PATENT QUALITY AND A TWO-TIERED PATENT SYSTEM*

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In this paper, we study the determinants of patent quality and volume of patent applications when inventors care about perceived patent quality. We analyze the effects of various policy reforms, specifically, a proposal to establish a two-tiered patent system. In the two-tiered system, applicants can choose between a regular patent and a more costly, possibly more thoroughly examined, "gold-plate" patent. Introducing a second patent-tier can reduce patent applications, reduce the incidence of bad patents, and sometimes increase social welfare. The gold-plate tier attracts inventors with high ex-ante probability of validity, but not necessarily applicants with innovations of high economic value.

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I. INTRODUCTION

The quality of patents has been a subject of growing concern. Bad patents—patents that would have failed the novelty or non-obviousness patentability requirements had their examiners been more informed—likely have adverse effects on our society. Patents, good or bad, have social costs. Patent holders can exclude others from use of inventions that might hinder future innovations and commercialization of products, or induce unnecessary costs of duplication and inventions around existing patents.

Our paper highlights another, largely overlooked, cost of bad patents—the negative externality imposed by bad patents on all patent holders. We argue that bad patents undermine the goals of the patent system because they reduce the value of holding patents. Third parties (e.g., competitors, investors, etc.) are likely less informed than the inventor herself about the probability of validity of a specific issued patent, but they have an overall perception of patent quality. How third parties perceive the quality of patents may affect a patentee's ability to deter entry, negotiate licensing fees, bargain, or secure venture capital funding. For example, if patent quality is perceived to be low, a potential entrant might be less worried about infringement and an investor might be less impressed by the fact that a start-up company holds a patent. Patent examination only provides an imperfect public signal of validity. If a patent system allows many bad patents, the perceived quality of patents is low and, therefore, so is the value of holding patents. This limits the ability of the patent system to reward true inventors.

We study the determinants of patent quality – the probability that a patented innovation is good (novel and non-obvious in light of the prior art). The true validity of an innovation is unknown, but every inventor has private information on the ex-ante (before examination) probability of validity of her own invention. In equilibrium, there is a threshold probability of validity above which inventors apply for a patent. This threshold and the perceived patent quality are jointly determined in equilibrium. An increase in patent quality lowers the threshold, but a lower threshold results in a lower patent quality.

Concerns over patent quality and the backlog problem[1] prompted several proposals for patent system reforms, for example, a patent opposition system (Merges, 1999), patent bounties (Thomas, 2001), community patent review (Noveck, 2006) and 'gold-plate' patents (Lemley, Lichtman & Sampat, 2005; Lemley & Lichtman, 2007). Our paper provides insights on the potential effects of such policies on the volume of patent applications and on the quality of patents. We show that an increase in the patenting fee reduces the number of patent applications that have low ex-ante probability of validity; it also increases the quality of patents (that is, the probability that granted patents are good) and thus, their value. Making the examination process more stringent has a positive effect on patent quality, but interestingly, it has an ambiguous effects on the volume of patent applications. On one hand, stringent examination reduces the probability of any applicant to receive a patent, which deters low probability of validity applicants. On the other hand, the increase in expected patent quality makes holding a patent more valuable.

We are particularly interested in evaluating the proposal to establish a two-tiered patent system. In the new system, applicants would be allowed to 'gold-plate' their patents by paying a higher fee and being subject to a more thorough review process. According to Lemley et al. [2005], this 'would dramatically improve the quality of economically significant patents.' The proposal has also attracted the attention of the current administration:

> [W]ith better informational resources, the Patent and Trademark Office could offer patent applicants, who know they have significant inventions, the option of a rigorous

[1] According to recent USPTO data, the unexamined patent applications backlog (i.e., patents which are awaiting First Office Action at any given time) is over 600,000 applications. See http://www.uspto.gov/dashboards/patents/main.dashxml (last accessed May 4, 2013).

> and public peer-review that would produce a 'gold-plate' patent much less vulnerable to court challenge. Where dubious patents are being asserted, the PTO could conduct low-cost, timely administrative proceedings to determine patent validity.[2]

Our paper formally models a two-tiered patent system and examines its outcomes compared to the standard (single-tiered) system.[3] We show that in equilibrium in a two-tiered system, innovators with high ex-ante probability of validity apply for gold-plate patents, intermediate applicants apply for regular patents (the lower tier) and the innovators with lowest probability of validity do not apply. If economically more significant patents tend to have higher probability of validity than the less significant ones (for example, due to more intensive prior art search), then their innovators will be more likely to apply for gold-plate patents. However, since the choice of patent tier can also depend on the benefits from patenting, sorting based on economic significance (which is one of the intended consequences of the two-tiered system) is not guaranteed.

We consider a family of two-tiered systems in which the lower tier has the same examination intensity and fees as the single-tiered system, and the higher tier offers equally or more intense examination for a higher fee. We call this an 'added-tier system.' We show that introducing an added tier will reduce the volume of patent applications and of bad patents. Intuitively, the gold-plate tier attracts the highest probability of validity applicants, making the quality of regular patents lower than in the single-tiered system. Thus, the equilibrium in this added-tier system excludes the worst applicants to apply under the single-tiered system. Gold-plate patents are of better quality than in the single-tiered system (because of better selection of applicants and more thorough examination). In the added-tier system, there are fewer bad patents.

We extend the model to consider the incentive to invest in R&D. The set of innovators then becomes endogenous, and depends on the incentives that the patent system provides. We define a simple welfare function that accounts for the surplus of innovators and consumers. We find that an added-tier system does not always offer a welfare improvement over the single-tiered system. Intuitively, reducing the volume of bad patents might come at the cost of decreased incentive to innovate.

Welfare under an optimal two-tiered system is at least as high as the welfare under an optimal single-tiered system. We show that when the benefit from having the highest patent quality is sufficiently large, the optimal two-tiered system results in strictly higher welfare than the optimal single-tiered system. This is true because the two-tiered system identifies a subset of high quality patents; when these offer sufficiently high benefits, the two-tiered system can increase welfare, as it allows benefiting from the high quality of gold-plate patents without increasing examination costs.

The rest of this paper proceeds as follows. In Section II, we discuss the related literature. In Section III, we describe the model. In Section IV, we focus on the analysis of the standard single-tiered patent system. In Section V, we analyze the two-tiered patent system. Section VI considers welfare and incentives to invest in R&D. Section VII offers a discussion on economic significance of innovations and the incentive to gold-plate patents. Section VIII concludes.

II. RELATED LITERATURE

This paper relates to a large body of literature on innovation and patent policy (see Scotchmer, 2006, for a detailed review). Specifically, our paper contributes to a body of literature that recognizes imperfections in the functioning of the patent examination process. Farrell and

[2] See Barack Obama on Technology and Innovation at http://obama.3cdn.net/780e0e91ccb6cdbf6e_6udymvin7.pdf

[3] Our model abstracts from some aspects of the original proposal. In particular, Lemley et al.'s [2005, 2007] proposal involves differences in the presumption of validity of patents in the two tiers.

Shapiro [2008] propose a model of licensing in the shadow of patent litigation. They define a patent's strength as the probability that it would be found valid and infringed if tested in court, and identify conditions under which weak patents impose a greater social cost. Langinier and Marcoul [2012] concentrate on incentives to search and disclose prior art given an imperfect examination process. Caillaud and Duchêne [2011] examine the impact of the patent office on firms' incentives to innovate and to apply for patents, and the overload problem patent examiners face. They consider the role of the patent fees as a policy instrument.

From a theoretical perspective, there is no consensus on the optimal level of the patent application fees. Rassenfosse and van Pottelsberghe de la Potterie [forthcoming] review the economic literature on the role of the patent fees. They present stylized facts on the patent fees of thirty patent offices worldwide, illustrating high heterogeneity in the level and structure of the patent fees. According to their paper, '[p]atent fees are generally applicant friendly and their setting appears to be governed by the imperative to balance budget or to adjust to the level of other patent offices. . . ' and only recently policy-makers have '. . . realized that the patent fees can be used as a policy tool.' Based on a survey of R&D labs in the U.S. manufacturing sector, Cohen et al. [2000] report that 36.7 percent of respondents indicated application costs as a reason that figured into their decision not to patent.

In our paper, patent tiers differ in the fees and examination intensities. Patent systems may offer tiers that differ along other dimensions. A patent renewal system can be understood as a multi-tier patent system in which innovators can choose to pay more for a longer patent life.[4] Crampes and Langinier [1998] suggest that renewals convey information, therefore an incumbent may prefer not to pay the renewal fee for the patent to signal low market profitability. Cornelli and Schankerman [1999] show that when firms have different R&D productivities, patent renewal systems can improve welfare. Scotchmer [1999] suggests a model with asymmetric information on the costs and benefits of research. She shows that all implementable decision rules can be implemented with renewal mechanisms.

Versions of tiered systems are already in place or being considered in some countries. Christie and Moritz [2005] describe Australia's two-tiered system. Patents in the lower tier ('innovation patents') are required a lower threshold of inventiveness and are not subject to opposition prior to grant. Innovation patents are granted a maximum of eight year term and permit up to five claims.

In Japan, applications are not examined unless there is a request for examination (for a fee) within three years of application. If a request for examination has not been made within the time limit, the application is deemed withdrawn.[5] Yamauchi and Nagaoka [2008] study the patent system reform in Japan. Patent offices in other countries including Canada, China, Germany, India, Korea, Romania, Russia and Thailand also offer deferred examination or some form of delayed examination request (see Norman et al., 2010).[6] One can view applications for which innovators did not request examination as belonging to a lower tier.[7]

Our paper also draws on literature that deals with testing and certification in the presence of asymmetric information. Our model has a certifier (i.e., the patent office), who can detect low quality (a non-patentable innovation) with some probability (determined by the examination intensity). According to Dranove and Jin [2010] who review the literature on quality disclosure and certification, '[m]ost of the theoretical work focuses on the incentives for firms to voluntarily disclose quality and for certifiers to provide unbiased certification about product quality.' The

[4] We focused on the application fees. Renewal fees are paid conditional on the patent being granted, and can be captured in our model by the benefit functions.

[5] Article 48(3) of the Japanese Patent Law. See http://www.jpaa.or.jp/english/aboutus/pdf/open_seminar.pdf

[6] Examination delays occur also in systems that do not offer deferred examination. In a model of the US patent system, Regibeau and Rockett [2010] explain the relationship between the importance of inventions and delays in examination.

[7] In the deferred system, applicants can switch from the lower tier (that offers no examination) to the higher tier by requesting examination. They cannot stay in the lower tier for too long.

role of the patent office is not only to reveal information, but to grant legal intellectual property rights. This affects the incentives of innovators to apply for patents and determines the nature of disclosure of information by the patent office. In some models in the certification literature (e.g., Lizzeri, 1999), the certifier perfectly observes quality. In other models (e.g., Gill & Sgroi, 2008), the certifier only observes a signal of quality. In our model, the test (examination) can identify 'bad' applications, but unless the examination is perfect, some bad applications remain undetected.

The study by Farhi, Lerner and Tirole [2012] is relevant to ours in its examination of tiered certification. In their paper, sellers (analogous to innovators in our model) want to be rated highly. Sellers start uninformed, but can quickly learn about the quality of their product. Farhi et al.'s [2012] paper investigates the questions of transparency (e.g., should failure to be certified be revealed?) and the coarseness of rating. One important difference in their analysis is that a seller who failed to be certified in the higher tier can go down the pecking order to be certified by a lower tier (e.g., journal submissions). In contrast, in the context of patents, if invalidating prior art was revealed in the gold-plate patent examination process, the applicant cannot apply for the lower patent tier.

III. THE MODEL

There exists a large heterogeneous population of inventors. Each inventor has one invention, which can be good or bad, but its true state is unknown. The inventor has private information – an ex-ante (before filing for a patent) probability that the invention is good, $\theta \in [0, 1]$. That is, θ is the probability that there does not exist any invalidating prior art.[8] Inventor types θ are independently drawn, the cumulative distribution function $F(\theta)$ is differentiable, with a positive density $f(\theta) > 0$.

An inventor can choose whether to apply for a patent. The patent application fee is P. Each application is examined in the patent office. For simplicity, we assume that patentability only depends on whether invalidating prior art is found in the examination process or not. The examiner searches for prior art exerting search effort such that, if there exists invalidating prior art, it would be found with a probability π. If no invalidating prior art is found, a patent is granted.[9] Hence, a bad innovation is granted a patent with probability $(1 - \pi)$ and a good innovation is always granted a patent.

By making the assumption that invalidating prior art is found with a known probability π, we implicitly assume that the patent office is committed to (on average) a certain examination intensity. We find this assumption to be reasonable because the patent office is a government agency that interacts with inventors repeatedly (creating a reputation); the information on its budget, the number of employees and the time allocated to patent examination (at least, on average) can be made public. According to Cockburn et al. [2003], the 'USPTO operates various internal systems to ensure 'quality control' through auditing, reviewing and checking examiner's work.' Thus, it seems reasonable that, by and large, the patent office can make sure its employees follow the guidance provided to them for examination procedure and intensity.[10]

We assume that the value of a patent to an inventor depends on the quality it is perceived to have by less informed third parties. In equilibrium, perceived quality is correct – it is the probability that a patented innovation is good (i.e., there does not exist any invalidating prior

[8] Patent applications often include several claims. Validity is determined claim by claim. We simplify here by assuming that the patent is either valid—all its claims are valid—or it is not.

[9] This simplifying assumption allows us to focus on the granting of bad (not truly novel) patents. In reality, the patent office may reject novel innovations, for example, due to misunderstanding of prior art that was found, or for reasons unrelated to the prior art.

[10] For models that account for examiners' incentives, see Langinier and Marcoul [2010] and Schuett [forthcoming].

art):

$$q = \Pr[\text{good patent} \mid \text{patent was granted}].$$

The benefit from holding a patent depends on whether it is good or bad, and on the perceived quality of patents. Let $G(q)$ denote the benefit from a good patent and $B(q)$ denote the benefit from a bad patent.[11] An inventor does not know for sure if her invention is good and if it will be granted a patent. Her expected payoff from a patent application is:

$$V(\theta, q) = \theta G(q) + (1-\theta)(1-\pi)B(q) - P. \tag{1}$$

The functions $G(q)$ and $B(q)$ are differentiable and satisfy the following assumptions:

$$G(q) \geq B(q) \geq 0 \text{ and } B'(q), G'(q) > 0 \text{ for all } q. \tag{2}$$

We assume that the benefit from a bad patent is lower because, if a dispute arises, it is less likely to be upheld in court. Benefits increase with perceived patent quality for several reasons: a higher perceived patent quality makes infringement less likely, and puts the patentee in a better position in negotiations over licensing or infringement disputes; a higher perceived quality also makes the patent more valuable as a signal to the investors and rival firms. Finally, for simplicity, the value to the inventor from an invention that is not protected by a patent is assumed to be zero.[12]

IV. THE SINGLE-TIERED PATENT SYSTEM

In this section, we examine the single-tiered patent system – the standard patent system in which inventors face the decision to apply for patent protection or not to apply, but have no choice regarding the intensity of the examination process.

IV(i). *Equilibrium*

The inventor applies for a patent if her expected benefit from applying exceeds that from not applying, $V(\theta, q) \geq 0$. Using (1), we find that for any quality q, there exists a cut-off probability $\theta_1(q)$, defined by:

$$\theta_1(q) = \begin{cases} 1 & if \quad P > G(q) \\ \frac{P-(1-\pi)B(q)}{G(q)-(1-\pi)B(q)} & if \quad G(q) \geq P \geq (1-\pi)B(q) \\ 0 & if \quad P < (1-\pi)B(q), \end{cases} \tag{3}$$

so that inventors with ex-ante probability of validity $\theta \geq \theta_1$ apply for the patent and those with $\theta < \theta_1$ do not apply. If $P > G(q)$, then patents are too costly and no one applies for a patent. If $P < (1-\pi)B(q)$, then the patenting fee is lower than the expected benefit of applying even if the patent is bad, so everyone applies for a patent. In the interior range, the threshold $\theta_1(q)$ decreases with q. That is, the higher the perceived patent quality, the more inventors apply for patents.

[11] We think of these benefits as capturing the value of holding a patent, this can include not only the value from market power in the market for a patented product, but also other benefits that a patent holder might enjoy, such as improved bargaining position, reputation, facilitation in cross-licensing agreements, etc.

[12] If secrecy allows innovators to benefit from non-patented innovations, the value of not patenting can be positive and might depend on the innovator's ex-ante probability of validity. In this case, the benefit from secrecy would need to be subtracted from the current expression $V(\theta, q)$. Our analysis remains qualitatively the same as long as the resulting net benefit from patenting is still increasing in θ, which would require the benefit from secrecy not to be too steep as a function of θ.

Taking into account a threshold ex-ante probability of validity $\theta_1 < 1$, above which inventors apply for a patent, the probability that a granted patent is good is given by:

$$(4) \qquad q_1(\theta_1) = \Pr(\text{good} \mid \text{granted}) = \frac{\Pr(\text{good and granted})}{\Pr(\text{granted})} = \frac{\int_{\theta_1}^{1} \theta f(\theta)\, d\theta}{\int_{\theta_1}^{1} [1 - \pi(1-\theta)] f(\theta)\, d\theta}.$$

Additionally, $q_1(1) = 1$.[13] The lowest value q_1 can obtain is $\int_0^1 \theta f(\theta)\, d\theta$, if all inventors apply for a patent ($\theta_1 = 0$) and examiners never find invalidating prior art ($\pi = 0$); the highest value it can obtain is $q_1 = 1$, when examination is perfect ($\pi = 1$). If $\pi < 1$, then $q_1(\theta_1)$ is increasing in θ_1, because a higher θ_1 indicates an overall better pool of applicants. Equilibrium in the single-tiered system is defined as follows.

Definition 1 *Equilibrium in the single-tiered system is characterized by a pair* (θ_1^*, q_1^*), *such that:*

$$(5) \qquad \theta_1^* = \theta_1(q_1^*) \text{ and } q_1^* = q_1(\theta_1^*),$$

where $\theta_1(.)$ *and* $q_1(.)$ *are defined in (3) and (4). Inventors of type* $\theta \geq \theta_1^*$ *apply for a patent and inventors of type* $\theta < \theta_1^*$ *do not apply for a patent. The equilibrium is interior if* $\theta_1^* \in (0,1)$.

It is easy to verify that a unique (not necessarily interior) equilibrium exists. This holds true because the equilibrium is an intersection between a decreasing function $\theta_1(q_1)$ and a strictly increasing function $q_1(\theta_1)$.

IV(ii). *Simple Policy Interventions*

The equilibrium pair (θ_1^*, q_1^*) depends on the examination intensity π, on the patenting fee P, and on the benefit functions $G(.)$ and $B(.)$.[14] In our first proposition, we examine how changes in policy-levers affect the volume of patent applications $[1 - F(\theta_1^*)]$, and patent quality q_1^*.

Proposition 1 *Assuming an interior equilibrium, (i) an increase in the patenting fee* (P) *results in an increase in patent quality and a decrease in patent applications; (ii) an increase in the examination intensity* (π) *results in an increase in patent quality, but has an ambiguous effect on the volume of patent applications.*

Figure 1 illustrates two equilibrium points, $E_1(\pi, P_1)$ and $E_2(\pi, P_2)$ which correspond to two systems with the same examination intensity (π) but different levels of the patent fee $(P_1 < P_2)$. A higher patent fee results in fewer patent applications for every q_1 (i.e., $\theta_1(q_1)$ shifts right), but no change in perceived quality $q_1(\theta_1)$ for any θ_1. The equilibrium E_2 has fewer patent applications (higher θ_1^*) and higher patent quality q_1^*.[15]

Place Figure 1 approximately here.

[13] By the l'Hospital rule, the limit of (4) as $\theta_1 \to 1$ is 1.

[14] The benefit functions can be affected by increased patent breadth and longer patent term. These policies were studied for example by Gilbert and Shapiro [1990], Klemperer [1990], O'Donoghue [1998], O'Donoghue, Scotchmer and Thisse [1998].

[15] A similar argument implies that a strengthening of patent protection (an increase in $G(.)$ and $B(.)$) results in a lower patent quality and more patent applications. In contrast, a post-grant opposition system (Merges, 1999) or a weakening of the presumption of validity are likely to lower the benefit functions resulting in an equilibrium with fewer patent applications and a higher patent quality.

Figure 2 illustrates two equilibrium points for two different examination intensities $E_1(\pi_1, P)$ and $E_2(\pi_2, P)$ with $\pi_1 < \pi_2$. A higher examination intensity results in fewer patent applications for a given quality (i.e., $\theta_1(q_1)$ shifts right), but also results in a higher quality for the given pool of applicants ($q_1(\theta_1)$ shifts up). The equilibrium $E_2(\pi_2, P)$ has a higher patent quality than $E_1(\pi_1, P)$. In the figure, the volume of applications increases, but this is not always the case. Tougher examination reduces the probability of any applicant to secure a patent, making a patent application less attractive, particularly to low probability of validity inventors; but the increase in perceived quality makes patents more valuable. When the benefit from a patent is sensitive enough to perceived patent quality, then the volume of applications could increase with examination intensity. Thus, a policy reform that would open patent examination to the public (e.g. Noveck, 2006) is expected to result in an increase in patent quality, but its effect on the volume of patent applications is ambiguous.

Place Figure 2 approximately here.

Our analysis throughout the paper assumes that the patent office can commit to its examination intensity. It is possible that examiners would intensify their examination if they face a worse pool of applicants (lower θ_1), as there is a greater need for examination to maintain quality. Alternatively, examiners might respond to a higher volume of applications with less intensive examination, due to the increased work-load. Consider the effects of an increase in the patent fee. We predicted fewer patent applications and a higher patent quality. If examiners intensify their examination, the effect would be to further increase patent quality. However, if examiners relax their examination intensity, this would moderate the positive effect that the increase in the fees has on patent quality. As long as the examiners' response to a higher volume of applications is small, we expect the predictions of our model to be relevant.

Our model has heterogeneous probabilities of validity, but uniform benefit functions. In a model with two dimensions of heterogeneity, quality and value, Koenen [2011] shows that there are conditions under which an increase in the patent fee may result in a decrease in average patent quality. In his model too, an increase in the fee increases the threshold for application, so that fewer invalid ideas are submitted. However, there is an additional effect not present in our analysis. Koenen explains, '[a]s the private value of patents decreases, the quality cutoff level for which patents are profitable increases, until at the margin only the best patents survive...raising patent fees therefore generically kills off high-quality patent application over-proportionally.'

V. THE TWO-TIERED PATENT SYSTEM

In their article 'What to Do about Bad Patents?,' Lemley et al. [2005] propose to establish a two-tiered patent system. The proposal was further discussed in Lemley and Lichtman [2007]. The two-tiered patent system would give applicants a choice between a low cost patent application which is not examined thoroughly, and a high cost patent application which would be subject to a thorough examination and earn a high presumption of validity. Lemley et al. [2005] suggested that inventors would likely pay for serious review of their inventions that are economically most important. Therefore, the two-tiered system will allow the patent office to 'focus its examination resources on important patents and pay little attention to the rest.' In this section, we extend our basic model to analyze a two-tiered patent system. We examine inventors' equilibrium selection of a patent tier and how it is affected by patent policy.

V(i). *Extending the Model*

We maintain most of our assumptions from the previous section, but now we introduce the two-tiered patent system. Inventors can choose to apply for a 'regular' patent, or for a 'gold-plate' patent. Following the proposal of Lemley et al. [2005], we assume that a gold-plate patent is associated with a higher fee: $P_{gp} > P_r$, and a more thorough examining procedure: $\pi_{gp} \geq \pi_r > 0$.[16] Patent tier (a regular or a gold-plate patent) is public information.[17]

The value of a patent to an inventor depends on both its ex-ante probability of validity θ and on the quality of patents of its tier (q_r for a regular patent, or q_{gp} for a gold-plate patent).[18] Patent quality depends on the patent tier for two reasons: the different examination intensities, and the different endogenously determined selection of patent applicants. An inventor whose ex-ante probability of validity is θ and who applies for a patent-tier $i \in \{r, gp\}$, obtains a value:

$$V_i(\theta, q_i) = \theta G(q_i) + (1-\theta)(1-\pi_i)B(q_i) - P_i. \tag{6}$$

Let us denote the set of inventors who apply for a regular patent by Θ_r and the set of inventors who file for a gold-plate patent by Θ_{gp}. When the set of applicants is non-empty, patent quality—the probability that a patent in tier $i \in \{r, gp\}$ is good—is $q_i = \Pr(\text{good}|\text{patent-tier } i \text{ granted})$ which is derived using Bayes' rule. When the set is empty, we set $q_i = 0$.[19] Thus we define:

$$q_i = \begin{cases} \dfrac{\int_{\Theta_i} \theta f(\theta) d\theta}{\int_{\Theta_i} [1-\pi_i(1-\theta)] f(\theta) d\theta} & if \quad \Theta_i \neq \emptyset, \\ 0 & if \quad \Theta_i = \emptyset. \end{cases} \tag{7}$$

We now define the equilibrium in our model. For simplicity (and without loss of generality), we assume that when indifferent between patenting or not patenting, inventors choose to patent and when indifferent between a regular patent and a gold-plate patent, inventors apply for the regular patent.

Definition 2 *A two-tiered patent system equilibrium is given by two disjoint sets of inventors* Θ_r *and* Θ_{gp} *in* $[0, 1]$ *and patent qualities* q_r *and* q_{gp} *such that:*

1. $\theta \in \Theta_r$, *if and only if* $V_r(\theta, q_r) \geq 0$ *and* $V_r(\theta, q_r) \geq V_{gp}(\theta, q_{gp})$;
2. $\theta \in \Theta_{gp}$, *if and only if* $V_{gp}(\theta, q_{gp}) > 0$ *and* $V_{gp}(\theta, q_{gp}) > V_r(\theta, q_r)$;
3. q_r *and* q_{gp} *satisfy equation (7).*

The first two conditions imply that inventors choose optimally between applying for a regular patent, a gold-plate patent or no patent; the third condition states that expectations about patent quality are rational given all inventors' choices and the existing patent policy. We will show that in any equilibrium, the sets Θ_r and Θ_{gp} can be defined using thresholds so that high types apply for gold-plate patents, and intermediate types apply for a regular patent.

Definition 3 *(i) A 'thresholds-equilibrium' is a two-tiered patent system equilibrium in which there exist* $0 \leq \theta_* \leq \theta^* \leq 1$ *so that in equilibrium inventors with types* $\theta > \theta^*$ *apply for a gold-plate patent, inventors with types in the range* (θ_*, θ^*) *apply for a regular patent and inventors with types* $\theta < \theta_*$ *do not apply for a patent.*

(ii) A thresholds-equilibrium is interior if $0 < \theta_* < \theta^* < 1$.

[16] It is possible to design a system with two tiers such that $P_1 > P_2$ and $\pi_1 < \pi_2$. Depending on the value of these policy controls, we could have an equilibrium in which low probability of validity applicants pay more to avoid tough examination, or an equilibrium in which high probability of validity applicants pay high fees to enjoy being part of a high quality patent tier. However, our characterization of a thresholds equilibrium and other results use the assumption that $\pi_{gp} \geq \pi_r$.and $P_{gp} \geq P_r$.

[17] The patent office can make information on patent tiers available. The policy is not likely to be effective if this information is not made public. We also note that in the case of the "peer-to-patent" project (see http://peertopatent.org/), it is publicly known who participates in the special examination process, as these applications are made public to solicit information from the public.

[18] In our model, innovators have the same benefit functions $G(.)$ and $B(.)$ in either tier. In practice, benefits in the gold-plate tier might be higher. For example, in Australia's reform, the lower tier patents are granted for a shorter duration. We conjecture that most of our findings would remain the same qualitatively.

[19] One can define the perceived quality of an empty set of innovators in different ways. Since we mostly focus on interior equilibria, we do not elaborate on this issue.

In an interior thresholds-equilibrium, at least some inventors apply for each patent tier, and some do not apply for a patent.[20] To guarantee that a thresholds-equilibrium exists, we assume a 'single crossing condition' for all q:

$$G'(q) - (1-\pi_r)B'(q) > 0. \tag{8}$$

This condition states that the cross-derivative of the payoff functions with respect to the inventor's type θ and patent quality q is positive. It holds when B is flatter or only moderately steeper than G.[21]

In an interior thresholds-equilibrium, the quality of gold-plate patents is higher than that of regular patents, $q_{gp} > q_r$. Otherwise, for all θ, a regular patent gives a higher value $V_r(\theta, q_r) \geq V_{gp}(\theta, q_{gp})$ as defined in (6) and the equilibrium would not be interior. It is easy to verify that any interior equilibrium is a thresholds-equilibrium. This holds because for given equilibrium qualities $q_{gp} > q_r$, the difference between the payoff functions $V_{gp}(.)$ and $V_r(.)$ is monotone increasing in θ. If a type θ innovator prefers to gold-plate her patent, any higher type would prefer the same.

An interior thresholds-equilibrium is characterized by threshold levels θ_*, θ^* and patent qualities q_r and q_{gp} such that $H(\theta_*, \theta^*, q_r, q_{gp}) = 0$ where the function $H = (h_1, h_2, h_3, h_4)$, is defined as follows:

(9)

$$\left\{ \begin{array}{l} h_1 := \theta_* G(q_r) + (1-\theta_*)(1-\pi_r) B(q_r) - P_r = 0, \\ h_2 := \theta^* \left[G(q_{gp}) - G(q_r)\right] + (1-\theta^*)\left[(1-\pi_{gp})B(q_{gp}) - (1-\pi_r)B(q_r)\right] - (P_{gp} - P_r) = 0, \\ h_3 := \int_{\theta_*}^{\theta^*} \left[\theta(1-q_r) - (1-\pi_r)(1-\theta) q_r\right] f(\theta) d\theta = 0, \\ h_4 := \int_{\theta^*}^{1} \left[\theta(1-q_{gp}) - (1-\pi_{gp})(1-\theta) q_{gp}\right] f(\theta) d\theta = 0. \end{array} \right\}$$

The first two equations define the thresholds: $h_1(.) = 0$ implies that an applicant with ex-ante probability of validity θ_* is indifferent between applying for a regular patent and not applying for a patent, $V_r(\theta_*, q_r) = 0$; $h_2(.) = 0$ implies that an applicant with ex-ante probability of validity θ^* is indifferent between applying for a regular patent and for a gold-plate one, $V_{gp}(\theta^*, q_{gp}) = V_r(\theta^*, q_r)$. The next two equations define the quality of regular and gold-plate patents, as obtained from rearranging equation (7).

To derive the effects of the fees and examination intensities on equilibrium, we implicitly differentiate the system of equations H in (9). We assume that the determinant of the Jacobian matrix (the matrix of partial derivatives) of this system is positive. We refer to this as the *Jacobian Condition*, and write it formally in the Appendix, in Definition 5. In Lemma 1 (Appendix A), we provide a sufficient condition for the Jacobian condition to hold in a special case used in proposition 6 and in Lemma 2 (Appendix B), a sufficient condition for it to hold for a linear model.[22]

Consider the effects of changes in the patenting fees.

Proposition 2 *Under the Jacobian Condition, around an interior equilibrium,*

(i) As the gold-plate patent fee (P_{gp}) increases, the overall volume of patent applications increases; the volume of gold-plate patent applications decreases; the quality of gold-plate patents and the quality of regular patents increase; the prevalence of bad patents increases as well;

[20] Non-interior equilibria are also possible. If patent fees are very small (large), it is possible that all innovators apply (no one applies). A two-tiered system could collapse into a single-tiered system with all innovators applying either to the regular tier, or to the gold-plate tier.

[21] Existence of equilibrium (not necessarily interior) can be shown using a fixed point argument. We omit the proof as the argument is standard, but it is available from the authors.

[22] By the implicit function theorem, the determinant of the Jacobian matrix, J, appears as the denominator of each of the comparative statics derivatives. It consists of mostly positive terms and we found it to be positive in numeric solutions of the model. If $J < 0$, the effects we report in the proposition are exactly reversed.

(ii) As the regular patent fee (P_r) increases, the overall volume of patent applications decreases.

The effects of the regular patent fee on the other equilibrium variables and the effects of examination intensities are, in general, indeterminate, but in Appendix B we state additional results in the special case of a linear model.

V(ii). *The Added-Tier System*

Consider a special family of two-tiered systems in which the regular tier has the same fee and examination intensity as the single-tiered system. We refer to such two-tiered system as an 'added-tier system.'

Definition 4 *Given a single-tiered system with examination intensity π and a patent fee P, an added-tier system is a two-tiered system with $P_{gp} > P_r = P$ and $\pi_{gp} \geq \pi_r = \pi$.*

We compare the single-tiered system with an added-tier system.

Proposition 3 *Consider a single-tiered system and an added-tier system. Assume each system has an interior equilibrium. Then in the added-tier system, (i) there are fewer patent applications than in the single-tiered system ($\theta_* > \theta_1$); (ii) the quality of regular patents is lower than in the single-tiered system ($q_r \leq q_1$); (iii) the quality of a gold-plate patents is higher ($q_{gp} \geq q_1$); (iv) overall, there are fewer bad patents than in the single-tiered system.*

Proposition 3 establishes that an added tier results in a decline in the overall volume of patent applications. The reason for this is that applicants with the highest probability of validity choose to gold-plate their patents, leaving an adverse selection of applicants for the regular patent-tier. Hence regular patents have lower perceived quality than the patents in the single-tiered system, and therefore are less attractive. Gold-plate patents have higher perceived quality than patents in the single-tiered system. Overall, there are fewer bad patents because there is a decline in low probability of validity patent applications and a more thorough examination of gold-plate patent applications.

An added-tier system involves more intense examination and this potentially increases the patent office's expenditure. To assure that the expenditure of the patent office does not exceed that in the single-tiered system, the gold-plate patent fee could be set to cover the additional cost of examination: $P_{gp} \geq P_r + [c(\pi_{gp}) - c(\pi_r)]$. If the examination intensity of gold-plate patents is not much higher ($\pi_{gp} - \pi_r$ is small), then increase in the fee can be small enough so that some inventors would indeed apply for a gold-plate patent.

In an added-tier system, innovators with probability of validity $\theta \leq \theta^*$ either do not apply for a patent, or apply for a patent that has a lower quality than a patent in the single-tiered system. Thus, these innovators are either as well off or worse off. Only innovators who have a high ex-ante probability of validity $\theta > \theta^*$ might be better off due to the higher quality of gold-plate patents. However, since examination intensity is higher and the fee is higher, it is not guaranteed that they are better off. The effect of the introduction of an added tier on the payoffs of innovators is negative, unless the benefit from increased quality of gold-plate patents is sufficiently large to offset the loss of payoff experienced by applicants who have low ex-ante probability of validity.

VI. R&D INVESTMENT AND WELFARE

An important goal of the patent system is to provide incentives to innovate. We have so far assumed a fixed set of innovators. In this section, we extend the model to consider the incentives to invest in R&D and social welfare.

Suppose each firm has one idea for innovation. The necessary R&D investment of each innovation is a random variable I uniformly distributed over $[0, \bar{I}]$. The probability of validity θ is drawn from a distribution F on $[0, 1]$. We assume that the probability of validity θ is revealed to the innovator after investment but before patenting. Under this assumption, the probability distribution F before investment is the same as the probability distribution conditional on R&D investment. We therefore keep the same notation for this distribution. We discuss the known θ case in the conclusion.

Welfare captures the surplus of innovators, and the additional social surplus that result from patented and non-patented innovation affecting consumers and other producers. We denote by S_C the social surplus when a firm invested in R&D, the resulting innovation was good and the innovation was not patented. We denote by S_G and S_B the added (i.e. not captured by the patentee) social surplus from a good and a bad patent respectively. Bad innovations that are not patented have no added social surplus. We assume, $S_C \geq S_G \geq 0 \geq S_B$.[23]

Innovators invest if their expected benefit from investment exceeds the cost. Because θ is yet unknown at the time the innovator has to decide on R&D investment, an innovator invests if the R&D cost is lower than her expected payoff from an innovation. We denote the expected payoff of innovators by IS (innovators' surplus). Innovators invest in R&D if $I \leq IS$.[24] The innovators' surplus can be interpreted as a measure for the incentive to invest in R&D. We define welfare as:

$$(10) \quad W = \int_0^{IS} \frac{1}{\bar{I}} \left\{ \underbrace{CCS}_{\text{conditional consumers' surplus}} + \overbrace{\underbrace{R}_{\text{PTO's net revenue}} + \underbrace{IS}_{\text{innovators' surplus}}}^{\text{net innovators' surplus}} - I \right\} dI.$$

$$(11) \quad = \frac{1}{\bar{I}} \underbrace{\left(CCS + R + \frac{IS}{2} \right)}_{\text{conditional social surplus}} IS.$$

We define each of the components of this welfare function for the two-tiered system. The same definitions apply to the single-tiered system, where $\theta_* = \theta_1$ and $\theta^* = 1$. The conditional consumers' surplus is defined by:

$$(12) \quad CCS_2 = \int_0^{\theta_*} \theta S_C f(\theta) d\theta + \int_{\theta_*}^{\theta^*} \left[\theta S_G + (1-\theta)(1-\pi_r) S_B \right] f(\theta) d\theta + \int_{\theta^*}^{1} \left[\theta S_G + (1-\theta)(1-\pi_{gp}) S_B \right] f(\theta) d\theta.$$

The first integration term captures surplus from good innovations that were not patented, and the second and third integration terms capture surplus from innovations that have received regular patents and gold-plate patents, respectively.

The net revenue of the patent office captures the patent fees collected from regular and gold-plate patents, net of the costs of examination. It is given by:

$$R_2 = \int_{\theta_*}^{\theta^*} \left[P_r - c(\pi_r) \right] f(\theta) d\theta + \int_{\theta^*}^{1} \left[P_{gp} - c(\pi_{gp}) \right] f(\theta) d\theta.$$

[23] For simplicity, we do not explicitly model the source of surplus and abstract from potential gains from better information about patent quality and from litigation costs.

[24] Our innovators' surplus is similar to the concept of "sellers' welfare" used by Farhi, Lerner and Tirole [2010] in their analysis of markets for certifications. In the context of a patent race, Grossman and Shapiro [1987] examined the effects of policy changes on the industry's expected profits and stated conditions under which industry profits measure welfare.

The innovators' surplus is defined by:

$$IS_2 = \int_{\theta_*}^{\theta^*} \left[\theta G\left(q_r\right) + (1-\theta)(1-\pi_r)B\left(q_r\right) - P_r\right] f(\theta)d\theta + \int_{\theta^*}^{1} \left[\theta G\left(q_{gp}\right) + (1-\theta)(1-\pi_{gp})B\left(q_{gp}\right) - P_{gp}\right] f(\theta)d\theta.$$

The first line in IS captures the surplus attained by innovators who choose to apply for the regular tier and the second line captures the surplus from the gold-plate tier.

It is easy to see that, for a given patent policy, welfare increases when the social value of patented or non-patented innovation increases, when the loss from bad patents decreases (S_G, S_C or S_B increase), and when the cost of examination $c(\pi)$ decreases. Given patent policy, the social surplus and the examination cost do not directly affect the equilibrium in a single-tiered or a two-tiered system. Therefore, these comparative statics results also hold for welfare at the optimal patent policy.

VI(i). *Innovators' Surplus and Welfare in Single-Tiered System*

An increase in the patent fee is typically thought to reduce the incentive to innovate. Our model suggests, however, that in addition to the direct negative effect of an increase in the patent fees, there is an indirect positive effect. An increase in the patent fees reduces applications from low probability of validity applicants and results in higher perceived patent quality. Taking into account that innovators' benefits increase with patent quality, there is an indirect positive effect of an increase in the patent fee that at least partially offsets the negative direct effect. This can be seen by differentiating the single-tiered system innovators' surplus (IS_1) with respect to P. By the definition of θ_1, the indirect effect of P on IS_1 through θ_1 is zero, therefore we have:

$$\frac{d\left(IS_1\right)}{dP} = \underbrace{-\int_{\theta_1}^{1} f(\theta)d\theta}_{\text{direct fee effect} \leq 0} + \underbrace{\int_{\theta_1}^{1} \left[\theta G'\left(q_1\right) + (1-\theta)(1-\pi)B'\left(q_1\right)\right] f(\theta)d\theta \frac{dq_1}{dP}}_{\text{quality increase effect} \geq 0}.$$

Proposition 4 *For uniformly distributed θ, if $\left[G\left(q\right) - \left(1-\pi\right)B\left(q\right)\right]$ is concave (or linear) in q, innovators' surplus decreases with the patent fee. There exist convex benefit functions for which innovators' surplus increases in a range of the patent fees.*

By (6), $\left[G\left(q\right) - \left(1-\pi\right)B\left(q\right)\right]$ represents the slope of the value function $V(\theta, q_1)$ with respect to θ. When this expression is concave (or linear) in q, the indirect effect of an increase in quality on the innovators' surplus is smaller in magnitude than the direct (negative) effect, so that innovators' surplus declines.[25]

As a self-funded agency, the USPTO relies on the fees to cover its costs. Should the patent office set a fee that exactly covers, exceeds or subsidizes its examination costs? This question is particularly relevant in light of the recent patent reform act that gives the patent office 'fee

[25] For an increase in examination intensity, we also have a negative direct effect and a positive indirect effect due to the increase in quality.

$$\frac{d\left(IS_1\right)}{d\pi} = \underbrace{-\int_{\theta_1}^{1} (1-\theta)B\left(q_1\right) f(\theta)d\theta}_{\text{direct examination intensity effect} \leq 0} + \underbrace{\int_{\theta_1}^{1} \left[\theta G'\left(q_1\right) + (1-\theta)(1-\pi)B'\left(q_1\right)\right] f(\theta)d\theta \frac{dq_1}{d\pi}}_{\text{quality increase effect} \geq 0}.$$

setting authority.'[26] We show that in the range where $P \leq c(\pi)$, the net innovator's surplus ($NIS = IS + R$) increases with the fee. Intuitively, by pricing at the social cost of examination, the marginal patent applicant generates no value, but lowers the average quality of all patents, and therefore if the patent office sets the net innovators' surplus as its objective function, the fee should be raised. An increase in the patent fees also increases conditional consumer surplus, because fixing the incentive to innovate, unpatented innovations generate more surplus than patented ones.

Proposition 5 *(i) The conditional consumers' surplus increases with the patent fees. (ii) In the range where $P \leq c(\pi)$, the net innovators' surplus and the conditional social surplus also increase with the patent fees.*

From (11) we know that welfare equals $W_1 = CSS\frac{IS_1}{\bar{I}}$. The effect of the increase in the patent fee on welfare is

$$\frac{dW_1}{dP} = \underbrace{\frac{dCSS}{dP}\frac{IS_1}{\bar{I}}}_{\text{effect on conditional social surplus}} + \underbrace{\frac{CSS}{\bar{I}}\frac{dIS_1}{dP}}_{\text{effect on incentive to innovate}}.$$

By Proposition 5, in the range $P \leq c(\pi)$ conditional consumers' surplus increases with the patent fee. However, an increase in the fee has an additional, potentially negative effect on the incentive to innovate. Thus, the welfare maximizing patent fee can, but does not necessarily, exceed the cost of examination.

VI(ii). *Welfare Improving Two-Tiered System*

Since the two-tiered system can be designed to mimic the best single-tiered system, welfare in an optimal two-tiered system is at least as high as welfare in the optimal single-tiered system. We show that when $G(1)$ (the benefit from having a good patent when perceived patent quality is high) is sufficiently large, welfare is strictly higher in the optimal two-tiered system. Intuitively, a subset of high probability of validity innovators apply for gold-plate patents, these have a very high perceived quality and thus enjoy the very high benefits. In the single-tiered system, a very high quality could only be obtained with either high examination intensity (which would be costly) or with a high patent fee that would exclude all but the very high validity applicants (which could reduce the incentive to innovate). With a two-tiered system on the other hand, the high quality of gold-plate patents can be enjoyed without excluding a significant volume of low ex-ante probability of validity applicants, because these applicants can still apply for the regular (low fee) tier.

To establish more formally that a two-tiered system can result in higher welfare, we consider an added-tier system that differs from the single-tiered system only in the gold-plate patent fee: $\pi_r = \pi_{gp} = \pi$ and $P_r = P$, but $P_{gp} > P$. There is a threshold gold-plate patent fee $\overline{P_{gp}}$ so that for $P_{gp} \geq \overline{P_{gp}}$, no innovator applies for a gold-plate patent and the two-tiered system results in the same equilibrium as the single-tiered system. We consider a small reduction in P_{gp} from $\overline{P_{gp}}$ so as to obtain an added-tier system, and examine the effects on welfare from (11). Generally, a decrease in P_{gp} results in an increase in the conditional consumers' surplus, but an indeterminate effect on the revenues of the patent office and on the innovators' surplus. When P_{gp} is decreasing from $\overline{P_{gp}}$ and $G(1)$ is 'high enough' compared to the benefit of a good patent in the single-tiered system $G(q_1)$, the revenue of the patent office increases because the additional fees collected from the gold-plate patent applicants exceeds the loss of fees from the applicants with low probability of validity that do not apply. Thus, when $G(1)$ is large enough, welfare increases with a small reduction in the gold-plate patent fee below $\overline{P_{gp}}$, which results in

[26] See http://www.gpo.gov/fdsys/pkg/BILLS-112hr1249eh/pdf/BILLS-112hr1249eh.pdf

a two-tiered system with higher welfare, even if the innovators' surplus decreases. In the proof of Proposition 6, we formalize the condition on $G(1)$. We note that the condition never holds for linear benefit functions, but holds for other (convex) functions.[27]

Proposition 6 *Welfare under an optimal two-tiered system is at least as high as welfare under the optimal single-tiered system. The optimal two-tiered system can result in strictly higher welfare than the optimal single-tiered system when $G(1)$ is sufficiently high compared to $G(q_1)$.*

To gain further insight on welfare improving two-tiered systems, we solved the model numerically. We will now informally describe some insights we gained.[28] Using a uniform distribution of types (θ) and quadratic benefit functions, we found two-tiered systems that increase welfare above that of an optimal single-tiered system. The improvement in welfare was higher for higher costs of examination. Intuitively, convex benefit functions offer particularly high benefits to the applicants with high patent qualities. If the cost of intense examination is low, high quality patents can be achieved with high examination intensity even in a single-tiered system. But when examination is more costly, the two-tiered system allows identifying a subset of high quality patents while keeping examination intensities relatively low.

In the numeric examples we solved, optimal two-tiered systems featured differential application fees $P_{gp} > P > P_r$, but examination intensities that were equal or close across the two tiers, and were lower than in the single-tiered system. The assumption that $\pi_{gp} \geq \pi_r$ (which was part of the policy reform proposed by Lemley et al., 2005) might be too restrictive. It is possible that welfare could be even higher with lower examination intensity in the gold-plate tier. The intuition why π_{gp} should not be too high is that patents with higher ex-ante probability of validity sort into the gold-plate patent tier. Therefore, at least ex-post stringent examination of gold-plate patents is not efficient. We note, however, that our model did not take liquidity constraints into account. If many applicants with high probability of validity cannot afford the high gold-plate patent fees, it might be better to design a system with high examination intensity for gold-plate patent applications instead of high fees so as not to exclude budget constrained high probability of validity applicants from the gold-plate tier.

VII. ECONOMIC IMPORTANCE AND GOLD-PLATE PATENTS

Lemley et al. [2005] suggested that 'most likely applicants would pay for serious review with respect to their most important patents but conserve resources on their most speculative entries.' We examine this statement in the context of our model.

Atal and Bar [2010] found that innovators with high R&D costs have a stronger incentive to search for prior art before investing in R&D, so as to save the cost if their invention is not novel. High cost R&D projects are also likely to be the ones with high economic value (to cover the R&D cost). We therefore expect that these innovators will have a higher probability of validity. Innovators who plan to commercialize their patented products are also likely to have more incentive to search for prior art because, before commercialization, they would need to ensure that they do not infringe on existing patents. Thus, it is plausible that economically significant innovations would tend to have higher ex-ante probability of validity, and would be more likely to gold-plate patents, supporting the view of Lemley et al. [2005].

Economic significance is likely manifested in higher benefit functions. So far we assumed that all innovators have the same benefit functions. Below we provide a rationale for why

[27] The proof of the proposition uses an added-tier system. We could not rule out the possibility that there exist other two-tiered systems that improve welfare even in a linear model, but numeric solutions we pursued did not yield welfare improvements while using linear benefit functions.

[28] We used the publicly available software R available at http://www.R-project.org to compute numeric solutions. Programs and more detailed results are available upon request from the authors.

differences in benefit functions imply an ambiguity with respect to how economic significance affects the incentives to gold-plate patents. We assume (1) innovators have heterogeneous (privately observed) benefit functions; and (2) there is an equilibrium with patent qualities $q_{gp} > q_r$. An innovator prefers the gold-plate patent if:

$$(13) \qquad \theta \left[G\left(q_{gp}\right) - G\left(q_r\right)\right] + (1-\theta)\left[(1-\pi_{gp})B\left(q_{gp}\right) - (1-\pi_r)B\left(q_r\right)\right] - \left(P_{gp} - P_r\right) > 0.$$

Differences in the benefit functions G and B affect the left hand side of (13) and hence the incentives to gold-plate. If for the economically significant patent, the function G is higher and steeper everywhere, then $[G(q_{gp}) - G(q_r)]$ would be higher for the economically significant patent, which suggests a larger incentive to gold-plate. If, however, both benefit functions are higher by a constant and $\pi_{gp} > \pi_r$, then $[G(q_{gp}) - G(q_r)]$ is the same, but $[(1-\pi_{gp})B(q_{gp}) - (1-\pi_r)B(q_r)]$ is lower for the economically more significant innovation as more is gained from a bad patent with larger benefits in the regular patent tier. As a result, the innovator with economically significant patent would more likely apply for a regular patent, creating an opposite effect from what was suggested by Lemley et al. [2005].[29]

Economically more significant innovations are likely different from the less valuable ones in the shape and level of both benefit functions, as well as in the ex-ante probability of validity. The combined effect results in an ambiguity over the question of whether applicants of economically significant innovations are, in fact, more likely to gold-plate their patents.

VIII. CONCLUDING REMARKS

Patent system reform has been a subject of intense policy debate in recent years with the quality of patents a central issue. This paper sheds light on the determinants of patent quality and of the volume of patent applications. Our analysis highlights an important aspect of the social costs of bad patents – they impose a negative externality on good patent holders (because they decrease average patent quality) and, therefore, decrease the value of patents to all inventors.

We considered a proposal to establish a two-tiered patent system, and found that, while adding a gold-plate tier to an existing regular-tier decreases the volume of applications and the probability that bad patents are issued, it does not always increase welfare. A two-tiered system can identify a subset of high quality patents – those in the gold-plate tier. Welfare gains from a two-tiered system arise when innovators' benefits from high quality patents are large compared to the benefits from lower quality patents. By sorting high validity applicants into the gold-plate tier, these high benefits can be enjoyed without the need to exclude all lower validity innovators from the patent system, or to expend extraordinary resources on examination. The optimal two-tiered system does not necessarily have overall fewer bad patents, but their instances would be lower in the gold-plate tier than in the regular tier.

Equilibrium selection sorts high probability of validity applicants into the gold-plate patent tier. If examination intensity in the gold-plate tier is more intense, this effort is aimed precisely at those applications that are least likely to be invalid, which seems inefficient. Indeed, numeric solutions of the model show that in an optimal two-tiered system, the examination intensity in the gold-plate tier is not necessarily more stringent, but the higher fee for gold-plate patents creates selection of high probability of validity applicants into the gold-plate tier. We also note that to implement a system with higher examination intensity for the gold-plate tier, it is important for the patent office to have strong mechanisms that monitor examiners' efforts; otherwise, there may be an incentive ex-post to reduce examination intensity in the gold-plate tier.[30]

[29] Additionally, private and social economic significance might not be the same. See Chang [1995].

[30] A way to facilitate the commitment to a higher examination intensity could be to establish a different examination procedure for gold-plate patent applications. For example, to open the examination of gold-plate patents but not that of the regular patents to the public peer review, as in the "peer-to-patent" project (see http://peertopatent.org/); or to assign a second reviewer to gold-plate patents but not to regular patents.

Equilibrium selection into the two tiers reveals information about the ex-ante probability of validity of innovations.[31] According to Lemley et al. [2005], a two-tiered system would sort economically significant patents. To the extent that economically significant innovations tend to have higher ex-ante probability of validity, our model agrees with this pattern of selection. However, it is likely that economically more significant patents have different benefit functions, in which case the gold-plate tier does not necessarily attract economically significant innovations.

Patent law states that 'a patent shall be presumed valid' and that the 'burden of establishing invalidity of a patent or any claim thereof shall rest on the party asserting such invalidity' (35 USC 282). Lemley and Lichtman [2007] suggest that gold-plate patent holders should enjoy a presumption of validity but patents in the lower tier should not. However, they explain that 'it is far from a simple matter to predict how changes in a legal presumption would change actual case outcomes.' Our model abstracts from the issue of presumption of validity.

We do not account for liquidity constraints that may prevent some inventors from gold-plating patents even if their ex-ante probability of validity is high. A two-tiered system might disadvantage small, financially constrained inventors who would be pooled with lower quality applicants in the lower tier. A fee schedule that allows discounts for small entities, as in the current system, can alleviate this concern.[32]

Our welfare analysis accounts for incentives to innovate. However, we assume, for simplicity, that the innovator learns her probability of validity only after R&D investment. This simplifies the analysis because it implies that the distribution of ex-ante probability of validity is the same before and after R&D investment. If, however, innovators have full or partial information on their probability of validity before investing in R&D, then high probability of validity innovators would have a stronger incentive to invest, and hence higher threshold of R&D cost. As a result, the probability distribution of types in the known θ case is endogenous—there is a better selection of types conditional on R&D investment. For example, an innovator whose probability of validity is lower than the patenting threshold will never invest in R&D when θ is known. A two-tiered system might provide a higher incentive to invest in R&D for high probability of validity applicants. It might also have an effect on the nature of R&D spending. For example, incremental innovations (i.e., small improvements compared to the existing prior art) have a lower ex-ante probability of validity, and so, these innovators will have a reduced incentive to invest in R&D, whereas innovators with a bigger inventive step will have an increased incentive to invest in R&D. Additionally, a two-tiered system might increase the incentive to search for prior art if it benefits inventors with high ex-ante probability of validity. A formal analysis of these effects is left for future work.

APPENDIX A: PROOFS

Proof of Proposition 1. Consider the range of interior equilibria $(1-\pi)B(q_1(0)) \leq P \leq G(1)$. The equilibrium is defined by the system:

$$\tag{14} \left\{ \begin{array}{c} l_1(.) := \theta_1 G(q_1) + (1-\theta_1)(1-\pi) B(q_1) - P = 0, \\ l_2(.) := \int\limits_{\theta_1}^{1} \left[\theta(1-q_1) - (1-\pi)(1-\theta) q_1\right] f(\theta)\, d\theta = 0. \end{array} \right\}$$

[31] A system with more than two tiers, perhaps even a continuum of patent tiers, might extract more information from the applicants. However, implementing a multi-tiered system might be more challenging in practice. Gill and Sgroi [2008] present a model with a continuum of tests.

[32] We note, however, that it might sometimes be hard for the patent office to verify whether a company that claims to be a small entity is really small, which might make it hard to implement a policy with sliding scale fees that are based on size.

The function $l_1(.)$ increases with θ_1 and q_1 :

$$\begin{aligned}
\frac{\partial l_1}{\partial \theta_1} &= G(q_1) - (1-\pi) B(q_1) \geq 0, \\
\frac{\partial l_1}{\partial q_1} &= \theta_1 G'(q_1) + (1-\theta_1)(1-\pi) B'(q_1) > 0.
\end{aligned}$$

The inequalities follow from the assumption (2). Similarly, $l_2(.)$ increases with θ_1 and decreases with q_1 :

$$\begin{aligned}
\frac{\partial l_2}{\partial \theta_1} &= -\left[\theta_1(1-q_1) - (1-\pi)(1-\theta_1) q_1\right] f(\theta_1) > 0, \\
\frac{\partial l_2}{\partial q_1} &= -\int_{\theta_1}^{1} \left[1 - \pi(1-\theta)\right] f(\theta) \, d\theta < 0.
\end{aligned}$$

We derive comparative statics around an interior equilibrium, $\theta_1(\pi, P)$ and $q_1(\pi, P)$ that solve (14). For any policy control variable $\eta \in \{\pi, P\}$, we have:

$$\begin{aligned}
\frac{\partial l_1}{\partial \eta} + \frac{\partial l_1}{\partial \theta_1}\frac{d\theta_1}{d\eta} + \frac{\partial l_1}{\partial q_1}\frac{dq_1}{d\eta} &= 0, \\
\frac{\partial l_2}{\partial \eta} + \frac{\partial l_2}{\partial \theta_1}\frac{d\theta_1}{d\eta} + \frac{\partial l_2}{\partial q_1}\frac{dq_1}{d\eta} &= 0.
\end{aligned}$$

Solving, we find:

$$\frac{d\theta_1}{d\eta} = \frac{\left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_2}{\partial \eta} - \frac{\partial l_1}{\partial \eta}}{\left[\frac{\partial l_1}{\partial \theta_1} - \left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_2}{\partial \theta_1}\right]} \text{ and } \frac{dq_1}{d\eta} = \frac{\left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_1}{\partial \eta} - \frac{\partial l_2}{\partial \eta}}{\left[\frac{\partial l_1}{\partial \theta_1} - \left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_2}{\partial \theta_1}\right]}.$$

We first determine the sign of the denominator. We have shown that in an interior equilibrium, $\frac{\partial l_1}{\partial \theta_1} \geq 0$, $\frac{\partial l_2}{\partial \theta_1} > 0$, $\frac{\partial l_1}{\partial q_1} > 0$ and $\frac{\partial l_2}{\partial q_1} < 0$. These results imply that $\left[\frac{\partial l_1}{\partial \theta_1} - \left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_2}{\partial \theta_1}\right] > 0$. Hence,

$$\begin{aligned}
sign\left(\frac{d\theta_1}{d\eta}\right) &= sign\left[\left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_2}{\partial \eta} - \frac{\partial l_1}{\partial \eta}\right], \\
sign\left(\frac{dq_1}{d\eta}\right) &= sign\left[\left(\frac{\partial l_1}{\partial q_1} / \frac{\partial l_2}{\partial q_1}\right)\frac{\partial l_1}{\partial \eta} - \frac{\partial l_2}{\partial \eta}\right].
\end{aligned}$$

Differentiating the functions l_1 and l_2 with respect to the patenting fee P and the examination intensity π, we find that $\frac{d\theta_1}{dP} > 0$, $\frac{dq_1}{dP} > 0$ and $\frac{dq_1}{d\pi} > 0$.

The sign of $\frac{d\theta_1}{d\pi}$ is ambiguous. For example, consider benefit functions $G(q) = 3q$ and $B(q) = q$. In a neighborhood of $\pi = \frac{1}{2}$, if $P = 1$, then the increase in π would result in an increase in θ_1. However, if $P = 2$, then the increase in π would result in a decrease in θ_1. ■

Definition 5 *(Jacobian Condition)*

The Jacobian condition holds if the determinant of the matrix of partial derivatives of the system (9) is positive.

Differentiating the system, it is found that the Jacobian condition holds iff the following holds true:

$$(15) \qquad J = \left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial q_r} - \frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta_*}\right)\left(\frac{\partial h_2}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} - \frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \theta^*}\right) - \frac{\partial h_1}{\partial \theta_*}\frac{\partial h_2}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} > 0.$$

We divide J by the positive term $\left(\underset{+}{\frac{\partial h_1}{\partial \theta_*}}\underset{+}{\frac{\partial h_2}{\partial \theta^*}}\underset{-}{\frac{\partial h_3}{\partial q_r}}\underset{-}{\frac{\partial h_4}{\partial q_{gp}}}\right)$ to obtain an expression $\widehat{J}$ that has the same sign as J. Substituting the derivatives of the functions h_i for the case of a uniform distribution function and rearranging, we find that the Jacobian condition holds if and only if:

$$\begin{aligned}
\widehat{J} &= \\
&\frac{[\theta_* G'(q_r)+(1-\theta_*)(1-\pi_r)B'(q_r)]q_r}{[G(q_r)-(1-\pi_r)B(q_r)]}\frac{(1-\pi_r q_r)}{(\theta^*+\theta_*)} + \frac{[\theta^* G'(q_{gp})+(1-\theta^*)(1-\pi_{gp})B'(q_{gp})]q_{gp}}{[G(q_{gp})-G(q_r)]-[(1-\pi_{gp})B(q_{gp})-(1-\pi_r)B(q_r)]}\frac{(1-\pi_{gp}q_{gp})}{(1+\theta^*)} \\
&+\frac{[\theta^* G'(q_{gp})+(1-\theta^*)(1-\pi_{gp})B'(q_{gp})]q_{gp}}{[G(q_{gp})-G(q_r)]-[(1-\pi_{gp})B(q_{gp})-(1-\pi_r)B(q_r)]}\frac{(1-\pi_{gp}q_{gp})}{(1+\theta^*)}\frac{[\theta_* G'(q_r)+(1-\theta_*)(1-\pi_r)B'(q_r)]q_r}{[G(q_r)-(1-\pi_r)B(q_r)]}\frac{(1-\pi_r q_r)}{(\theta^*+\theta_*)} \\
&+1-\left(\frac{[\theta^* G'(q_r)+(1-\theta^*)(1-\pi_r)B'(q_r)]q_r}{[G(q_{gp})-G(q_r)]-[(1-\pi_{gp})B(q_{gp})-(1-\pi_r)B(q_r)]}\frac{(1-\pi_r q_r)}{(\theta^*+\theta_*)}\right) \\
&> 0.
\end{aligned} \tag{16}$$

Remark: *All terms in this expression are positive, but the last appears with a negative sign. If the last term is smaller than 1, then $\widehat{J} > 0$. We derive sufficient conditions for $\widehat{J} > 0$ in Lemmas 1 and 2 below.*

Proof of Proposition 2. We derive comparative statics around an interior equilibrium that solves $H(.) = 0$ where H is defined in (9). Denote an interior equilibrium by $\theta_*(P_{gp}, P_r, \pi_{gp}, \pi_r), \theta^*(P_{gp}, P_r, \pi_{gp}, \pi_r), q_r(P_{gp}, P_r, \pi_{gp}, \pi_r)$ and $q_{gp}(P_{gp}, P_r, \pi_{gp}, \pi_r)$. The proportion of innovators who are granted bad patents in a two-tiered patent system is given by:

$$N_2 = (1-\pi_r)\int_{\theta_*}^{\theta^*}(1-\theta)f(\theta)d\theta + (1-\pi_{gp})\int_{\theta^*}^{1}(1-\theta)f(\theta)d\theta. \tag{17}$$

First, we note , given our assumptions, it is easy to find that for h_i defined in (9), we have:

$$\begin{aligned}
\frac{\partial h_1}{\partial \theta_*} &> 0, \frac{\partial h_1}{\partial q_r} > 0, \\
\frac{\partial h_2}{\partial \theta^*} &> 0, \frac{\partial h_2}{\partial q_r} < 0, \frac{\partial h_2}{\partial q_{gp}} > 0, \\
\frac{\partial h_3}{\partial \theta_*} &= \frac{\partial h_3}{\partial \theta^*} > 0, \frac{\partial h_3}{\partial q_r} < 0, \\
\frac{\partial h_4}{\partial \theta^*} &> 0, \frac{\partial h_4}{\partial q_{gp}} < 0.
\end{aligned} \tag{18}$$

To derive comparative statics, for any policy control variable $\eta \in \{P_{gp}, P_r, \pi_{gp}, \pi_r\}$, we differentiate the system H with respect to each policy control variable. We have:

$$\begin{aligned}
\frac{\partial h_1}{\partial \eta} + \frac{\partial h_1}{\partial \theta_*}\frac{d\theta_*}{d\eta} + \frac{\partial h_1}{\partial q_r}\frac{dq_r}{d\eta} &= 0, \\
\frac{\partial h_2}{\partial \eta} + \frac{\partial h_2}{\partial \theta^*}\frac{d\theta^*}{d\eta} + \frac{\partial h_2}{\partial q_r}\frac{dq_r}{d\eta} + \frac{\partial h_2}{\partial q_{gp}}\frac{dq_{gp}}{d\eta} &= 0, \\
\frac{\partial h_3}{\partial \eta} + \frac{\partial h_3}{\partial \theta_*}\frac{d\theta_*}{d\eta} + \frac{\partial h_3}{\partial \theta^*}\frac{d\theta^*}{d\eta} + \frac{\partial h_3}{\partial q_r}\frac{dq_r}{d\eta} &= 0, \\
\frac{\partial h_4}{\partial \eta} + \frac{\partial h_4}{\partial \theta^*}\frac{d\theta^*}{d\eta} + \frac{\partial h_4}{\partial q_{gp}}\frac{dq_{gp}}{d\eta} &= 0.
\end{aligned}$$

Solving the system, we find

$$\frac{d\theta_*}{d\eta} = \frac{\frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\left(\frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \eta} - \frac{\partial h_2}{\partial \eta}\frac{\partial h_4}{\partial q_{gp}}\right) + \left(\frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \eta} - \frac{\partial h_1}{\partial \eta}\frac{\partial h_3}{\partial q_r}\right)\left(\frac{\partial h_2}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} - \frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \theta^*}\right) + \frac{\partial h_1}{\partial \eta}\frac{\partial h_2}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}}}{\left[\left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial q_r} - \frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta_*}\right)\left(\frac{\partial h_2}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} - \frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \theta^*}\right) - \frac{\partial h_1}{\partial \theta_*}\frac{\partial h_2}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}}\right]},$$

$$\frac{d\theta^*}{d\eta} = \frac{\frac{\partial h_2}{\partial q_r}\frac{\partial h_4}{\partial q_{gp}}\left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial \eta} - \frac{\partial h_1}{\partial \eta}\frac{\partial h_3}{\partial \theta_*}\right) + \left(\frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \eta} - \frac{\partial h_2}{\partial \eta}\frac{\partial h_4}{\partial q_{gp}}\right)\left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial q_r} - \frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta_*}\right)}{\left[\left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial q_r} - \frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta_*}\right)\left(\frac{\partial h_2}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} - \frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \theta^*}\right) - \frac{\partial h_1}{\partial \theta_*}\frac{\partial h_2}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}}\right]}.$$

Under the Jacobian Condition, the denominator is positive. Hence, for any policy control variable $\eta \in \{P_{gp}, P_r, \pi_{gp}, \pi_r\}$, we have:

$$
\begin{aligned}
sign\left(\frac{d\theta_*}{d\eta}\right) &= sign\left[\begin{array}{c} \underset{-}{\left(\frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\right)}\left(\underset{+}{\frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \eta}} - \underset{+}{\frac{\partial h_2}{\partial \eta}\frac{\partial h_4}{\partial q_{gp}}}\right) - \frac{\partial h_1}{\partial \eta}\underset{+}{\left(\frac{\partial h_2}{\partial q_r}\frac{\partial h_3}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}}\right)} \\ + \left(\underset{+}{\frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \eta}} - \underset{+}{\frac{\partial h_1}{\partial \eta}\frac{\partial h_3}{\partial q_r}}\right)\underset{+}{\left(\frac{\partial h_2}{\partial \theta^*}\frac{\partial h_4}{\partial q_{gp}} - \frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \theta^*}\right)} \end{array}\right], \\
sign\left(\frac{d\theta^*}{d\eta}\right) &= sign\left[\begin{array}{c} \underset{-}{\left(\frac{\partial h_2}{\partial q_r}\frac{\partial h_4}{\partial q_{gp}}\right)}\left(\underset{+}{\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial \eta}} - \underset{-}{\frac{\partial h_1}{\partial \eta}\frac{\partial h_3}{\partial \theta_*}}\right) \\ + \underset{+}{\left(\frac{\partial h_1}{\partial \theta_*}\frac{\partial h_3}{\partial q_r} - \frac{\partial h_1}{\partial q_r}\frac{\partial h_3}{\partial \theta_*}\right)}\left(\underset{+}{\frac{\partial h_2}{\partial q_{gp}}\frac{\partial h_4}{\partial \eta}} - \underset{+}{\frac{\partial h_2}{\partial \eta}\frac{\partial h_4}{\partial q_{gp}}}\right) \end{array}\right], \\
sign\left(\frac{dq_r}{d\eta}\right) &= sign\left(-\frac{\partial h_3}{\partial \eta} - \underset{-}{\frac{\partial h_3}{\partial \theta_*}}\frac{d\theta_*}{d\eta} - \underset{-}{\frac{\partial h_3}{\partial \theta^*}}\frac{d\theta^*}{d\eta}\right), \\
sign\left(\frac{dq_{gp}}{d\eta}\right) &= sign\left(-\frac{\partial h_4}{\partial \eta} - \underset{-}{\frac{\partial h_4}{\partial \theta^*}}\frac{d\theta^*}{d\eta}\right), \\
sign\left(\frac{dN_2}{d\eta}\right) &= sign\left[(\pi_{gp} - \pi_r)(1-\theta^*) f(\theta^*)\frac{d\theta^*}{d\eta} - (1-\pi_r)(1-\theta_*) f(\theta_*)\frac{d\theta_*}{d\eta}\right].
\end{aligned}
$$

The signs in the above expressions are obtained using (18).

Proposition 2(i): Everything else being fixed, differentiating h_1, h_2, h_3 and h_4 with respect to P_{gp}, we get:

$$\frac{\partial h_1}{\partial P_{gp}} = \frac{\partial h_3}{\partial P_{gp}} = \frac{\partial h_4}{\partial P_{gp}} = 0, \frac{\partial h_2}{\partial P_{gp}} = -1.$$

Therefore, $\frac{d\theta_*}{dP_{gp}} < 0$, $\frac{d\theta^*}{dP_{gp}} > 0$, $\frac{dq_{gp}}{dP_{gp}} > 0$, $\frac{dq_r}{dP_{gp}} > 0$ and $\frac{dN_2}{dP_{gp}} > 0$.

Proposition 2(ii): As we have done above, everything else being fixed, differentiating h_1, h_2, h_3 and h_4 with respect to P_r, we get:

$$\frac{\partial h_1}{\partial P_r} = -1, \frac{\partial h_2}{\partial P_r} = 1, \frac{\partial h_3}{\partial P_r} = \frac{\partial h_4}{\partial P_r} = 0.$$

Therefore, $\frac{d\theta_*}{dP_r} > 0$. ■

Proof of Proposition 3. (i) Suppose, by contradiction, that $\theta_* \leq \theta_1$. Then, in the added-tier system, the quality of regular patents would be lower than the quality of a patent in the single-tiered system ($q_r < q_1$) for two reasons: (a) more low ex-ante probability of validity inventors apply ($\theta_* \leq \theta_1$ and $\frac{\partial q_r}{\partial \theta_*} > 0$), and (b) some high ex-ante probability of validity inventors apply for a gold-plate patent ($\theta^* < 1$ and $\frac{\partial q_r}{\partial \theta^*} > 0$). However, applying for a regular patent becomes less appealing than applying for a patent in the single-tiered system, which would imply $\theta_* > \theta_1$, a contradiction. Hence, in the new system, there must be fewer patent applications: $\theta_* > \theta_1$.

(ii) If $q_r > q_1$, then $\theta_* \leq \theta_1$ which, as we saw in (i), yields a contradiction. Thus, $q_r \leq q_1$.

(iii) Using $l_2(\theta_1, q_1; \pi, P)$ in (14) in the proof of Proposition 1, we can re-write the equilibrium equation for q_{gp} as:

$$l_2(\theta^*, q_{gp}; \pi_{gp}, P) = \int_{\theta^*}^{1} [\theta(1-q_{gp}) - (1-\pi_{gp})(1-\theta) q_{gp}] f(\theta) d\theta = 0.$$

We have already shown (see proof of Propositions 1) that $\frac{\partial l_2}{\partial \theta_1} > 0$ and $\frac{\partial l_2}{\partial \pi} > 0$. By assumption, $\pi_{gp} \geq \pi_r = \pi$. By part (i) of this proof, we have $\theta^* > \theta_* > \theta_1$. Therefore, $q_{gp} > q_1$.

(iv) Proportion innovators who are granted bad patents in a single-tiered patent system is given by:

$$N_1 = (1-\pi) \int_{\theta_1}^{1} (1-\theta) f(\theta) d\theta$$

and the proportion innovators who are granted bad patents in this added-tier system is given in (17) in the proof of Proposition 2. Because $\theta^* > \theta_* > \theta_1$ and $\pi_{gp} \geq \pi_r = \pi$, we have:

$$N_1 - N_2 = (1-\pi) \int_{\theta_1}^{\theta_*} (1-\theta) f(\theta) d\theta + (\pi_{gp} - \pi) \int_{\theta^*}^{1} (1-\theta) f(\theta) d\theta > 0.$$

■

Proof of Proposition 4. For uniformly distributed θ, we have:

$$\frac{dIS_1}{dP} = -(1-\theta_1) + (1-\theta_1) \left[\frac{(1+\theta_1)}{2} G'(q_1) + \frac{(1-\theta_1)}{2} (1-\pi) B'(q_1) \right] \frac{dq_1}{dP}.$$

In a range of corner solutions $\theta_1 = 0$, we have $\frac{dq_1}{dP} = 0$ and $\frac{dIS_1}{dP} < 0$. We consider the range of interior solutions, with $\theta_1 > 0$, which holds for $P > \frac{B}{2-\pi}$ so that applicants with type $\theta = 0$ find patenting too costly. Hence, $\frac{dIS_1}{dP} > 0$ iff the following holds:

$$\left[\frac{(1+\theta_1)}{2} G'(q_1) + \frac{(1-\theta_1)}{2} (1-\pi) B'(q_1) \right] \frac{dq_1}{dP} > 1.$$

From (14) , we know that:

$$\theta_1 = \frac{(1-\pi) q_1 - (1-q_1)}{(1-\pi q_1)} > 0$$

and hence $q_1 > \frac{(1-q_1)}{(1-\pi)}$. Substituting for $\frac{dq_1}{dP}$ from the proof of Proposition 1 and re-arranging, we therefore get $\frac{dIS_1}{dP} > 0$ iff the following holds:

$$\frac{(1-q_1)(1-\pi q_1)}{2(1-\pi)} \left[G'(q_1) - (1-\pi) B'(q_1) \right] > \left[G(q_1) - (1-\pi) B(q_1) \right].$$

We know that:

$$\frac{(1-q_1)(1-\pi q_1)}{2(1-\pi)} \leq q_1 \frac{(1-\pi q_1)}{2} \leq q_1.$$

If the benefit functions are linear, or, more generally, if $[G(q) - (1-\pi) B(q)]$ is concave in q, then we have:

$$[G(q) - (1-\pi) B(q)] \geq q \left[G'(q) - (1-\pi) B'(q) \right] \text{ for all } q,$$

which gives us the following:

$$\begin{aligned} [G(q_1) - (1-\pi) B(q_1)] &\geq q_1 \left[G'(q_1) - (1-\pi) B'(q_1) \right] \\ &\geq \frac{(1-q_1)(1-\pi q_1)}{2(1-\pi)} \left[G'(q_1) - (1-\pi) B'(q_1) \right], \end{aligned}$$

and this implies that $\frac{dIS_1}{dP} < 0$.

Suppose the benefit functions are $G(q) = Gq^n$, $B(q) = Bq^n$, $n > 2$, and $G > B$. Then, in the range of interior solutions, $\frac{dIS_1}{dP} > 0$ iff $\frac{n(1-q_1)(1-\pi q_1)}{2q_1(1-\pi)} > 1$ where by the equilibrium conditions (14) q_1 is the solution of the following:

$$\frac{(1-q_1)}{(1-\pi q_1)} = \frac{G - \frac{P}{q_1^n}}{2\left[G-(1-\pi)B\right]}. \tag{19}$$

To show that the condition for $\frac{dIS_1}{dP} > 0$ sometimes holds, consider $\pi = 0$ and $P > \frac{B}{2^n}$ so that we have an interior solution, $\theta_1 > 0$. Then $\frac{dIS_1}{dP} > 0$ for $\frac{n(1-q_1)}{2q_1} > 1$ or $q_1 < \frac{n}{2+n}$. Taking, for example, $n = 4$, IS_1 increases when $q_1 < \frac{2}{3}$ which by (19) holds true when $P < \left(B + \frac{1}{2}G\right)\left(\frac{2}{3}\right)^5$. ■

Proof of Proposition 5. We first show that in a single-tiered system, the conditional consumers' surplus increases with P :

$$\frac{dCCS_1}{dP} = \left[\theta_1 \left(S_C - S_G\right) + (1-\theta_1)(1-\pi)\left(-S_B\right)\right] f(\theta_1) \frac{d\theta_1}{dP} \geq 0.$$

The inequality is strict in the range of interior equilibrium.

We next claim that the net innovators' surplus increases with P when $P \leq c(\pi)$. To show this, we differentiate NIS_1 with respect to P and use the definition of θ_1 and the results of Proposition 1:

$$\frac{dNIS_1}{dP} = -\left[P - c(\pi)\right] \underbrace{f(\theta_1)\frac{d\theta_1}{dP}}_{\geq 0} + \underbrace{\frac{\partial NIS_1}{\partial q_1}\frac{dq_1}{dP}}_{\geq 0} \geq 0.$$

By (11), the conditional social surplus in a single-tiered system is given by:

$$CSS_1 = CCS_1 + (P - c(\pi))\left(1 - F\left(\theta_1\right)\right) + \frac{IS_1}{2}.$$

Consider first a range where IS_1 increases with P, if such range exists for the given functional forms of the model. Then,

$$\frac{dCSS_1}{dP} = \frac{dCCS_1}{dP} + \left(1 - F\left(\theta_1\right)\right) - \left(P - c(\pi)\right) f\left(\theta_1\right)\frac{d\theta_1}{dP} + \frac{1}{2}\frac{dIS_1}{dP},$$

which is positive when $P \leq c(\pi)$ because $\frac{dCCS_1}{dP} \geq 0$ and in this case $\frac{dIS_1}{dP} \geq 0$.

Now assume that IS_1 is decreasing in P. Rearrange the conditional social surplus so that:

$$CSS_1 = CCS_1 + NIS_1 - \frac{IS_1}{2}.$$

Then,

$$\frac{dCSS_1}{dP} = \frac{dCCS_1}{dP} + \frac{dNIS_1}{dP} - \frac{1}{2}\frac{dIS_1}{dP} > 0$$

because we know that $\frac{dCCS_1}{dP} \geq 0$; in the range $P \leq c(\pi)$, we also know that $\frac{dNIS_1}{dP} \geq 0$, and we are considering the case where $\frac{dIS_1}{dP} < 0$.

Therefore, the conditional social surplus is maximized at a fee higher than the cost of examination: $P^* > c(\pi)$. ■

Proof of Proposition 6. We derive a sufficient condition for a two-tiered system to strictly increase welfare above that in a given optimal (welfare-maximizing) single-tiered system. Let P and π denote the patent fees and examination intensity in an (interior) optimal single-tiered system. We consider an added-tier system that only differs from the single-tiered system in the patent fee for gold-plate patents. That is, $P_r = P$, $\pi_r = \pi_{gp} = \pi$, and $P_{gp} > P$. Let the threshold gold-plate patent fee above which no innovator would apply for the gold-plate tier be:

$$\overline{P_{gp}} = P + G(1) - G(q_1).$$

This is the fee at which type $\theta = 1$ would be indifferent between applying for the regular tier or for a gold-plate tier which has a perceived patent quality $q_{gp} = 1$. For any $P_{gp} \geq \overline{P_{gp}}$, the added-tier system results in the same equilibrium as the single-tiered system with which we started. For $P_{gp} < \overline{P_{gp}}$, some high θ innovators apply for the gold-plate tier. To show that for some parameter values welfare in the two-tiered system is higher than in the single-tiered system, we differentiate the welfare function with respect to P_{gp} and evaluate the derivative at $\overline{P_{gp}}$. Because $W_2\left(\overline{P_{gp}}\right) = W_1$, when $\frac{dW_2}{dP_{gp}}|_{\overline{P_{gp}}} < 0$, welfare in the two-tiered system is higher for some $P_{gp} < \overline{P_{gp}}$. Differentiating W_2 with respect to P_{gp}, we get:

$$\frac{dW_2}{dP_{gp}} = \frac{1}{\bar{\bar{I}}}\left\{\begin{array}{c}\left[CCS_2 + (1-\theta^*)(P_{gp} - c(\pi)) + (\theta^* - \theta_*)(P - c(\pi)) + \frac{IS_2}{2}\right]\frac{dIS_2}{dP_{gp}} + \\ \left[\frac{dCCS_2}{dP_{gp}} - \frac{d\theta^*}{dP_{gp}}(P_{gp} - c(\pi)) + (1-\theta^*) + \left(\frac{d\theta^*}{dP_{gp}} - \frac{d\theta_*}{dP_{gp}}\right)[P - c(\pi)] + \frac{1}{2}\frac{dIS_2}{dP_{gp}}\right] IS_2\end{array}\right\}.$$

We find $\frac{dIS_2}{dP_{gp}}$ and $\frac{dCCS_2}{dP_{gp}}$, and substitute these expressions in. Then, taking the limit as $P_{gp} \nearrow \overline{P_{gp}}$, we have $P_{gp} \to [P + G(1) - G(q_1)], \theta^* \to 1, \theta_* \to \theta_1, CCS_2 \to CCS_1, IS_2 \to IS_1$. Substituting and rearranging, we find:

$$\frac{dW_2}{dP_{gp}}|_{\overline{P_{gp}}} = \frac{1}{\bar{\bar{I}}}\left\{\begin{array}{c}[CCS_1 + (1-\theta_1)(P - c(\pi)) + IS_1]\left[\frac{dIS_1}{dP} + (1-\theta_1)\right]\frac{dq_r}{dP_{gp}}/\frac{dq_1}{dP} + \\ \left\{\left(\frac{dCCS_1}{dP}/\frac{d\theta_1}{dP}\right)\frac{d\theta_*}{dP_{gp}} - [P - c(\pi)]\frac{d\theta_*}{dP_{gp}} - \frac{d\theta^*}{dP_{gp}}[G(1) - G(q_1)]\right\} IS_1\end{array}\right\}_{\overline{P_{gp}}}.$$

Further manipulation of this expression and using the first order conditions for optimality in the single-tiered system yields:

$$\frac{dW_2}{dP_{gp}}|_{\overline{P_{gp}}} = \frac{1}{\bar{\bar{I}}}\left\{\begin{array}{c}[CCS_1 + (1-\theta_1)(P - c(\pi)) + IS_1]\left[\frac{dIS_1}{dP} + (1-\theta_1)\right]\left(\frac{d\theta^*}{dP_{gp}}/\frac{d\theta_1}{dP}\right) \\ + [CCS_1 + (1-\theta_1)(P - c(\pi))](1-\theta_1)\underbrace{\left(\frac{d\theta_*}{dP_{gp}}/\frac{d\theta_1}{dP}\right)}_{<0} \\ -\frac{d\theta^*}{dP_{gp}}[G(1) - G(q_1)] IS_1\end{array}\right\}_{\overline{P_{gp}}}$$

$$(20) \quad < \underbrace{\frac{IS_1\frac{d\theta^*}{dP_{gp}}}{\bar{I}}}_{>0}\left\{\underbrace{[CCS_1 + (1-\theta_1)(P - c(\pi)) + IS_1]\frac{\frac{dIS_1}{dP} + (1-\theta_1)}{\frac{d\theta_1}{dP}IS_1} + G(q_1)}_{:=K} - G(1)\right\}_{\overline{P_{gp}}}$$

Let K be defined as in (20). Note that K is finite and it only depends on the parameters and solution of the given optimal single-tiered system. Therefore, if this condition does not hold, we can find another benefit function that coincides with the original benefit functions everywhere except for a range of qualities $(1-\varepsilon, 1]$ for some small $\varepsilon > 0$ so as not to change the solution to the single-tiered system, yet have $G(1) > K$. Thus, when the benefit function is large enough at high values of perceived patent quality, a two-tiered system can improve welfare. Note that, in the derivations above, we use comparative statics results from Proposition 2. These hold under the Jacobian condition. We complete the proof by showing in Lemma 1 that for large enough $G(1)$, the Jacobian condition holds near $\overline{P_{gp}}$. ■

Lemma 1 *For θ uniformly distributed, in an added-tier system with $P_r = P, \pi_r = \pi_{gp} = \pi$ and $P_{gp} \to \overline{P_{gp}}$, the Jacobian condition holds when $G(1)$ is sufficiently large.*

Proof. By (16) the Jacobian condition holds if:

$$(21) \qquad 1-\frac{\left[\theta^{*}G'\left(q_{r}\right)+\left(1-\theta^{*}\right)\left(1-\pi_{r}\right)B'\left(q_{r}\right)\right]q_{r}}{\left[G\left(q_{gp}\right)-G\left(q_{r}\right)\right]-\left[(1-\pi_{gp})B\left(q_{gp}\right)-(1-\pi_{r})B\left(q_{r}\right)\right]}\frac{\left(1-\pi_{r}q_{r}\right)}{\left(\theta^{*}+\theta_{*}\right)}>0.$$

In the added-tier system we use in Proposition 6, the system has $\pi_{gp}=\pi_r=\pi$, and $P_r=P$. For values $P_{gp}\rightarrow[G(1)-G(q_1)+P]$, we know $\theta^*\rightarrow 1$ and $q_{gp}\rightarrow 1, \theta_*\rightarrow\theta_1$ and $q_r\rightarrow q_1$. Substituting these limits in (21), we find the sufficient condition:

$$1-\frac{G'\left(q_{1}\right)q_{1}}{\left[G\left(1\right)-G\left(q_{1}\right)\right]-\left(1-\pi\right)\left[B\left(1\right)-B\left(q_{1}\right)\right]}\frac{\left(1-\pi q_{1}\right)}{\left(1+\theta_{1}\right)}>0,$$

which holds when:

$$G\left(1\right)-(1-\pi)B\left(1\right)>G'\left(q_{1}\right)q_{1}\frac{\left(1-\pi q_{1}\right)}{\left(1+\theta_{1}\right)}+G\left(q_{1}\right)-(1-\pi)B\left(q_{1}\right).$$

Note that the right hand side only depends on the solution of the single-tiered system. This latter condition holds when $G(1)$ is sufficiently large. As argued in the proof of Proposition 6, if the condition does not hold, we can choose another function G that coincides with the original $G(.)$ everywhere, except in a small enough range near 1, where it increases to a high $G(1)$. ■

APPENDIX B: THE LINEAR MODEL

We define here the linear model in which we assume a uniform distribution of types and linear benefit functions.

Definition 6 *(Linear model) In the linear model, the distribution of inventors' types is uniform:* $F(\theta)=\theta$, *the benefit-functions are linear:* $G(q)=(G+G'q)$ *and* $B(q)=(B+B'q)$, *satisfying our earlier assumptions (2) and (8).*

We derive two independent sufficient condition for the Jacobian Condition to hold in the linear model. The first is more likely to hold when π_{gp} is large relative to π_r, and the second is stated for $\pi_{gp}=\pi_r$, and would be sufficient more generally when the π_{gp} is close to π_r.

Lemma 2 *In the linear model,*
(i) If $(P_{gp}-P_r)+(\pi_{gp}-\pi_r)(B+B')-G'>0$, *then the Jacobian condition holds.*
(ii) If $\pi_{gp}=\pi_r\leq\frac{1}{4}$, *and* $G'>2B'$, *then the Jacobian condition holds.*

Proof. (i) We substitute the linear functional forms in the sufficient condition (21) that appears in Lemma 1. The Jacobian condition holds if:

$$1-\frac{\left[\theta^{*}G'+\left(1-\theta^{*}\right)\left(1-\pi_{r}\right)B'\right]q_{r}}{G'\left(q_{gp}-q_{r}\right)-\left[\left(1-\pi_{gp}\right)\left(B+B'q_{gp}\right)-\left(1-\pi_{r}\right)\left(B+B'q_{r}\right)\right]}\frac{\left(1-\pi_{r}q_{r}\right)}{\left(\theta^{*}+\theta_{*}\right)}>0$$

We rearrange to get the condition as following:

$$\frac{\left(\theta^{*}+\theta_{*}\right)}{1-\pi_{r}q_{r}}-\frac{\left[\theta^{*}G'+\left(1-\theta^{*}\right)\left(1-\pi_{r}\right)B'\right]q_{r}}{\left[\left[G'-\left(1-\pi_{r}\right)B'\right]\left(q_{gp}-q_{r}\right)+\left(\pi_{gp}-\pi_{r}\right)\left(B+B'q_{gp}\right)\right]}>0.$$

Substituting θ^* from the equilibrium condition $h_2(.)=0$ in (9), this inequality holds if:

$$\left[\frac{\left(P_{gp}-P_{r}\right)+\left(\pi_{gp}-\pi_{r}\right)\left(B+B'q_{gp}\right)-G'q_{gp}+\left(q_{gp}-\theta^{*}q_{r}\right)\left[G'-\left(1-\pi_{r}\right)B'\right]}{\left[\left[G'-\left(1-\pi_{r}\right)B'\right]\left(q_{gp}-q_{r}\right)+\left(\pi_{gp}-\pi_{r}\right)\left(B+B'q_{gp}\right)\right]}\right]>0.$$

Under our assumptions, the denominator of this expression is positive, and (by the single crossing condition) so are the last two terms in the numerator. Hence a sufficient condition for the Jacobian condition to hold is:

$$(P_{gp} - P_r) + (\pi_{gp} - \pi_r)\left(B + B'\right) - G' > 0.$$

(ii) Substituting the linear functional forms and $\pi_{gp} = \pi_r = \pi$ into (16) and omitting only positive terms from that expression, we find that the Jacobian would be positive if the following holds:

$$\frac{\left[\theta^* G' + (1-\theta^*)(1-\pi)B'\right] q_{gp}}{\left[G' - (1-\pi)B'\right]\left[q_{gp} - q_r\right]} \frac{(1-\pi q_{gp})}{(1+\theta^*)} + 1 - \frac{\left[\theta^* G' + (1-\theta^*)(1-\pi)B'\right] q_r}{\left[G' - (1-\pi)B'\right]\left[q_{gp} - q_r\right]} \frac{(1-\pi q_r)}{(\theta^* + \theta_*)}$$
$$> \quad 0.$$

We substitute the following:

$$q_r = \frac{(\theta^* + \theta_*)}{2 - 2\pi + \pi(\theta^* + \theta_*)} \text{ and } q_{gp} = \frac{(1+\theta^*)}{2 - 2\pi + \pi(1+\theta^*)}$$

and rearrange this condition to obtain the sufficient condition:

$$\frac{\left[G' - (1-\pi)B'\right]}{\left[\theta^* G' + (1-\theta^*)(1-\pi)B'\right]} > \pi \left(1 + \underbrace{\frac{\pi(\theta^* + \theta_*)}{2(1-\pi)}}_{\leq\frac{1}{3}}\right) \underbrace{\frac{(q_{gp} - q_r)}{(1-\theta_*)}}_{\leq 1} + \pi \underbrace{\frac{(1-\pi q_r)}{2(1-\pi)}}_{\leq\frac{2}{3}}.$$

Since we assumed $\pi \leq \frac{1}{4}$, the expression on the right hand side is bounded by $\frac{1}{2}$, and the right hand side is larger than $\frac{1}{2}$ when $G' > 2B'$. ■

For the linear model, we can extend Proposition 2 with the following additional comparative statics results.

Proposition 7 *Under the Jacobian Condition, in the linear model,*

(i) As the regular patent fee (P_r) increases, the volume of gold-plate patents increases and the quality of gold-plate patents decreases. Overall, there are fewer bad patents.

(ii) As the examination intensity of gold-plate patents (π_{gp}) increases, the overall volume of patent applications increases, the volume of gold-plate patent applications decreases, the quality of gold-plate patents and the quality of regular patents increase.

(iii) The overall volume of patent applications decreases with the examination intensity of regular patents (π_r).

Proof. We continue to use the derivations from the proof of Proposition 2.

Proposition 7(i): Substituting the functional forms from the linear model described in the Definition 6, into expressions we derived in the proof of Proposition 2, we have $\frac{d\theta^*}{dP_r} < 0$, $\frac{dq_{gp}}{dP_r} < 0$ and $\frac{dN_2}{dP_r} < 0$.

Proposition 7(ii): Keeping everything else fixed in the linear model, differentiating h_1, h_2, h_3 and h_4 with respect to π_{gp}, we get

$$\begin{aligned}
\frac{\partial h_1}{\partial \pi_{gp}} &= \frac{\partial h_3}{\partial \pi_{gp}} = 0, \\
\frac{\partial h_2}{\partial \pi_{gp}} &= -(1-\theta^*)\left(B + B' q_{gp}\right) < 0, \\
\frac{\partial h_4}{\partial \pi_{gp}} &= -\frac{(1-\theta^*)^2}{2} q_{gp} < 0.
\end{aligned}$$

Hence, $\frac{d\theta_*}{d\pi_{gp}} < 0$, $\frac{d\theta^*}{d\pi_{gp}} > 0$, $\frac{dq_r}{d\pi_{gp}} > 0$ and $\frac{dq_{gp}}{d\pi_{gp}} > 0$.

Proposition 7(iii): Keeping everything else fixed in the linear model, differentiating h_1, h_2, h_3 and h_4 with respect to π_r, we get

$$\begin{aligned}
\frac{\partial h_1}{\partial \pi_r} &= -(1-\theta_*)\left(B + B'q_r\right) < 0, \\
\frac{\partial h_2}{\partial \pi_r} &= (1-\theta^*)\left(B + B'q_r\right) > 0, \\
\frac{\partial h_3}{\partial \pi_r} &= -\frac{(\theta^* - \theta_*)^2}{2} q_r < 0, \\
\frac{\partial h_4}{\partial \pi_r} &= 0.
\end{aligned}$$

Therefore, $\frac{d\theta_*}{d\pi_r} > 0$. ■

We have considered changes in each policy control variable separately. If the patent office has to cover costs and it couples an increase in examination intensity (π_r) with a corresponding increase in the patenting fee (P_r), from Propositions 2 and 7, we conclude that such change would result in a decline in the volume of patent applications, but has an indeterminate effect on the proportion of innovators who are granted bad patents. Similarly, an increase in both π_{gp} and P_{gp} results in a higher volume of patent applications, but has an indeterminate effect on the proportion of innovators who are granted bad patents.

REFERENCES

Atal, V. and Bar, T., 2010, 'Prior Art: To Search or Not to Search,' *International Journal of Industrial Organization,* 28(5), pp. 507-521.

Caillaud, B. and Duchêne, A., 2011, 'Patent Office and Innovation Policy,' *International Journal of Industrial Organization,* 29(2), pp. 242-252.

Chang, H., 1995, 'Patent Scope, Antitrust Policy and Cumulative Innovation,' *RAND Journal of Economics,* 26, pp. 34-57.

Christie, A. F. and Moritz, S. L., 2005, 'Australia's Second-Tier Patent System: A Preliminary Review,' report no. 02/04, Intellectual Property Research Institute of Australia, University of Melbourne, Melbourne, Australia.

Cockburn, I., Kortum, S. and Stern, S., 2003, 'Are All Patent Examiners Equal? Examiners, Patent Characteristics and Litigation Outcomes,' in W. Cohen and S. Merrill (eds.) *Patents in the Knowledge-based Economy* (National Academies Press, Washington DC).

Cohen, W., Nelson, J. and Walsh, J., 2000, 'Protecting Their Intellectual Assets: Appropriability Conditions and Why U.S. Manufacturing Firms Patent (or Not),' NBER working paper no. 7552. Available at: http://www.nber.org/papers/w7552.

Cornelli, F., and Schankerman, M., 1999, 'Patent Renewals and R&D Incentives,' *RAND Journal of Economics*, 30(2), pp. 197-213.

Crampes, C. and Langinier, C., 1998, 'Information Disclosure in the Renewal of Patents,' *Annales d'Economie et de Statistique,* 49/50, pp. 262-288.

Dranove, D., and Jin, G., 2010, 'Quality Disclosure and Certification: Theory and Practice,' *Journal of Economic Literature*, 48(4), pp. 935-963.

Farhi, E., Lerner, J. and Tirole, J., 2012, 'Fear of Rejection? Tiered Certification and Transparency,' Available at: http://idei.fr/doc/by/tirole/fear091212.pdf.

Farrell, J. and Shapiro, C., 2008, 'How Strong Are Weak Patents,' *American Economic Review*, 98(4), pp. 1347-1369.

Gill, D. and Sgroi, D., 2008, 'Sequential Decisions with Tests,' *Games and Economic Behavior,* 63, pp. 663-678.

Gilbert, R. and Shapiro, C., 1990, 'Optimal Patent Length and Breadth,' *RAND Journal of Economics,* 21(1), pp. 106-112.

Grossman, G. and Shapiro, C., 1987, 'Dynamic R and D Competition,' *Economic Journal*, 97, pp. 372-397.

Japan Patent Attorneys Association, 2012, 'Recent Situation of the Japanese Intellectual Property Protection Scheme,' Available at: http://www.jpaa.or.jp/english/aboutus/pdf/open_seminar.pdf.

Klemperer, P., 1990, 'How Broad should the Scope of Patent Protection be,' *RAND Journal of Economics,* 21(1), pp. 113-130.

Koenen, J., 2011, 'Patent Litigation and Patent Reform,' working paper, University of Bonn, Bonn, Germany. Available at: http://www.wiwi.uni-bonn.de/koenen/Patents.pdf.

Langinier, C., and Marcoul, P., 2010, 'Monetary and Implicit Incentives of the Patent Examiners,' working paper, University of Alberta, Edmonton, Canada. Available at: http://www.ualberta.ca/~langinie/papers/ptoJuly_09.pdf.

Langinier, C. and Marcoul, P., 2012, 'Search of Prior Art and Revelation of Information by Patent Applicants,' working paper, University of Alberta, Edmonton, Canada. Available at: http://www.ualberta.ca/~langinie/papers/PA_March_2012.pdf.

Lemley, M., Lichtman, D. and Sampat, B., 2005, 'What to do About Bad Patents?' *Regulation*, 28(4), pp. 10-13.

Lemley, M., Lichtman, D., 2007, 'Rethinking Patent Law's Presumption of Validity,' *Stanford Law Review*, 60(1), pp. 45-72.

Lizzeri, A., 1999, 'Information Revelation and Certification Intermediaries,' *RAND Journal of Economics*. 30(2), pp. 214-231.

Merges, R. P., 1999, 'As Many as Six Impossible Patents before Breakfast: Property Rights for Business Concepts and Patent System Reform,' *Berkeley Technology Law Journal*, 14(2), pp. 577-615.

Norman, D. K., Wamsley, H. C. and Richardson, E. A., 2010, 'Alternatives to Prompt, High-Quality Examination of All Patent Applications,' Available at: http://www.ficpi.org/AIPLA-FICPI-Colloquium/E4-Norman&Wamsley&Richardson(IPO)(handout).pdf.

Noveck, B., 2006, 'Peer to Patent: Collective Intelligence, Open Review, and Patent Reform,' *Harvard Journal of Law and Technology*, 20(1), pp. 123-162.

O'Donoghue T., 1998, 'A Patentability Requirement for Sequential Innovation,' *RAND Journal of Economics,* 29, pp. 654-679.

O'Donoghue, T., Scotchmer, S. and Thisse, J., 1998, 'Patent Breadth, Patent Life, and the Pace of Technological Progress,' *Journal of Economics and Management Strategy*, 7(1), pp. 1-32.

de Rassenfosse, G., and van Pottelsberghe de la Potterie, B., forthcoming, 'The Role of Fees in Patent Systems: Theory and Evidence,' *The Journal of Economic Surveys*.

Regibeau, P. and Rockett, K., 2010, 'Innovation Cycles and Learning at the Patent Office: Does the Early Patent Get the Delay?' *Journal of Industrial Economics*, 58(2), pp. 222-246.

Schuett, F., forthcoming, 'Patent Quality and Incentives at the Patent Office,' *RAND Journal of Economics*.

Scotchmer, S., 2006, *Innovation and Incentives* (MIT Press, Cambridge, MA).

Scotchmer, S., 1999, 'On the Optimality of the Patent Renewal System,' *RAND Journal of Economics*, 30(2), pp. 181-196.

Thomas, J. R., 2001, 'Collusion and Collective Action in the Patent System: A Proposal for Patent Bounties,' *University of Illinois Law Review*, 2001(1), pp. 305-353.

Yamauchi, I., and Nagaoka, S., 2008, 'Complementary Reforms of Patent Examination Request System in Japan,' working paper no. 08-07, Institute of Innovation Research, Hitotsubashi University, Tokyo, Japan. Available at: http://pubs.iir.hit-u.ac.jp/admin/en/pdfs/file/932.