invention to the employer, however, she must offer the employer the right to use the invention (Rebel 1993).

The Danish Employees' Invention Act is similar to the Swedish law. The right to the invention remains with the employee-inventor. The inventor is obliged to report all inventions to the employer. For inventions which were made in the course of the employee's normal work the employer can claim the right to the invention. The claiming of the right has to be declared no later than four months from receipt of the invention report. Disagreements are brought before a board of arbitration. The inventor’s claim to a reasonable compensation is deemed to be satisfied with his regular salary (Rebel 1993).

In the United Kingdom, France, Italy, Austria, the Netherlands and Japan, regulations concerning employee-invention are part of the respective national patent laws. According to Section 39 (1) of the English Patents Act[2] inventions “made in the course of the normal duties of the employee” or made in the course of “duties falling outside his normal duties, but specifically assigned to him” belong to the employer. The remaining inventions belong to the inventor himself. Compensation is to be paid only if the invention is of outstanding benefit to the employer (Section 40 (1) English Patents Act). Disputes concerning the compensation are submitted to court or are decided by the comptroller within the firm (Section 41 English Patents Act).[3]

The French Patent Law also assigns inventions which are made in fulfillment of an employment contract to the employer. The employee-inventor may come into possession of additional compensation (compensation beyond normal salary) if a claim to compensation is regulated by plant agreement (i.e., between employer and works council) or by contractual agreements between employer and inventor. Disputes concerning compensation have to be resolved by an arbitration commission or in court (Reitzle et al. 2000).

The Italian legal regulations differ from the French ones with respect to inventor

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[2] See http://www.patent.gov.uk/patent/legal/consolidation.pdf for the English Patents Act of 1977 (access on August 18, 2005).

[3] See Littler/Pearson (1979) and Orkin (1984) for a more detailed description of compensation of employee-inventors in the UK.

compensation. If no special arrangements have been made, the inventor is entitled to a reasonable compensation, depending on the economic value of the invention. The amount payable to the inventor decreases with the degree of involvement of the employer in the creation of the invention (Rebel 1993).

In Austria, employees explicitly referred to as "inventors" are excluded from receiving a compensation or only receive a limited payment. Inventors are considered to be sufficiently compensated for inventive efforts with their regular monthly salary. However, special agreements leading to some compensation for the inventors are allowed. The amount of remuneration depends on the economic value of the invention (Rebel 1993).

Almost the same regulations are applied in the Netherlands. An inventor obtains an additional compensation if and only if she has not already been sufficiently remunerated by her regular salary. The amount of compensation is again derived from the economic value of the invention which is determined by the employer (Rebel 1993).

The Japanese Patent Act basically assigns the right to the invention to the employee (§ 35 Japanese Patent Act). The employer receives the right to a non-exclusive license and is not obligated to pay compensation. Assignment of an employee-invention to the employer may be regulated in advance by contract or employment negotiations. In this case, the right to the invention is passed to the employer or the employer receives an exclusive license. The employee is then entitled to receive a reasonable remuneration on the part of the employer (Yano 1992).[4]

In Switzerland and Liechtenstein employee-inventions are subject to civil law. According to Art 332 Obligation Law (Obligationenrecht), patentable and not patentable inventions made during the employee's normal work duties are to be reported to the employer. Rights to the invention are assigned to the employer. Payment of compensation is compulsory. The amount of payment depends on the economic value of the service invention, the duties and position of the employee in the firm, the contribution made by the employer and by third parties, and finally on the extent internal equipment has been used for making the invention. Disputes have to be solved by labor court (Rebel 1993).

In the United States[5] and in Canada, there exist no special legal provisions pertaining to inventor compensation. Basically, the inventor principle is applied which means that the invention belongs to the inventor. Therefore, patents are always applied for in the inventor's name, and are then assigned to the employer. Conditions concerning an assignment of the invention to the employer are to be regulated by contractual agreements. Typical employment contracts in the US therefore specify the following obligations for employee-inventors: first, the employee-inventor has to notify the employer of each invention made. Second, the employee-inventor has to keep secret any invention or company related information, and finally, the inventor has to confer all rights to the invention to the employer during the employer-employee relationship. The employee-inventor in return has no legal claim to

[4] In a recent case, the inventor of blue laser diode technology, Shuji Nakamura, was awarded inventor compensation at the amount of *US$ 188.7 million* on January 30th 2004. See http://www.compoundsemi.com/documents/articles/news/3693.html (access on July 29, 2005).

[5] See Merges (1991) for the description of the U.S. regulations concerning service inventions. Kline (1992) and Savitsky (1991) also provide insights into the compenation practices in the US.

compensation. Compensation may also be determined in the employment contract. In cases where no contractual agreements exist between the employer and the employee-inventors and where the employer was instrumental in making the invention (e.g., by providing the inventor with the necessary tools, materials, or financial resources), the employer receives a "shop right". Due to this shop right, the employer obtains a non-exclusive license. In exchange, the employer pays a license-fee of 1 US$ representing a symbolic inventor compensation (Leptien 1996, 98; Rebel 1993).

2.3 Historical Aspects of the German Employees' Inventions Act

While regional patent systems existed in German states already in the 18th century, the first federal German Patent Law came into force in 1877. Given the limited number of employee-inventors at the end of the 19th century, there was little need for specific legal regulation concerning employee-inventors. But the increase in the number of employee-inventors at the beginning of the 20th century led to an increasing demand for legislation (Kurz 1997, 1). A first cooperative agreement between employers and employees in the chemical industry was negotiated during the First World War. The Chemists' Collective Bargaining Agreement[6] (*Chemikertarifvertrag*) for academically trained employees was passed in 1920. As of 1934, considerable efforts were made to replace collective labor agreements (*Tarifverträge*) by a law regulating the cooperation between employer and employee-inventor. Finally, in 1939 the parties involved came to a compromise. But the draft law was rejected by the government due to its complexity. In 1942, as the Second World War turned out to become an economic war, the minister of armament single-handedly enforced a legal regulation, the Provision on the Handling of Inventions of Subordinates (*Verordnung über die Behandlung von Erfindungen von Gefolgschaftsmitgliedern*)[7]. The regulation already contained a number of provisions that were converted into today's Act on Employees' Inventions without substantial modifications. The Provision on the Handling of Inventions of Subordinates (PHIS), for instance, included the obligation of the subordinate to report the invention (§3 PHIS), the obligation to keep the invention secret (§6 (3) PHIS), the claiming right of the employer within 6 months after receiving the report of an invention (§4 PHIS), and the claim of the subordinate to reasonable remuneration. Mode and amount of the remuneration had to be negotiated between employer and subordinate (§5 PHIS) (Kurz 1997, 91ff). On March 20, 1943, the Remuneration Guidelines for Subordinates' Inventions (*Richtlinien für die Vergütung von Gefolgschafts-erfindungen*) were added to the provisions. The guidelines provided instructions to estimate the degree of the inventive effort, necessary to calculate the amount of remuneration. The degree of inventive effort depended on (1) the conceptual formulation of the problem ,i.e., the degree of the subordinate's own initiative, (2) the solution of the problem, and (3) the position of the subordinate within the firm (Kurz, 1977, 103).

In the aftermath of the war, employers and unions were keen to reestablish the German patent system as soon as possible. The draft law, becoming the first government bill (*Regierungsentwurf*) for an Act on Employees' Inventions in 1952, was prepared by the Federal Ministry of Justice (*Bundesjustizministerium*) and also by the German Association for Intellectual Property Rights and Copyright Protection (*Deutsche Vereinigung für*

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6 *Reichstarifvertrag für die akademisch gebildeten Angestellten der chemischen Industrie* as of April 27, 1920.
7 See Reichsgesetzblatt I, 1943, p. 466.

gewerblichen Rechtsschutz und Urheberrecht). The government bill proposed the establishment of a board of arbitration at the German Patent Office. Due to a lengthy discussion about amendments, the German Bundestag could not pass the draft law during the legislative period between 1949 and 1953. Thus the Federal Ministry of Justice worked on a new proposal. In 1955, the second government bill was brought forward. The second proposal excluded technical improvement proposals[8], release under reserve of a use (*Freigabe unter Benutzungsvorbehalt*) was replaced by restricted claiming of inventions, and the provisions on inventions of university professors and scientific assistants[9] were added. By means of this proposal passing of the law became possible.

In 1957 the German Employees' Inventions Act became effective. The need for this legislation arose because of a conflict between the German Employment Law and the Patent Law. According to the German Employment Law, the results of the work of an employee belong to the employer, whereas the Patent Law assigns the property of an invention to the inventor himself. The Employees' Inventions Act produced a balance between employer and employee. Whenever the rights to the patent are transferred to the employer, the employer must in return pay the employee-inventor a reasonable compensation. Moreover, the law was supposed to strengthen incentives for inventors in corporations (Leptien 1996, 83).

2.4 Regulations of the German Employees' Inventions Act as of 1957

In its current form, the German Employees' Inventions Act applies to all patentable inventions (patented or not) or inventions which are eligible for a utility model as well as to any other technical improvement proposals made by employees (§§2, 3 ArbNErfG[10]). The Act applies to inventions made by inventors in organizations which are governed under German law or in German subsidiaries of international organizations. It provides a set of rules concerning rights and liabilities of both the employer and the employee.

The Act distinguishes between service inventions and free inventions. Service inventions are inventions which either result from the obligatory activity of the employee in the company or "(…) are substantially based on experience or activities of the company" (§4 ArbNErfG). Other inventions, for instance, inventions made by employees during their leisure time or by self-employed inventors, are free inventions. According to §5 ArbNErfG the employee is obligated to report a service invention to the employer immediately.[11] Within the period of

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[8] The first government bill assigned the monopoly principle (*Monopolprinzip*) to inventions and the supplementary benefit principle (*Sonderleistungsprinzip*) to technical improvement proposals. According to the monopoly principle, the inventor was granted a compensation for providing his employer with a monopoly (the right from the patented invention). According to the supplementary benefit principle, the right to a compensation arises from an effort not bounded by contract. Since the new proposal aimed at aligning the law with the monopoly principle, technical improvement proposals were excluded from the second government bill (Kurz 1997, 232).

[9] According to §42 ArnErfG, containing the handling of university inventions, inventions of professors, lecturers and scientific assistants were free inventions. Meanwhile, §42 ArbNErfG, and in particular the so-called professorial privilege, has been revoked. On February 7, 2002, the modified §42 ArbNErfG became effective, which treats university inventions as inventor-employee inventions and therefore, as service inventions.

[10] Arbeitnehmererfindungsgesetz (ArbNErfG)

[11] Free inventions also have to be reported without delay. In case the employer does not contradict that the

four months from the receipt of the report of the invention, the employer can claim the invention on a restricted or unrestricted basis (§6 ArbNErfG). If the employer does not claim the invention the legal title to the invention is released to the inventor. In case of an unrestricted claim to the invention, all rights to the invention are transferred to the employer, and the employer is obliged to file a national patent application for the invention. A restricted claim provides the employer with a non-exclusive right to use the invention, which implies that the employer is not allowed to grant licenses on the patented invention (Reitzle et al. 2000). Restricted claims turn out to be quite infrequent – in our data, only 2.6 percent of all patents are claimed by the employer on a restricted basis. In the case of a restricted claim, the employer has no obligation to file a German patent application. An inventor, who wants his invention to be protected by a patent, has to file the application in his own name.

Once the invention is claimed, either in restricted or unrestricted form, the employer has the obligation to reasonably compensate the inventor. The inventor's right to remuneration arises as soon as the employer has claimed the right to the service invention (unrestricted claiming of right) or as soon as the employer has claimed the right to the invention and uses it (restricted claiming of right). Guidelines for the Remuneration of Employees' Inventions in Private Employment[12] were first issued by the Federal Minister for Labor and Social Affairs (Bundesminister für Arbeit und Sozialordnung) in 1959. These guidelines are based upon the Remuneration Guidelines for Subordinates' Inventions from March 20, 1943. They regulate in some detail how the compensation is determined. The compensation is supposed to be proportional to the value of the invention. According to Section 1 of the guidelines, three different methods exist for calculating the value of the invention:

- by using a licensing analogy, i.e., by determining the license fee that would have to be paid for the use of a comparable invention owned by a third party,
- by calculating the benefits from the invention accruing to the employer, i.e., the difference between costs and revenues resulting from the use of the invention, or
- by estimation of the value of the invention, i.e., by determining the price which would have had to be paid by the company to buy the invention from a free inventor.

The estimation of the value of the invention provides the basis for the calculation of the compensation payable to the inventor. In a second step, the share of value accruing to the inventor(s) is determined. According to §9 (2) ArbNErfG, the proportion attributable to the inventor(s) depends:

- on the economic exploitability of the service invention, i.e., the value of the invention, which is determined according to the three above described methods,

invention is free, it is at the employee's disposal (§§ 18, 19 ArbNErfG).

[12] See Bundesanzeiger No. 156 of 18.08.1959, Annex. The Guidelines were amended by Sept. 1, 1983, see Bundesanzeiger 1983, p. 9994. The guidelines are not legally binding provisions. They only provide an informative basis for calculating the inventors' compensation. However, the Board of Arbitration at the German Patent and Trademark Office as well as the courts check the appropriateness of compensation by means of these guidelines (Leptien 1996, 86).

- on the duties and position of the employee in the company, i.e., the share of the inventor in the creation of the service invention decreases the more it is expected of him by reason of his position and by the amount of salary paid to him at the time of the report of the invention, and also
- on the degree of involvement of the company in the creation of the service invention, i.e., the share of the inventor in the creation of the service invention increases the greater his own initiative in recognizing the problem, and the smaller the company's support with technical assistance.

If more than one employee-inventor is responsible for a service invention, the relative contributions of the inventors have to be specified. §12 (2) ArbNErfG constitutes that the compensation must be determined for each inventor separately. Each inventor has to be informed about the total amount of remuneration and the share received by the other co-inventors.

Disputes arising between employees and employer regarding the inventors' compensation can be brought before the Board of Arbitration at the German Patent and Trademark Office in Munich or Berlin (§§28-36 ArbNErfG). The Arbitration Board issues a proposal for a settlement. This proposal is binding for both parties unless a written opposition is filed within one month. Should an appeal be filed against the proposal, the proceedings before the Arbitration Board are deemed to have been unsuccessful and the filing of an action with the court having jurisdiction (the respective district court) is possible. On average, fewer than 100 disputes per year are negotiated before the Arbitration Board (GPTO 2003). Compared to the annual number of patent applications to which the German Employees' Inventions Act applies[13], this number is quite small.

2.5 The Impact of the German Employees' Inventions Act

Since its inception in 1957, the German Employees' Inventions Act has been subject to many controversial discussions. Within the last 20 years, a number of economic and legal studies have analyzed the advantages and disadvantages of the law and of the associated institutions. The Act aimed at creating a social balance between employer and employee, as well as providing incentives for inventive activities. Several theoretical and empirical analyses have examined to what extent this original objective of the Employees' Invention Act has been attained. In the following section, we summarize some results from this literature.

We first address literature, providing potential advantages of the German law. According to Merges (1999), the Employees' Invention Act enhances the degree of legal certainty for employee-inventors. Due to the law, inventors are entitled to receive compensation in exchange for the assignment of the rights to the invention. A transfer of rights to the employer is economically plausible, since the employer may have made specific investments in complementary assets to exploit the employee's invention. To ensure employment, firms have to balance risks by holding a patent portfolio. Successful inventions can compensate for losses (Merges 1999). Apart from spreading the risk, employee-inventors would not be able to afford

[13] In 2002 e.g., the German Patent and Trademark Office (GPTO) received 51,513 patent applications from enterprises which are governed by German law and thus by the inventor compensation scheme (GPTO 2003).

costs associated with patent applications.

The following two empirical analyses highlight the importance of remuneration for inventive activity: Already in 1931, Rossman asked 710 inventors about their motives and incentives which cause them to invent. The most important motives of inventing turned out to be “love of inventing”, “desire to improve”, and “financial gain” (Rossman 1931, 523f). The relevance of monetary incentives, in particular inventor compensation, was also confirmed by Staudt et al. (1990) who conducted a survey of 522 employee-inventors. Respondents were drawn by random sampling from a list of all German patents published in 1987 and held by German applicants. Results show that more than 70 percent of the inventors rank inventor compensation as important. Less important are advancement, trainings, or flexible working hours (Staudt et al. 1990).

Results from the above described analyses indicate that inventors basically regard the legal regulations as motivating for inventive activity. But the literature also points to some dysfunctional effects that the Employees’ Invention Act may have. For example, delayed payments are generally thought to provide relatively weak incentives for inventive effort. A study of 10 major inventions conducted by Globe at el. (1973) shows that inventions are brought to market several years after the date of patent application. The results of this study show that the shortest time lag from invention to commercialization and therefore to payment of the remuneration amounts to 6 years. Brockhoff (1997) argues that large firms frequently are organized in terms of profit centers and therefore are keen to delay payment. Additionally, exorbitant administration efforts impede annual payment. As a rule, compensation is paid in two- or three-year intervals (Brockhoff 1997).

Another frequently discussed issue concerns the actual calculation of the remuneration. First of all, the German Employees’ Inventions Act does not provide detailed provisions concerning the calculation of the compensation. Inventors, therefore, complain about the strong influence that employers may have on how remuneration is determined. Furthermore, in many cases there is a choice among potential reference quantities (e.g., sales or production quantity) which can influence the amount of compensation considerably (Gaul 1988). In this context, Kersten (1996) criticizes that compensation is calculated as proportion of overall turnovers achieved with a product. Therefore, radical innovations (which initially generate very low levels of revenues, but a large relative increase in revenues) are disadvantaged in comparison to incremental innovations or modifications of existing technology. To counteract such effects, Kersten proposes to limit compensation to the actual increase in sales due to the invention.

Additionally, the allocation of remuneration between co-inventors may lead to a reduction of employee inventors’ motivation. Each inventor is entitled to be informed on the total amount of remuneration and the shares that each co-inventor receives. However, the attribution of performance is difficult and often leads to controversies. Furthermore, an increase in the number of co-inventors reduces compensation for every single inventor. The motivation within a research team may suffer from such disputes (Staudt et al. 1992, Heimbach 1992). Moreover, the profitability of new products is also impacted by efforts made by employees other than inventors. Manly (1978) criticizes that legal regulations “ (...) single out one cog in the innovative wheel – the inventor”. The author especially argues that today's R&D processes are characterized by cooperation within interdisciplinary teams of specialists from different functions within the firm. The German Employees' Invention Act in contrast is only applicable for employee-inventors.

Moreover, Staudt et al. (1992) find that 27.9 percent of the questioned inventors complain about superiors being mentioned in invention reports because of their hierarchical position, but not due to their contribution to the invention. The phenomenon of executives being included as co-inventors without having made a contribution to the invention is also reported by Brockhoff (1997) and Schmeisser (1986).

Delay of payment, intransparent calculation of remuneration and unfair allocation of remuneration between co-inventors are only three examples of causes for disputes between employer and employee-inventor. According to §28 ArbNErfG, the Board of Arbitration may be called upon in case of a dispute. However, both Giummo (2003) and Manly (1978) find that the number of conflicts brought before the Arbitration Board at the German Patent and Trademark Office is relatively small when compared to the overall number of patents for which such a conflict could in principle arise.[14] But they differ in their interpretation of this indicator. Manly (1976) interprets the limited amount of disputes as a sign of an effective operation of legal regulations in Germany. Conversely, Giummo (2003) argues that inventor employees are unlikely to jeopardize their careers by initiating a legal conflict with their employer. In his interpretation, the low number of conflicts is not informative about the actual effectiveness of the legal provisions governing inventor compensation.

Another possible interpretation may be that inventors are not sufficiently informed about the legal provisions of the German Employees' Inventions Act. Leptien (1996) surveyed 116 inventors of German firms active in the electrical engineering, mechanical engineering and chemical industries. One of the major findings is that 13 percent of the inventors are inadequately informed about the regulations of the Employees' Invention Act. Staudt et al. (1992) confirm that employee-inventors have only partial knowledge of their rights.

Given the controversy surrounding inventor compensation in general and the German institutions in particular, it is not surprising that some observers have called for the abolition of the law. For example, Brockhoff (1997) proposes to replace the collective legal regulation with an individual incentive system for employee-inventors, where compensation is a result of negotiations between inventor and employee.

3 Research questions and hypotheses

While a number of studies have looked at particular features of the German Employees' Inventions Act, little representative large-sample evidence has been produced. The most reliable information on the amounts paid out to inventors comes from Giummo's (2003) study. But his figures are not representative, since they reflect inventor compensation in a few large corporations. The questions that we address in this study are the following:

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[14] In 2002 the patent stock of the GPTO amounted to 376,744 patents. This number includes patents granted by the EPO with effect in Germany. According to the GPTO annual report, more than 80% of the applications filed with the GPTO are attributable to German firms. Therefore, patents coming under the German Employees' Invention Act at least amount to 300,000. In comparison, the Arbitration Board at the GPTO received 95 requests in 2000, 81 requests in 2001, and 87 requests in 2002 (GPTO 2003).

- Does the German Employees' Inventions Act create substantial rewards?
- Which type of inventor profits the most from the German Employees' Inventions Act?
- How does compensation differ across industries, technical fields, etc.?
- Do inventors consider the law important in providing suitable incentives?
- Do inventors point to significant disincentives created by the law?

To answer these questions, we collected data on inventor compensation (measured as the share of gross salaries before bonus payments) associated with a particular patent, characteristics of the patent and of the associated invention process as well as information on inventor biographies.

Given that the German Employees' Inventions Act regulates compensation relatively precise, our hypotheses for the empirical tests are easily derived:

H1. Inventor compensation increases with the value of the patent right.

H2. Inventor compensation decreases with the number of co-inventors.

H3. Inventor compensation decreases with the inventor's rank in the organization.

H4. Measured as a share of gross salaries, inventor compensation does not vary across industries.

H5. Measured as a share of gross salaries, inventor compensation does not vary with firm size.

The first three hypotheses reflect largely the regulatory components of the German Employees' Inventions Act. The latter two state that inventor compensation follows typical patterns of industry and firm size. A large number of studies have documented wage differentials between industries and between firms of different size. We measure inventor compensation as the share of gross salaries without inventor-specific remuneration; in our regressions industry and firm size variables should therefore have no statistically discernable effect if inventor compensation is proportional to gross wages.[15]

4 Data Source and Sample

4.1 Data Source – the German Inventor Survey

Data underlying this survey was collected within the scope of a European project sponsored by the European Commission. The project named PatVal (The Value of European Patents:

[15] Strictly speaking, the GEIA even allows us to be quite specific about the functional form of our regressions. The compensation is proportional to patent value, to the inventor's share in the invention, and to another factor measuring the inventor's contribution to the service invention. The latter depends on the economic exploitability of the service invention, the duties and position of the employee in the company, and also on the degree of involvement of the company in the creation of the service invention.

Empirical Models and Policy Implications Based on a Survey of European Inventors) started in January 2002. The main objective of the PatVal project is to create a database of characteristics of the invention process. The data were obtained from a survey of European inventors which were named in EPO patent grants. The survey responses were combined with information drawn from the patent documents and an extended patent database.
Research groups from six European universities collaborated on this project. In each of the six countries (France, Germany, Great Britain, Italy, Spain, and the Netherlands) domestic inventors were asked simultaneously about their granted EP patents as well as the invention process leading to the specific patent. A detailed description of the research design and of descriptive statistics is presented in Giuri et al. (2005).

This survey only relies on the German dataset of the PatVal survey. Therefore, units of observation are inventors who lived in Germany at the time of application of the respective patent. 10,500 EP patents containing inventors living in Germany were chosen by a stratified random sample from a list of all granted EP patents with priority date between 1993 and 1997 (15,595 EP patents). A stratified random sample was used in order to oversample potentially important patents. To do this, the sample contains all patents an opposition had been filed against by a third party (1,048) as well as patents which were not opposed but received at least one citation (5,333). Out of the remaining patents (9,212) a random sample of 4,119 patents was drawn. Within this sample, 118 inventors moved to another country in the meantime, and 857 are multiple inventors, which means they filled out at least two questionnaires. The remaining 8,357 inventors live in Germany and are represented with one patented invention in the dataset.

The questionnaire was mailed to the identified inventors. As addressee we chose the first inventor listed on the patent document. In cases where a verification of the inventor's address had not been possible the second inventor was chosen. If the address of the next inventor could not be verified, we proceeded until an address definitely turned out to be correct or a new address could be assigned to the inventor. In cases where the invention had been made by a single inventor or verification of the addresses had not been possible, we chose the first inventor (the only inventor) mentioned on the patent document. The selected inventors were provided with a cover letter together with the questionnaire. The letter also contained a link leading to a web questionnaire in order to give the inventors the possibility to choose between the paper-based and the web-based questionnaire. To date, we received 3,346 responses, resulting in a response rate of 32%.[16]
The questionnaire is divided into six sections: Section A contains personal information about the inventors, section B contains information on their educational backgrounds. Section C covers data on employment and mobility of the inventors. Section D is about the invention process (collaborations, important sources of knowledge). Section E contains information on

[16] We tested whether inventors who answered the questionnaire early differed significantly from inventors who answered late. The first 10% of respondents were considered early respondents whereas the last 10% were the late respondents in this analysis. Each of the two groups contained about 300 inventors. The most important dependent and explanatory variables were tested for differences: the value of the surveyed patent, the value of the patent family as well as the strategic value of the patent, additionally, the compensation for the surveyed patent and the compensation for all patents as share of annual income, finally, the inventor's age as well as the number of employees of the applicant. Results show no significant differences (at the 10% level) between the two groups.

the inventors' rewards as well as the German Employees' Inventions Act. This section will be most important for the following analysis. Section F finally deals with the value of the patents.

We merged the data from the questionnaire with bibliographic and procedural information on the respective patents obtained from the online epoline-database provided by the EPO. The epoline-database contains information on all published EP patent applications as well as on all published PCT applications since the foundation of the EPO in 1978. The dataset is an equivalent of the epoline-data as of March 31st, 2003 and covers over 1,200,000 patent files with application dates ranging from June 1st, 1978 to July 25th, 2002.

4.2 Variables

From the datasets described above, we generated a number of variables which are used in our empirical analysis. We briefly describe them here.

- PATSHARE - share of salary received as inventor compensation for the surveyed patent. In the survey, we asked the respondents, which share of their fixed salary they had received for the patent in question. We employ an Ordered Probit estimator to relate this variable to the exogenous regressors described below.
- EDUCATION – the questionnaire asked respondents to indicate their terminal degree. In order to simplify the analysis, we aggregate our education variables to three groups: secondary school or vocational training, vocational academy or university studies, doctoral or postdoctoral studies.
- AGE – the age of the inventor at the time of the survey.
- INVPROD – inventor productivity adjusted for age. We divide the total number of patent applications and inventions kept secret by age minus 25. One way of justifying this measure would be the assumption that inventors became active at the age of 25 and continued to work with constant productivity. Obviously, this is a stark simplification, but it will serve to generate a first version of an age-corrected productivity figure.
- MAINFIELD – main technical field. This variable aggregates the technical fields to which the inventions belong to.
- FIRMSIZE – number of employees. We obtained the firm size variable from the questionnaire. We use log(number of employees) in our regressions.
- INVENTORS – the number of inventors. The amount of inventor compensation received by any of the inventors depends on the total number of inventors. Since we do not have exact information on the contributions made by the inventors, we use this variable to control for differences between inventions coming from teams of differential size.
- PATVALUE – the monetary value of the patent. A central question in our survey asked respondents to indicate the value interval for their patent. The intervals were less than 30,000 €, between 30,000 € and 100,000 €, between 100,000 € and 300,000 €, between 300,000 € and 1 million €, between 1 and 3 million €, between 3 and 10 million €, and above 10 million €. We generate a set of 7 dummy variables

from this group and include them (with the exception of the first) in the regressions.

- STRATVALUE – strategic value of the patent. This variable indicates if the patent belongs to (a) the top decile of patents in this industry, (b) the top quartile, but not the top decile, (c) the top fifty percent but not the top quartile, and (d) the lower half of the patents in the industry. We maintain three of the four dummy variables in the regressions. Since these are likely to be collinear with the PATVALUE dummies, we use these measures as alternatives, not in conjunction.
- ORIGINALITY and GENERALITY. These measures were first proposed and computed by Trajtenberg et al. (1997) for US patents.
- PCT – a dummy variable indicating that a PCT application had been filed for this patent.
- CITES – citations received within 5 years following the publication of the search report. These measures were obtained from a citation database maintained at the Institute for Innovation Research.
- FAMSIZE – size of patent family. We measure the size of the overall international patent family by computing the number of equivalent patents in existence. This number is obtained from the ESPACE server maintained by the European Patent Office.
- MOBILITY variables – in order to test if mobile inventors (and patents based on inventions made by mobile inventors) differ from suitable control groups. We use dummy variables indicating that the inventor either (a) did not change to another employer after having made the invention (reference group) or (b) changed employers once or (c) changed employers twice or (d) changed employers more than twice since the date of the invention.
- CITY variables – two dummies indicating if the invention has been made in a city with more than 1 million inhabitants or in a city with between 500,000 and 1 million inhabitants. The reference group are inventions made in rural areas or cities with fewer than 500,000 inhabitants.
- INVENTION CONTEXT variables – these variables reflect characteristics of the invention process, in particular, (a) if the invention came about as the planned result of an R&D project, (b) whether it was an expected by-product of such an R&D process, (c) whether it was an unexpected by-product, or (d) whether the invention was made during the leisure time of the inventor. The reference group is given by inventions that were the product of a non-R&D process, for instance, inventions made in production or other functions of the firm.

5 Survey Evidence - Descriptive Statistics

The sample used for the multivariate analysis contains data from questionnaires received from 1,983 inventors. These are considerably fewer observations than in the overall sample – the reduction is due to the fact that some inventors were independent inventors (266 cases) and that some variables we need for the analysis are missing (1,097 cases). Table 1 presents summary statistics, i.e. mean values and standard errors for the variables described before.

The compensation for the surveyed patent (as share of annual gross income) ranges from 0 to 100 at an average of 1.8. 100% means that inventors double their annual income due to inventors' compensation. Payment for *all patents* of the surveyed inventors ranges from 0 to 500 at an average of 8.3. Over all, 18 inventors receive more than their annual income due to compensation for all of their patents. The distributions of these variables are depicted in Figure 1 and Figure 2. It is clear from these graphs that inventor compensation has a right-skew distribution – most inventors receive no or very small compensations for their inventions, while few inventors can add substantial sums to their gross salary. The inventors are characterized by a high educational level. On average, 50% of the inventors in the sample earned a university degree; another 38% undertook doctoral or postdoctoral studies. At the time of the survey, the inventors were aged between 32 and 76 at an average of 53 years. The inventors' productivity ranges from 0.1 to 32.3 patents per year of inventive activity, with a mean of 1.0. This result confirms previous findings by Lotka (1926), who found that the productivity of inventors follows a highly skew distribution.

Almost 60% of all patents were assigned to the chemical/pharmaceutical industry and to mechanical engineering. On average, patents were held by companies employing 52,278 employees. The number of employees ranges between 1 and 500,000 with a standard deviation amounting to 97,340. The median of the monetary patent value, ranging from "< 30,000 Euro" to "more than 10 million Euro", falls in the third category "100,000 to 300,000 Euro". The strategic patent value has its mean at "the patent belongs to the top 50% but not top 25% of the patents within the technological field". The number of citations received within 5 years after publication of the search report ranges from 0 to 13 at an average of 0.5 citations.

Tables 2 to 5 summarize the univariate or bivariate relations between the share of compensation received for the surveyed patent and a number of exogenous variables, i.e., inventors' age and education, firm size and number of inventors, monetary patent value, and strategic patent value. Table 6 tabulates the average values of a number of variables by technical field.

As to inventor age and education, Table 2 suggests that there are almost monotonic relationships between these variables and inventor compensation for the surveyed patent.[17] With greater educational attainment, the compensation share is decreasing. Presumably, this reflects the impact of the rank of the individual within the corporation (H3). As age increases, inventors tend to earn a higher share as compensation for the surveyed patent. This may very well reflect selection processes – productive inventors are retained in R&D, so that over time, a positive correlation between value of a patent and inventor age emerges. Note that the effect must be strong, since it even compensates the base effect in our dependent variable. As inventors get older, their base salary is presumably increasing due to seniority effects. If this presumption is correct, the inclusion of patent value in our multivariate regressions should render the age variable insignificant. In our value regression, the age variable should have a large positive coefficient. As we will see later, both predictions are actually born out.

A typical finding in labor economics suggests that wages in large firms are higher than those in smaller firms. Since we cannot control for the level of gross wages, there is some

[17] Similar results emerge for the overall compensation (inventor compensation for all inventions divided by the gross salary before compensation payments).

ambiguity associated with the tabulation of the compensation share variable. If the compensation share is also a positive function of firm size, we would expect the compensation variable to rise or be constant as firm size increases. The descriptive statistics in Table 3 do not confirm that view. At best, we find an inversely U-shaped relationship. It seems clear that the compensation shares in larger firms are smaller. However, note that this may reflect differences in the organization of R&D – inventor teams in large firms may very well have more members, thus reducing each inventor's share. In the multivariate regression, we will control for such effects. Should firm size not have a statistically significant impact, then we would conclude that inventor compensation (in absolute terms) is depending on firm size just as gross wages are. The relationship between compensation and the number of inventors is more straightforward – as the invention team gets larger, the average compensation share for each inventor is reduced.

Table 4 displays the relationship between the monetary value of the patent (as indicated by the inventor) and the inventor's compensation (again for the patent under consideration). The compensation share is (almost) monotonically increasing with patent value. Similarly, in Table 5 we can see clear evidence that the other "relevance variable" – the strategic and economic importance of the patent – has a plausible and statistically significant association with inventor compensation. This finding is again in accordance with the Guidelines for Remuneration as well as § 9 (2) ArbNErfG, determining that the economic exploitability of an invention determines the amount of payment. Note that the first group of patents – those ranked among the top 10 percent in strategic and economic importance – account for 16.8% percent of the observations. That simply reflects the fact that our stratified sampling approach has led to an oversampling of valuable and strategically important patents.

Table 6 summarizes mean values of a number of regressors by technical field. A brief inspection of this table shows that the compensation share is strongly affected by the number of inventors. While patents in chemicals and pharmaceuticals are the most highly cited and account for the largest patent families, the average number of inventors per patent is also relatively large. The average compensation share per patent in chemicals and pharmaceuticals is therefore the lowest of all technical fields. Nonetheless, the table also yields the puzzling result that overall compensation shares are the highest in the technical field of consumer goods and civil engineering. This table suggests that there are significant differences in inventor compensation across technical fields. But again, since various variables may have countervailing effects, the technical field impact needs to be considered in the multivariate setting. Before we turn to our multivariate results, we briefly comment on our qualitative survey responses.

To learn more about the motivating or discouraging effect of the German Employees' Inventions Act, the inventors were asked to give their opinion concerning the underlying legal regulations. The answers were divided into three groups according to their attitude towards legal regulations. Figure 3 shows that 59.5% of the inventors believe the Employees' Invention Act to be largely motivating, whereas 28.3% assume a negative effect on their motivation. The remainder, a group of 12.2% of the surveyed inventors, do not attach much importance to the legal regulations concerning their inventive performance.

The first group contains 920 inventors, assigning an overall positive effect to the legal regulations. Figure 4 shows frequencies of the incentive drivers mentioned by the inventors in the first group. Financial incentives turn out to be second to none, mentioned by 57.2% of the sub-sample. The advantage of well-defined legal provisions (18.0%) and the acknowledgement of inventive performance (16.6%) range far behind, in the second and third place. Also important for the employee-inventors is the employer's support concerning formalities of the patent application (3.6%) as well as the absorption of costs and risks by the employer (9.3%).

Inventors who regard the German legislation concerning employee inventions as discouraging for the invention process represent the second sub-sample (n_2 = 437). Figure 5 displays that "compensation too small" is the most frequently mentioned disincentive (33.6%). One third of the inventors in the second sub-sample consider compensation as too low, compared to their inventive performance. Almost one third (32.0%) complain about the lack of transparency concerning the determination of an appropriate compensation and about the intense influence capability of the employer on its calculation. 15.3% of the respondents mention delays in the payment of compensation (or even no payment) as non-satisfying.

Due to a decision of the Federal Court of Justice in November 1989[18], tax benefits for employee-inventor compensations have been cancelled. Therefore, it is not surprising that 6% of the second sub-sample complain about tax regulations. 9% complain about the additional burden of administration necessitated. Also mentioned by the inventors are conflicts with the employer (6%) as well as conflicts between inventors among themselves (6%). The particular problem concerning inventor - employer-conflicts is that inventors do not want to jeopardize their careers by contesting their inventor awards in court or by otherwise turning against their employers. Inventors come into conflicts with colleagues due to enviousness, resulting in an impairment of team work as well as in an interference of communication between colleagues. Results even show that inventors hinder a sequential or substitutional invention not deriving from them, in order not to loose the compensation granted for their earlier invention (2%).

Finally, the inventors reported a phenomenon, already observed by Staudt et al. (1992): the co-inventorship of superiors (1.8%). Superiors are mentioned as a co-inventor, not due to their inventive performance or participation in the inventive process, but due to their position within the firm. Given the notoriety that this phenomenon has received in the literature, our results suggest that its importance may have been overstated considerably.

6 Multivariate Analysis

Our multivariate analysis proceeds in two steps. First, we try to determine how our variables are related to the (presumably) most important determinant of inventor compensation – the patent's value. We use the ordinal information from our survey (see Table 4) and employ an ordered probit framework for the analysis. Our second step – the analysis of the compensation share variable – also treats the data as ordinal. We observe considerable bunching around particular integer values (0, 1, 2, 5, 10, 15, ...) in our data so that a transformation to an ordinal scale appears appropriate.[19]

The first part of the analysis confirms earlier results which suggest that the value of patents is highly correlated with a number of indicator variables. We consider the results in column (3)

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[18] Bundesverfassungsgerichts-Beschluss vom 29.11.1989 (1 BvR 1402/87, 1 BvR 1528/87) BStBl. 1990 II p. 479.

[19] However, it turns out that results from a Tobit-type analysis with a metric dependent variable are quite similar to the ones described here.

for the overall value specification first. Citations, legal challenges (opposition) and the size of the patent family are (as expected) positively associated with patent value. Somewhat unexpectedly, two other R&D process variables turn out to have a significant impact. First, patented inventions that are the planned product of R&D projects are more valuable than unplanned results or mere by-products of R&D. This result may reflect a selection effect – firms will actively try to develop ideas in R&D projects, if they expect the project to yield valuable results. This interpretation is strengthened by another result – the more inventors are involved in the invention, the more valuable it tends to be. Again, choosing relatively large teams is likely to reflect a company's assessment that it should try to achieve the invention quickly – presumably, because it is a valuable invention.

The surprise lies in the second R&D process variable with a positive coefficient – inventions made during the inventor's leisure time are considerably more valuable than other types of inventions. This result may reflect two very different phenomena – first, taking the positive coefficient at face value, it may indeed be the case that leisure time provides the optimal environment for creative break-throughs. On the other hand, the result may involve strategic behavior on the part of inventors who wish to enhance their contribution to the inventive process. Social desirability may play a big role in generating this result, and we will investigate it in more detail in the future.

A final comment on the value regression concerns the technical field dummy variables. In column (3), they do not contribute jointly any more to the explanation of patent value. This appears to be due to the inclusion of the R&D context variables in column (3).

We now turn to the inventor compensation regressions in columns (4), (5) and (6). Our expectation is that the results should reflect strongly the legal provisions of the German Employees' Inventions Act. Indeed, in all specifications, the dominant determinant of compensation is the patent's value. The coefficients of the dummy variables are increasing as the value of the patent increases, and they are highly significant throughout. Moreover, the results are very stable as we include more variables.

The number of inventors has the expected negative coefficient which is again highly significant in all specifications. Interestingly, inventor productivity and educational attainment carry a negative sign. This result is consistent with the view that these variables proxy for the inventor's rank in the organization which should be negatively associated with the level of compensation for service inventions.

Firm size and the technical field to which the invention belongs have no impact whatsoever. Moreover, the value correlates opposition, citations and family size do not have any impact, nor do any of the other variables in that group. Apparently, the inclusion of the value dummy variables leaves little explanatory power for these variables. Similarly, the variables describing the context of the invention have no explanatory power.

The remarkable picture emerging from the compensation regression is that those variables which should have an impact due to the text of the law do indeed have an impact. While that was expected, it seems remarkable that technical field and other variables cannot develop any additional explanatory power. It seems that on average, the GEIA is indeed applied fairly consistently across different industries and technical fields. This statement leaves considerable room for deviations from the average, but it is highly unusual that a set of control variables such as those for the technical field of the invention does not have any statistical role in the regression.

7 Conclusions

This paper has discussed in some detail differences in national legal provisions dealing with the compensation that inventors are entitled to for their service inventions. Germany assumes an unusual role in this comparison, since inventor compensation is regulated to a level of detail that is not found in other countries. The extent of compensation can be considerable. In our sample, the inventors report that they receive on average about 8 percent of their gross salaries as compensation for service inventions. Our multivariate analysis yields the surprising result that the law appears to be applied very consistently across different technical fields. We find that the patent's value, the number of inventors and variables associated with the inventor's position in the company have the expected impact. Moreover, by comparing these results to those of a value regression, we can assure ourselves that the lack of explanatory power of other variables is not due to measurement problems. Taken together, there is reason to believe that inventor compensation is largely a meritocratic system.

The qualitative results from our survey confirm that view to some degree. The majority of inventors views the compensation system positively. Yet, there appear to be areas in which an improvement or reform is necessary. We will consider these areas in more detail in subsequent research.

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Table 1
Descriptive Statistics (N = 1,983)

Variable	Mean	S.D.	Min.	Max.
Share of salary received as inventor compensation for the surveyed patent	1.76	5.26	0	100
Share of salary received as inventor compensation for all patents[1]	7.94	25.70	0	500
Education (terminal degree)				
Lower secondary school	0.01		0	1
Upper secondary school	0.01		0	1
Vocational training	0.06		0	1
Trade and technical school	0.03		0	1
University studies	0.50		0	1
Vocational academy	0.02		0	1
Doctoral/postdoctoral studies	0.38		0	1
Age of the inventor at the time of the survey	52.90	9.32	32	76
Inventor productivity	1.02	1.61	0.1	32.26
Main technical field				
Electricity/electronics	0.15		0	1
Instruments	0.09		0	1
Chemicals/pharmaceuticals	0.27		0	1
Process engineering	0.19		0	1
Mechanical engineering	0.24		0	1
Consumer goods/civil engineering	0.07		0	1
Number of employees	52.28	97.34	1	550,000
Number of inventors	2.49	1.65	1	15
Monetary value of the patent	3[2]		1	10
Strategic value of the patent	3[2]		1	4
Originality	0.04	0.14	0	0.67
Generality	0.01	0.07	0	0.63
Oppositions received	0.11		0	1
PCT application filed	0.27		0	1
Citations received within 5 years	0.54	1.14	0	13
Size of patent family	5.40	3.96	1	33
Job mobility				
Inventor did not change the employer	0.83		0	1
Inventor changed employer once	0.11		0	1
Inventor changed employer twice	0.04		0	1
Inventor changed employer three times	0.01		0	1
Inventor changed employer more than three times	0.00		0	1
Environment of the invention				
More than 1 million inhabitants	0.10		0	1
500,000 to 1 million inhabitants	0.12		0	1
Less than 500,000 inhabitants	0.78		0	1
Invention process				
R&D project / planned result	0.29		0	1
R&D project / expected by-product	0.18		0	1
R&D project / unexpected by-product	0.18		0	1
Invention arose during normal job / not R&D	0.29		0	1
Invention arose during leisure time	0.05		0	1

1: Multiple inventors are included once (N = 1,800)
2: Median

Table 2
Inventor Compensation by Age and Education

Age (groups)	Educational achievement (groups)			
	Secondary school/ vocational training	Vocational academy/ university studies	Doctoral/postdoctoral studies	Total
31 to 40	1.25	1.46	0.70	1.25
	(14)	(103)	(39)	(156)
41 to 50	2.56	1.68	1.44	1.63
	(54)	(380)	(341)	(775)
51 to 60	2.70	1.81	1.46	1.81
	(79)	(263)	(202)	(544)
61 to 70	5.32	1.80	1.23	2.06
	(64)	(282)	(162)	(508)
Total	3.36	1.72	1.36	1.76
	(211)	(1,028)	(744)	(1,983)

Note: In a bivariate ANOVA, the effect of education is highly significant (F = 11.68, p = 0.000), whereas age effects are not significant (F = 0.93, p = 0.423)

Table 3
Inventor Compensation by Firm Size and Number of Inventors

Firm size in number of employees (groups)	Number of inventors (groups)				
	1	2	3	4 and more	Total
less than 250	2.44	2.56	0.82	0.91	2.07
	(97)	(54)	(30)	(21)	(202)
251 to 1,500	2.70	2.33	1.38	1.42	2.23
	(180)	(118)	(61)	(55)	(414)
1,501 to 10,000	2.24	1.45	1.44	2.36	1.90
	(183)	(143)	(99)	(99)	(524)
more than 10,000	1.75	1.46	1.46	0.91	1.37
	(227)	(202)	(161)	(253)	(843)
Total	2.23	1.77	1.39	1.31	1.76
	(687)	(517)	(351)	(428)	(1,983)

Note: In a bivariate ANOVA, the effect of the size of inventor teams is significant at the 10% level (F = 2.42, p = 0.064), whereas firm size effects are not significant (F = 1.97, p = 0.116)

Table 4
Inventor Compensation by Monetary Patent Value

Patent value	Compensation for this patent (share of gross annual income)		
	Number of observations	Share of Obs.	Mean
less than 30,000 €	190	9.6%	0.71
30,000 to 100,000 €	381	19.2%	1.24
100,000 to 300,000 €	449	22.6%	1.71
300,000 to 1 million €	433	21.8%	1.63
1 to 3 million €	263	13.3%	2.05
3 to 10 million €	162	8.2%	2.80
more than 10 million €	105	5.3%	3.97
Total	1,983	100.0%	1.76

Note: In a univariate ANOVA, the effect of the monetary patent value is highly significant ($F = 6.33$, $p = 0.000$).

Table 5
Inventor Compensation by Strategic Patent Value

Strategic importance of patent	Compensation for this patent (share of gross annual income)		
	Number of observations	Share of Obs.	Mean
top 10 percent	332	16.7%	2.70
top 25 percent	362	18.3%	2.71
top 50 percent	452	22.8%	1.72
lower 50 percent	837	42.2%	1.00
Total	1,983	100.0%	1.76

Note: In a univariate ANOVA, the effect of the strategic patent value is highly significant ($F = 13.64$, $p = 0.000$).

Table 6

Means of Compensation for this Patent, Compensation for all Patents, Number of Inventors, Number of Citations Received, and Size of the Patent Family by Main Technological Field (N = 1,983)

Main technical field	Compensation for this patent	Compensation for all patents	No. of inventors	No. of citations received within 5 years	Size of patent family
Electricity/electronics	1.39	6.48	2.19	0.48	4.42
Instruments	1.41	6.23	2.01	0.59	4.29
Chemicals/pharmaceuticals	1.59	6.78	3.29	0.73	7.26
Process engineering	2.09	9.40	2.37	0.51	5.06
Mechanical engineering	1.94	9.54	2.23	0.41	4.70
Consumer goods / civil eng.	2.19	13.58	1.83	0.34	5.01
Total	1.76	8.31	2.49	0.54	5.40

Note: In a univariate ANOVA, the effect of the main technical field turned out to be highly significant ($F = 42.03$, $p = 0.000$).

Table 7
Multivariate Analysis of Patent Value and Inventor Compensation

	ORDERED PROBIT ON PATENT VALUE			ORDERED PROBIT ON INVENTOR COMPENSATION		
	(1)	(2)	(3)	(4)	(5)	(6)
30,000 - 100,000 Euro				0.4247***	0.4201***	0.4332***
				(0.1522)	(0.1528)	(0.1522)
100,000 - 300,000 Euro				0.6332***	0.6214***	0.6282***
				(0.1488)	(0.1487)	(0.1485)
300,000 - 1 Mio Euro				0.7554***	0.7532***	0.7668***
				(0.1465)	(0.1466)	(0.1465)
1 - 3 Mio Euro				0.8835***	0.8864***	0.8995***
				(0.1551)	(0.1552)	(0.1551)
3 - 10 Mio Euro				1.1410***	1.1350***	1.1401***
				(0.1662)	(0.1663)	(0.1671)
more than 10 Mio Euro				1.4803***	1.4957***	1.4945***
				(0.1779)	(0.1803)	(0.1802)
ln (number of inventors)	0.1222***	0.0843**	0.0773*	-0.2000***	-0.1877***	-0.1971***
	(0.0405)	(0.0405)	(0.0410)	(0.0542)	(0.0545)	(0.0555)
ln (number of employees)	-0.0070	-0.0035	-0.0023	-0.0109	-0.0120	-0.0144
	(0.0108)	(0.0110)	(0.0111)	(0.0141)	(0.0141)	(0.0142)
electricity/electronics	-0.2562***	-0.1684**	-0.1620*	-0.0905	-0.1159	-0.1257
	(0.0827)	(0.0849)	(0.0872)	(0.1163)	(0.1176)	(0.1208)
instruments	-0.1947**	-0.1194	-0.1151	0.0511	0.0303	0.0351
	(0.0931)	(0.0948)	(0.0947)	(0.1240)	(0.1260)	(0.1280)
process engineering	-0.1540**	-0.0901	-0.0950	0.0284	0.0173	0.0376
	(0.0764)	(0.0774)	(0.0782)	(0.1056)	(0.1053)	(0.1059)
mechanical engineering/machinery	-0.1617**	-0.0842	-0.0796	0.0597	0.0363	0.0494
	(0.0778)	(0.0795)	(0.0800)	(0.0993)	(0.0999)	(0.1014)
consumer goods/civil engineering	-0.2021**	-0.1476	-0.1649	0.0669	0.0598	0.0645
	(0.1009)	(0.1031)	(0.1044)	(0.1443)	(0.1440)	(0.1454)
ln (1+inventor productivity)	0.1089**	0.1097**	0.1026*	-0.3797***	-0.3759***	-0.3815***
	(0.0540)	(0.0536)	(0.0537)	(0.0802)	(0.0804)	(0.0805)
vocational academy/university studies	0.0133	0.0086	0.0145	-0.2234**	-0.2277**	-0.2367**
	(0.0735)	(0.0742)	(0.0745)	(0.0994)	(0.0999)	(0.1006)
doctoral/postdoctoral studies	0.0708	0.0384	0.0344	-0.5049***	-0.4965***	-0.5109***
	(0.0844)	(0.0847)	(0.0857)	(0.1187)	(0.1192)	(0.1211)
ln (age of the inventor)	0.2154	0.2808**	0.2376*	0.1401	0.1288	0.1386
	(0.1334)	(0.1389)	(0.1417)	(0.1779)	(0.1813)	(0.1833)
measure of originality		-0.0128	-0.0008		-0.2514	-0.2304
		(0.1626)	(0.1649)		(0.2388)	(0.2383)
measure of generality		-0.5109	-0.5535		-0.2370	-0.2330
		(0.4055)	(0.4060)		(0.5036)	(0.5012)
oppositions received		0.2473***	0.2448***		-0.0092	-0.0091
		(0.0724)	(0.0730)		(0.1062)	(0.1065)
PCT application filed		-0.0135	-0.0071		0.0574	0.0634
		(0.0584)	(0.0589)		(0.0779)	(0.0781)
cites received within 5 yrs		0.0665***	0.0669***		0.0005	0.0014
		(0.0223)	(0.0221)		(0.0294)	(0.0295)
size of patent family		0.0346***	0.0334***		-0.0098	-0.0098
		(0.0073)	(0.0074)		(0.0094)	(0.0094)
changed employer once		0.1018	0.0919		-0.0214	-0.0187
		(0.0714)	(0.0713)		(0.1076)	(0.1085)
changed employer twice		0.1951	0.1814		-0.0538	-0.0522
		(0.1239)	(0.1253)		(0.1565)	(0.1566)
changed employer more than twice		-0.2275	-0.2277		-0.4272	-0.4191
		(0.2005)	(0.1978)		(0.3171)	(0.3192)
city with more than 1 mio inhabitants			0.0449			0.0919
			(0.0834)			(0.1065)
city with 500.000 to 1 mio inhabitants			0.0076			0.0419
			(0.0752)			(0.0947)
R&D project, planned result			0.1262**			0.1068
			(0.0634)			(0.0833)
R&D project, expected by-product			0.0118			-0.0349
			(0.0687)			(0.0948)
R&D project, unexpected by-product			-0.1359*			0.0866
			(0.0734)			(0.0967)
invention arose during leisure time			0.2773***			-0.0480
			(0.1037)			(0.1613)
Log Likelihood	-3620.573	-3591.251	-3581.022	-1550.377	-1547.776	-1545.692
Pseudo R-squared	0.0068	0.0149	0.0177	0.0580	0.0596	0.0609
Chi-squared (df)	47.75 (11)	100.61 (20)	115.06 (26)	177.40 (17)	184.34 (26)	190.23 (32)
Observations	1983	1983	1983	1983	1983	1983

Robust standard errors in parentheses
* significant at 10%; ** significant at 5%; *** significant at 1%

Figure 1
Share of Salary Received as Inventor Compensation for this Patent (N = 1,983)

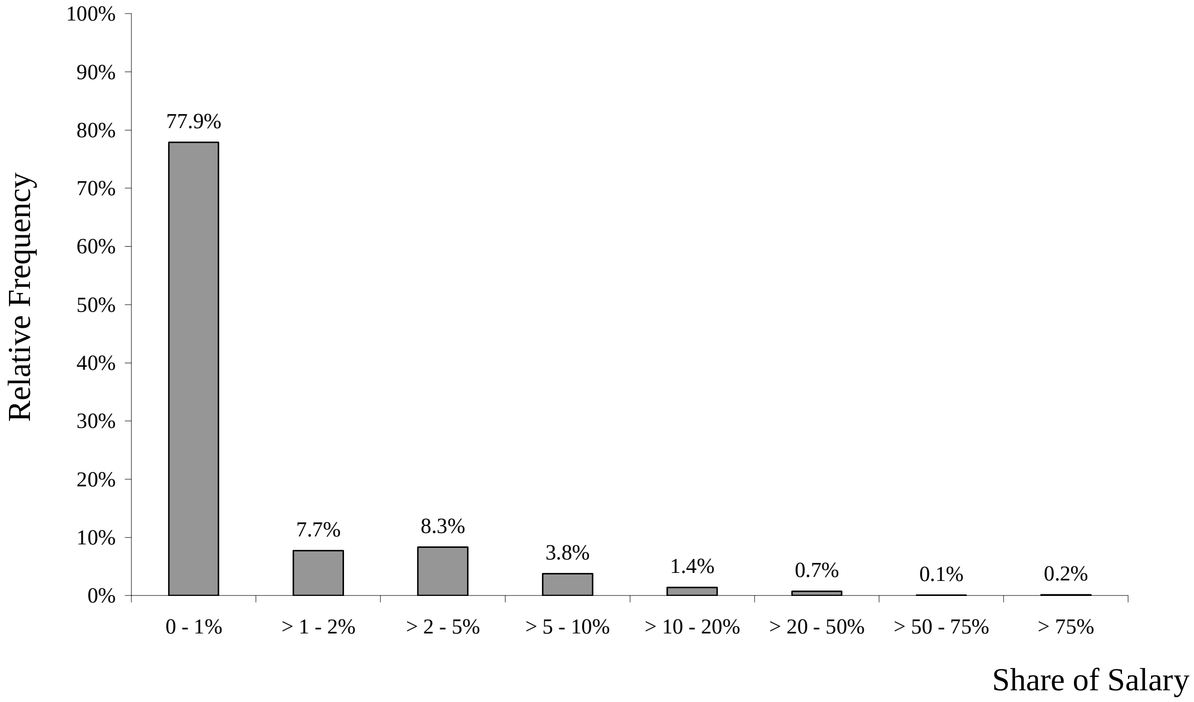

Figure 2
Share of Salary Received as Inventor Compensation for all Patents (N = 1,800[1])
[1] Multiple inventors are included once

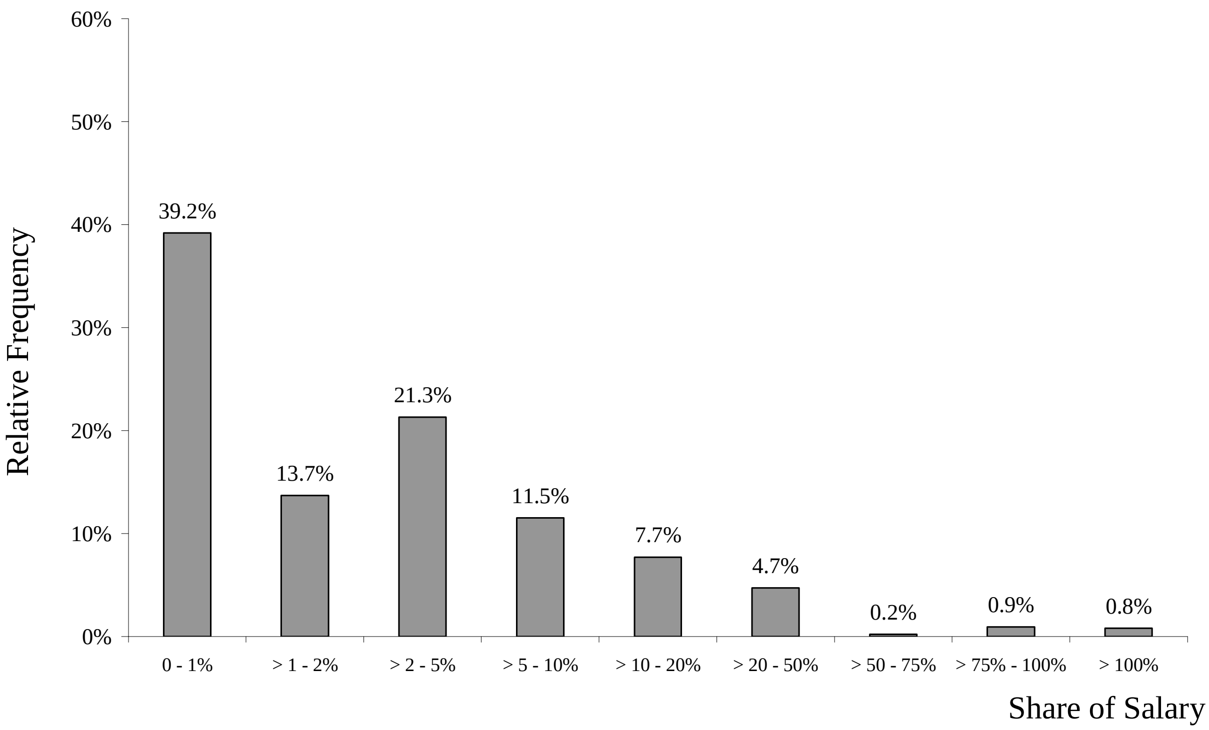

Figure 3
Effect of the German Employees' Inventions Act on Incentives for Innovation

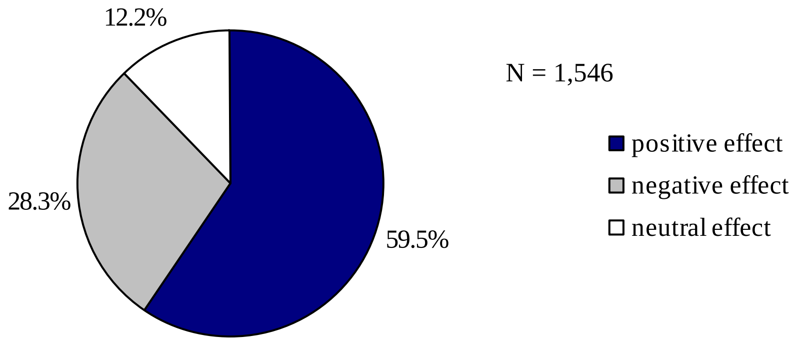

Figure 4
Incentives Emerging from the German Employees' Inventive Act
(Sub-Sample of Inventors who Assign a Positive Effect to Motivation
due to the Legal Regulations)

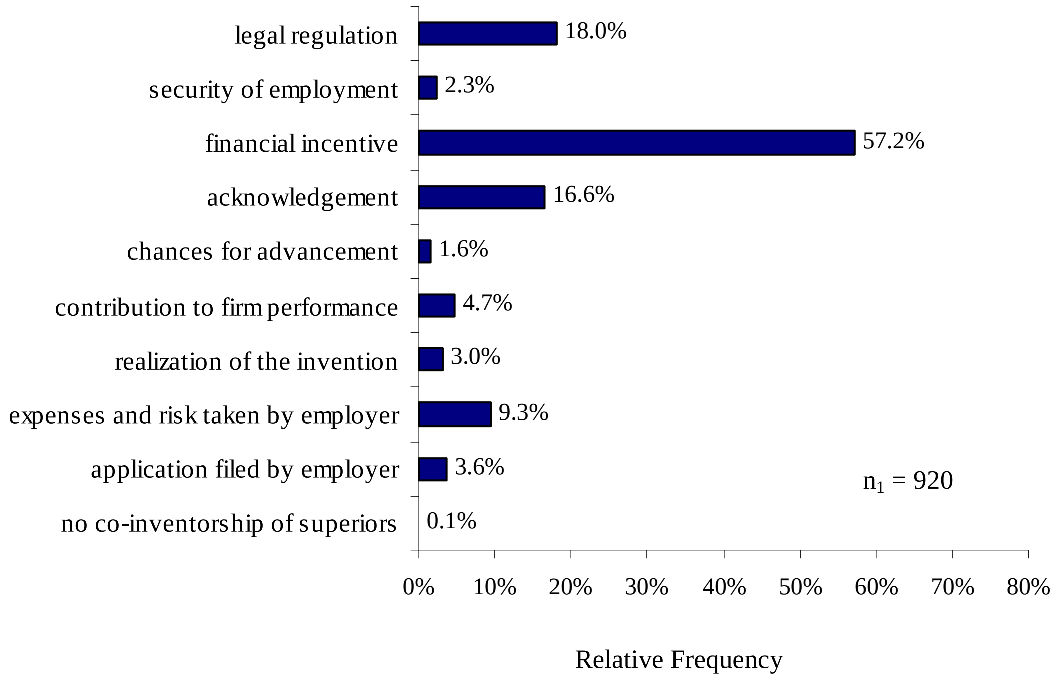

Figure 5

Disincentives Emerging from the German Employees' Inventive Act
(Sub-Sample of Inventors who Assign a Negative Effect to Motivation
due to the Legal Regulations)

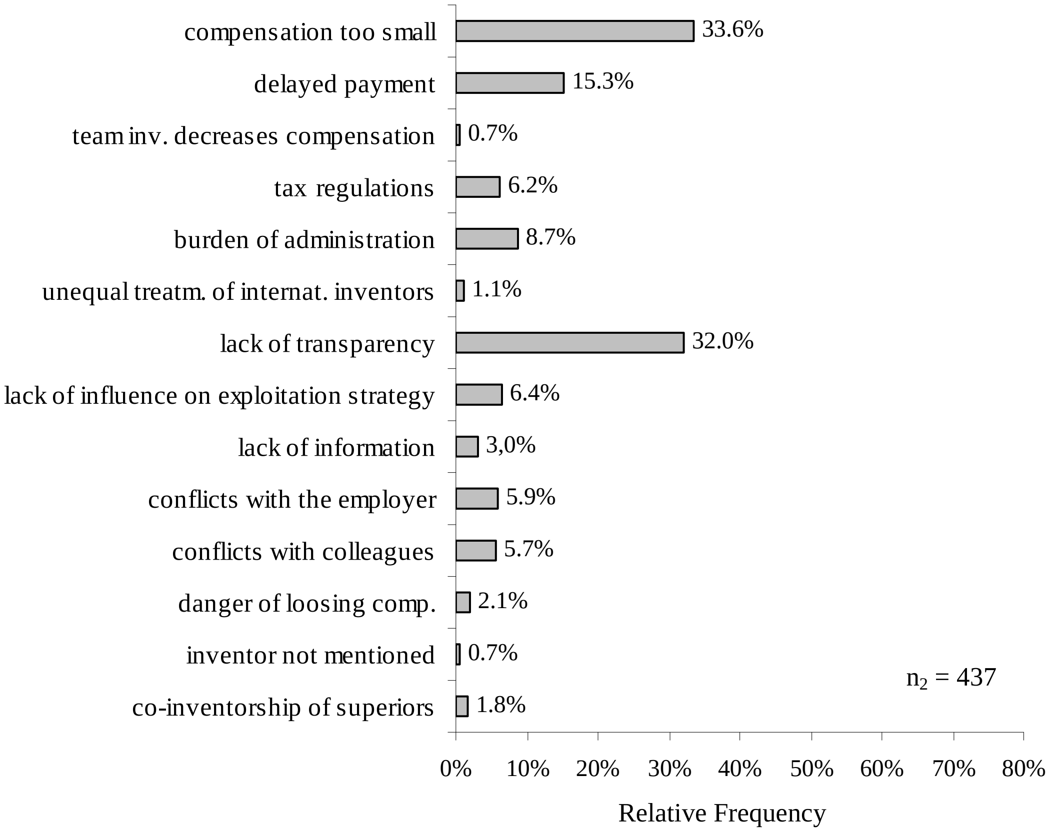

Figure 6

No effect Emerging from the German Employees' Inventive Act
(Sub-Sample of Inventors who Assign a Neutral Effect to Motivation
due to the Legal Regulations)