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RISKS TO THE RETURNS TO MEDICAL INNOVATION: THE CASE OF MYRIAD GENETICS

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ABSTRACT

We describe the broad range of uncertainties faced by the developers of medical technologies. Empirically, we estimate the asset market incidence of two realizations of uncertainties we classify as within-market policy risks. The events we analyze concern the intellectual property of Myriad Genetics, Inc., an American molecular diagnostics firm. In June 2013, the Supreme Court invalidated several of Myriad's intellectual property claims. Subsequently, the Center for Medicare and Medicaid Services (CMS) re-evaluated the reimbursements it pays for the services at issue in the Supreme Court's ruling. Each of these events moved Myriad's market capitalization by several hundred million dollars, or on the order of 20 percent. Myriad's exposure to the realization of these events reflected the concentration of its revenue streams among the affected services. We discuss the implications of the risks we analyze for the total volume of medical innovation and for its organization across firms.

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I Introduction

Risk and expected returns shape the aggregate volume and organization of innovative activity. While the theory underlying these linkages has received ample attention, cataloging and quantifying the risks relevant in any particular industry requires attention to institutional detail and empirical documentation. In this paper, we consider the relevance of risks we term "within-market policy risks" for the returns to the development of medical technology.

In Section 2, we organize the risks faced by medical innovators into a typology. First among our typology's broad categories are pre-market risks. This category, which has been widely studied, includes standard risks associated with product development and regulatory approval. Our second broad category encompasses within-market economic risks. These risks, also widely studied, include input cost variability, the introduction of competing products and, more broadly, threats to a product's demand. A third category involves what we call within-market policy risks. This category includes risks such as patent invalidation and other legal or legislative threats to a product's reimbursement status within public and private insurers' payment systems.

In Section 3, we empirically assess the asset market incidence of two distinctive realizations of within-market policy risk. Specifically, we analyze the market capitalization of Myriad Genetics, a company known primarily for its development of the BRCA1 and BRCA2 molecular diagnostic tests for breast and ovarian cancer. As detailed in Section 3, Myriad's case is noteworthy along multiple dimensions. Myriad's intellectual property was addressed by the Supreme Court, which ultimately invalidated some of its patent claims. Following the Supreme Court's decision, the Center for Medicare and Medicaid Services (CMS) re-evaluated its reimbursements for the affected services. Further, Myriad's finances were unusually reliant on the revenues generated by the affected product

lines. The validity of the disputed patent claims and the generosity of Medicare's reimbursements thus had significant implications for Myriad's future profitability.

Section 3's analysis reveals that the resolution of these policy risks significantly affected Myriad's market capitalization. We estimate that the Supreme Court's invalidation of Myriad's intellectual property reduced its valuation by roughly 23 percent, or in excess of $500 million. Subsequent re-determination of Medicare's reimbursements for Myriad's tests similarly moved Myriad's market capitalization by several hundred million dollars. We further observe that Myriad's capitalization exhibited high volatility throughout the time period in question. We conclude with a brief discussion of these policy risks' implications for aggregate levels of medical innovation, for the direction of innovative effort, and for the structure of the firms in which this innovation takes place.

II The Risks Faced by Medical Innovators

Innovators face a large number of uncertainties. This section presents a typology of the risks to which those who invest in innovation, and in particular in medical innovation, are exposed. We begin by defining three broad categories of risk. We then discuss the extent to which these risks have been analyzed in prior work and, to the extent that they have, how they have been found to affect innovative activity.

II.a A Broad Typology of Risks

In this section we succinctly define three broad categories of risk faced by medical innovators and their investors.

Pre-Market Risks: Pre-market risks encompass all risks realized prior to a product's introduction to the market. Such risks occur over the course of the development and regulatory approval processes.

Within-Market Economic Risks: Within-market economic risks encompass all standard economic threats to the demand for an innovator's product or to a firm's production costs. Such risks include the introduction of superior or lower-cost substitutes. Demand may also be affected by changes in the prevalence of the medical condition at which a given innovation is targeted.

Within-Market Policy Risks: Within-market policy risks encompass post-approval, policy-driven threats to an innovation's profitability. By nature, such risks depend on the specifics of the markets under consideration. Examples include reassessments of the validity of intellectual property claims and reassessments of a technology's efficacy and side effects. They also include changes in the generosity of public insurers' reimbursements, both in aggregate and for specific products.

II.b Implications for the Volume and Organization of Medical Innovation

Uncertainties have implications for both the volume and organization of innovative activity. When uncertainties involve disproportionately downside risks, they reduce expected returns and will thus tend to discourage innovative activity. Uncertainty has further been found to stall both investment and overall economic activity *conditional* upon expected returns (Bloom, 2009; Shoag and Veuger, 2015). To the extent that the associated risks can be diversified across product lines, they may tend to increase the scale of the organizations within which innovative activity takes place. In the remainder of this section, we illustrate the uncertainties at work in the context of medical innovation and discuss the state of the evidence on their relevance.

II.b.1 Pre-Market Risks

Pre-market risks include the uncertainties of the product development and regulatory approval processes. The scientific difficulty of discovery and the stringency of regulatory approval shape medical innovation's expected returns. Because some aspects of the uncertainty they introduce can be smoothed through scale, these uncertainties can have implications for innovation's organization.

Broad descriptions of pharmaceutical development find that roughly 1 in 5,000 to 10,000 molecules investigated by basic researchers ultimately make their way to market (Lipsky and Sharp, 2001). With expected total costs between pre-clinical and clinical development approaching $3 billion (Mullard, 2014), it should not be surprising that pharmaceutical development has historically been concentrated among firms of substantial scale. That said, biotechnology's rise has been associated with a proliferation of smaller players (Cockburn, 2004). While research on pre-market risks has focused primarily on the pharmaceutical sector, Stern (2014) explores the impact of regulatory uncertainty on the development of new medical devices.

Recent evidence from cancer trials shows that the expected length of the approval process shapes the direction and volume of innovative activity (Budish et al., 2013). Because firms patent potential cancer treatments early in the approval process, the process's length reduces a firm's period of patent exclusivity. And because it is easier to demonstrate the efficacy of drugs targeted at cancers that tend to kill quickly, Budish et al. (2013) find that firms invest relatively little in the development of treatments for cancers with low rates of short-term mortality.

II.b.2 Within-Market Economic Risks

Within-market economic risks include a variety of standard, post-approval uncertainties involving a product's profitability. Such uncertainties include input cost variability, changes in the number of potential purchasers, and changes in the availability of alternatives developed by competitors. The introduction of competing products has received detailed attention in the growth literature, in particular in the context of "creative destruction" models of growth and innovation (Aghion and Howitt, 1992). As detailed in the following paragraph, the demand-side drivers of potential market size have received significant attention in the relevant empirical literature.

Within-market economic risks are widely studied in the empirical literature, which finds that medical innovation is highly responsive to the relevant incentives. Research has found both drug and medical device innovation to exhibit significant responsiveness to the market contractions and expansions implied by shifting demographics, coverage regimes, and public health requirements. Acemoglu and Linn (2004), for example, find that pharmaceutical research tracked the predictable changes in market size driven by the baby boom's population bulge. Clemens (2013) finds that the market expansion resulting from Medicare's introduction led to a substantial increase in U.S.-based patenting in medical equipment and devices. Finally, Finkelstein (2004) finds that changes in inoculation policy significantly altered the course of vaccine development.

II.b.3 Within-Market Policy Risks

Within-market policy risks involve legal uncertainties that influence a product's market standing. In this context, the political economy and public choice literatures focus most of their attention on regulatory capture and lobbying. That is, much research has analyzed efforts to write the rules of the game, as opposed to navigating them as they are (Ades and

Di Tella, 1999; Kroszner and Stratmann, 1998; Djankov et al., 2002). The corporate strategy literature devotes more attention to rule navigation. This literature typically adopts the perspective of a single firm, as in Wilson and Veuger (2015), and tends not to consider the regulatory environment's impact on an industry's organization and aggregate outcomes.

We emphasize the risks associated with intellectual property claims and public insurers' reimbursement policies.[1] Initial patent or product approval carry no guarantees of permanence. The risks of patent invalidation or revocation of product approval have straightforward implications for innovation's expected returns. Similarly, public insurers have no obligation to maintain the reimbursement rates upon which they initially settle.

These policy risks have received limited attention in the literature on medical innovation. Below, we estimate the asset market incidence of two recent realizations of such risks. The first involves the Supreme Court's invalidation of a subset of the patent claims held by Myriad Genetics, Inc. Following the invalidation of Myriad's patent claims, the federal Medicare program re-evaluated the reimbursement rates it pays for the relevant medical services.[2] Our second piece of analysis involves the asset market incidence of a major announcement in this reimbursement re-evaluation process.

Our analysis of these instances of product-specific reimbursement risk can be contrasted with the implications of recent work on aggregate medical reimbursement risk (Koijen et al., 2014). Diversification across product lines can provide relief from idiosyncratic reimbursement risk, but not against aggregate reimbursement risk. Because aggregate reimbursement risk cannot be diversified away, it has relatively direct implications for the industry-wide risk premium and the volume of innovative activity. By contrast,

[1] Product liability risk is another major type of within-market policy risk.

[2] Reimbursement changes may alter the returns to innovation through effects on both prices and on the quantity demanded. In some cases, the quantity demanded is mediated by health providers' technology adoption decisions. An expanding body of research, including studies by Acemoglu and Finkelstein (2008), Clemens and Gottlieb (2014), and Freedman et al. (2012), finds that technology adoption responds to reimbursement policy in the standard direction.

product-specific reimbursement risks create a rationale for pooling the revenue streams associated with a diverse array of medical products. The same can be said for the risk of product-specific patent invalidation. Our analysis thus highlights risks that are of particular relevance for small-scale innovators, with implications for innovative activity's organization.

III The Relevance of Within-Market Policy Risks: Evidence from the Case of Myriad Genetics

This section presents evidence that within-market policy risks can exert significant influence over the fortunes of medical innovators and their investors. The evidence stems from events involving the intellectual property of Myriad Genetics, Inc (hereafter simply "Myriad"). Myriad provides molecular diagnostic screening and holds patents covering a variety of claims related to the services it provides. As detailed below, Myriad's revenue stream was highly exposed to the performance of a single product line. The events we analyze thus involved sufficient risk that, as shown, the resolution of the associated uncertainties significantly moved Myriad's market capitalization.

III.a Background on Myriad Genetics

Myriad, founded in 1991, is an American molecular diagnostic firm headquartered in Salt Lake City, Utah, and traded publicly on the NASDAQ Global Select Market (Myriad Genetics, Inc., 2014). The firm's market capitalization has averaged $2.1 billion over the past five years, while its net income averaged some $130 million (YCharts, 2014). It develops and commercializes medical tests that analyze individuals' genomes and proteomes to establish their proneness to diseases, to diagnose diseases, to prognosticate the progression of diseases, and to assess the suitability of modes of treatment for the individuals in

question (Myriad Genetics, Inc., 2014).

Myriad's finances are notable in terms of their exposure to the performance a single product line. Its BRAC*Analysis* product for assessing risk for breast and ovarian cancer accounted for 75 percent of its $613 million in total revenue for the fiscal year ending in June 2013 and 67 percent of its $778 million in total revenue in the year ending in June 2014 (Myriad Genetics, Inc., 2013, 2014). Legal decisions and Medicare reimbursement determinations linked to this product line are the focus of our empirical analysis.

Our focus is on two significant events in Myriad's recent history. The first event is the June 2013 Supreme Court (SCOTUS) decision in Association for Molecular Pathology v. Myriad Genetics, Inc. The case in question was originally heard in the Southern District Court of New York. At stake were certain patents obtained by Myriad that gave it "the exclusive right to synthetically create BRCA cDNA." After the decision of the District Court, two hearings in the United States Court of Appeals for the Federal Circuit, and two petitions to the Supreme Court, the Supreme Court invalidated a number of Myriad's patent claims on June 13th, 2013 (Hamel et al., 2013).

Following the Supreme Court's decision, CMS re-evaluated its reimbursements for the affected diagnostic tests. The institutional mechanics of CMS's reimbursement re-determination require a bit of elaboration. The Supreme Court's decision enabled competitors' entry into Myriad's previously exclusive markets. When Myriad supplied monopolistically, the determination of its reimbursement rate involved CMS and Myriad alone.[3] Prospective competitors, including Ambry Genetics, submitted data to CMS implying that they could provide the relevant services at lower cost. CMS initially responded to this pric-

[3]The relevant market institutions, namely those of the market for a health care service financed primarily through third-party payment, and in particular by Medicare, distinguish the pricing problem from the standard monopoly case. The payment is effectively determined through a negotiation between CMS and Myriad that is guided by Myriad's submission of cost information to CMS. CMS implicitly acknowledges that providers like Myriad require compensation for the fixed costs of research and development, enabling pricing above marginal cost.

ing information by reducing its reimbursement rate from $2,795 to $1,438 per test. This appears to have been largely anticipated as a consequence of prior events, as Myriad's market capitalization responded moderately to this initial downward revision. During a period of public comment, however, CMS partially reversed its reduction in response to Myriad's submission and analysis of new pricing data. This upward revision, announced on April 1st, 2014, brought its reimbursement from $1,438 to $2,184 per test (GenomeWeb, 2014). This reversal of fortunes, which appears to have been largely unanticipated, is the second event we analyze.

III.b Overview of Our Empirical Analysis

In the remainder of this section, we analyze the "abnormal" returns of Myriad genetics stock. Our goal in analyzing abnormal returns is to estimate the effects of decisions by the Supreme Court and CMS on Myriad's market capitalization. At least two difficulties must be overcome for our analysis to be informative regarding the asset market incidence of the events we analyze. The first difficulty involves the standard empirical problem of establishing a relevant counterfactual: the normal return. We do this in two ways.

First, we use the performance of benchmark indices to approximate what would have happened to Myriad's market capitalization in the absence of the events we analyze. The indices we consider include the NBI, the S&P 400 and 500, and the CCMP. The NBI is the NASDAQ Biotechnology Index, which includes firms classified as either biotechnology or pharmaceutical that have a market capitalization at least of $200 million and that meet several other eligibility criteria. The S&P 400 includes U.S. mid-cap companies, namely companies with an unadjusted market capitalization ranging between $1 billion and $4.4 billion. The S&P 500 includes the 500 largest firms that trade on either NASDAQ or the New York Stock Exchange. To qualify, firms must have an unadjusted market capitaliza-

tion of at least $4.0 billion, be headquartered in the U.S., and meet several other criteria. The CCMP is the NASDAQ Composite Index, which includes all NASDAQ stocks that are not, among other things, exchange-traded funds, derivatives, or preferred shares. It includes over 3,000 firms.

The ideal benchmark for our analysis would be an index including firms subject to similar aggregate shocks, and exhibiting similar volatility under "normal" market conditions, as Myriad. Because the NBI includes other firms in the biotechnology sector, it is relatively well-suited from the perspective of capturing firms that would experience aggregate shocks similar to those experienced by Myriad. We use the S&P 400 because, as an index of mid-cap firms of which Myriad is one, it may capture the degree of volatility one might expect for a firm of Myriad's size. The S&P 500 and CCMP have less to recommend them as benchmarks for Myriad *per se*, but provide a broader sense of the performance of equities over the analysis period. As shown below, our analysis of Myriad's relative performance depends little on the index to which we compare it.

Second, we calculate cumulative abnormal returns by applying a standard "market model" event study methodology using the same indices just discussed (MacKinlay, 1997). With R_t indicating Myriad's return and R_t^m indicating the return on the benchmark index at time t, we estimate $R_t = \alpha + \beta R_t^m + \varepsilon_t$ for the period from 150 through 30 days before the event, under the assumption that $E[\varepsilon_t] = 0$ and $Var[\varepsilon_t] = \sigma_\varepsilon^2$. The abnormal return, AR_t, is then computed as the difference between the actual return, R_t, and the normal return predicted by the model: $AR_t = R_t - (\alpha + \beta R_t^m)$. The sum of these abnormal returns over select trading days is then the cumulative abnormal return.

The second difficulty we face involves the role of expectations. Abnormal returns capture changes in the expected net present value of a firm's stream of future profits relative to the market. Expectations regarding each event will, of course, be reflected in Myriad's valuation prior to the event's realization. It was known, for example, that the Supreme

Court would issue a decision. It was unknown whether that decision would go "for" or "against" Myriad and to what degree. For simplicity, suppose the decision was binary and that it was, at time t, expected to go against Myriad with probability p. Letting π_t denote Myriad's expected profit in period t and δ the relevant discount factor, we write the decision's impact on Myriad's profitability as:

$$\sum_{t=0}^{\infty} \frac{(1-p)\pi_t^{FOR} + p\pi_t^{AGAINST}}{(1+\delta)^t} - \sum_{t=0}^{\infty} \frac{\pi_t^{AGAINST}}{(1+\delta)^t}. \tag{1}$$

The change in market capitalization thus captures

$$(1-p)\sum_{t=0}^{\infty} \frac{\pi_t^{FOR} - \pi_t^{AGAINST}}{(1+\delta)^t}, \tag{2}$$

which is the decision's total incidence scaled by 1-p.

The total incidence of the events we study could thus be recovered given knowledge of the relevant probabilities. As we do not have such knowledge, we are only able to estimate suggestive bounds. Importantly, the estimates will in no case overstate an event's total impact on Myriad's expected profit stream. Commentary surrounding the timing of the Supreme Court decision suggests a significant division of views regarding the extent to which the court's ruling would invalidate Myriad's intellectual property. By contrast, CMS's April 1st increase in the reimbursement rates applicable to BRAC*Analysis* was largely unexpected. The abnormal returns to the latter event may thus come close to approximating the CMS decision's total incidence. The abnormal returns to the former event may represent closer to half of the Supreme Court ruling's total incidence.

III.c An Initial Look At Myriad's Returns Relative to the Market

Figure 1 presents Myriad's cumulative returns relative to each of the benchmark indices over an interval extending from May 2013 through September 2014.[4] The interval encompasses the Supreme Court's decision of June 13th, 2013, and CMS's April 1st, 2014, reimbursement re-determination. Both events are indicated in the figure by dashed vertical lines. Two facts are readily apparent from the figure. First, this extended interval of legal challenges has been associated with substantial volatility in Myriad's stock price. Second, while volatility has been the rule rather than the exception, the Supreme Court decision and announcement of Medicare's reimbursement decision emerge as noteworthy events within the history. The analyses presented in Figure 2, Figure 3, and Table 1 further elaborate on the impact of these events.

III.d Event 1: The Effect of Patent Invalidation on Myriad's Stock Price

Figure 1 reveals that Myriad experienced a large, negative abnormal return following the Supreme Court's invalidation of its patents. Figure 2 displays the size of Myriad's decline relative to the changes in the price of each stock in the benchmark indices, with changes calculated from June 13th to June 19th of 2013. The first panel, for example, presents a histogram of the price changes for each firm in the CCMP, while the second panel presents a histogram of the price changes in the BMI. The percentage change in Myriad's stock price, a decline of 23.59%, is represented in each panel by a dashed line. The histograms reveal Myriad's decline to be well below the experience of other firms in the comparison

[4]Note that Figure 1 presents cumulative relative returns of the form:

$$\frac{\text{Myriad}_t - \text{Myriad}_0}{\text{Myriad}_0} - \frac{\text{Benchmark Index}_t - \text{Benchmark Index}_0}{\text{Benchmark Index}_0} \tag{3}$$

In Table 1, we analyze abnormal returns constructed using the "market model" approach from the finance literature.

indices. The bulk of the price changes over this time period ranged from -5 to 5%.

Table 1's Panel A presents an analysis of Myriad's abnormal returns over a set of shorter windows surrounding the Supreme Court's decision. These include the day of the event (from closing the day before to closing the day of), the four day period starting at close before the event, and the four day period that commences at close three days before the event. Cumulative abnormal returns are calculated using the standard "market model" and are again presented relative to each of the four comparison indices described above. Below each estimate of the relevant abnormal return, we present t-statistics implied by standard errors that characterize variation in Myriad's abnormal returns over a period of relative legal calm. Across the presented permutations of event windows and benchmark indices, our estimates of Myriad's abnormal returns range between -19% and -27%. The estimates are statistically distinguishable from 0 at conventional significance levels in all cases.

Figure 1 reveals that Myriad's market capitalization recovered during early 2014. It is difficult to link these gains directly to any one event. One point of interest is that, in spite of the Supreme Court's decision, Myriad temporarily maintained its standing as the exclusive provider of BRAC*Analysis*. The market's reaction to the Supreme Court's decision appears to have overstated its implications for Myriad's legal position to enforce this exclusivity. Competitor Ambry Genetics, for example, found itself opposed by a plaintiff's coalition including Myriad and Toronto's SickKids Hospital, which receives royalties linked to Myriad's patents (Crowe, 2013). A flurry of further legal action ensued, with Myriad filing suit against no fewer than seven potential competitors. No fewer than three competitors similarly filed suit against Myriad. Appendix I details these and other events following the Supreme Court's decision.[5]

[5]Beyond cataloguing court cases, the appendix details events related to Myriad's strong early-2014 performance, which was buoyed in part by favorable news involving research on new prospective product

III.e Event 2: The Effect of an Unanticipated Reimbursement Shock on Myriad's Stock Price

Figure 1 shows that Myriad experienced a large, positive abnormal return following the announcement of Medicare's increase in the reimbursements for Myriad's tests. Mirroring Figure 2, Figure 3 shows the size of Myriad's gain relative to the changes in the price of each stock in the benchmark indices. In this case, the changes are calculated from April 1st through April 7th of 2014. It is again apparent that Myriad's experience falls outside the experience of the vast majority of stocks in the benchmark indices over the relevant period.

Table 1's Panel B presents an analysis of Myriad's abnormal returns over a set of shorter windows surrounding CMS's reimbursement rate re-determination. As in Panel A, these include the day of the event (from closing the day before to closing the day of), the four day period starting at close before the event, and the four day period that commences at close three days before the event. Across the presented permutations of event windows and benchmark indices, our estimate of Myriad's abnormal returns range between 13% and 20%. The estimates are statistically distinguishable from 0 at conventional significance levels in all cases, though not to the same degree as in the analysis of the Supreme Court's invalidation of Myriad's patents.

III.f Implications of the Magnitudes of Myriad's Changes in Market Capitalization

We conclude this section by considering the economic magnitudes of the observed changes in Myriad's market capitalization. Both the Supreme Court decision and the reimbursement re-determination altered Myriad's market capitalization by around $500 million.[6]

lines.

[6] Although the latter event involved a smaller change in percent terms, Myriad's early-2014 performance was sufficiently positive that its baseline market capitalization was higher.

The precise nature of the information transmitted by these decisions is, of course, difficult to determine. It is unclear, for example, with what probability investors expected the Supreme Court's decision to go against Myriad, and to go against it to the degree that it did. Consequently, $500 million is a lower bound on investors' initial assessments of the decision's full economic impact.

We now turn to Medicare's reimbursement re-determination. In the fiscal year ending June 30th, 2014, Myriad generated $520 million in revenue from its BRAC*Analysis* product line. Were these services reimbursed at $1,438 rather than $2,184, the resulting revenue would have been $340 million. The differential, assuming application of Medicare's rate for all services, thus amounts to $180 million per year. The increase in Myriad's market capitalization is nearly three times this amount.

Medicare accounts for a modest share of Myriad's BRAC*Analysis* revenues. Over the period in question, analysts put Medicare's share at 10 percent (Britt, 2013). The direct effect of Medicare's reimbursement rate increase would thus have improved Myriad's net income by only $18 million per year. The change in Myriad's market capitalization thus amounts to nearly 30 years of the implied change in Myriad's Medicare revenue. This far exceeds the remaining life of any of the relevant patents.

Rationalizing the change in Myriad's market capitalization requires effects beyond Medicare itself. Market analysts anticipated such changes, noting that "While Medicare represents only 10 percent of [Myriad's] sales, one would expect commercial plans to follow suit" (Britt, 2013). While the magnitude of Medicare's influence on private insurers' payment rates need not necessarily be large, recent work has found it to be substantial (Clemens and Gottlieb, 2013). In the present case, private payment spillovers appear to have significantly amplified the effects of Medicare's payment change. Such spillovers can thus augment the risks inherent in public insurers' reimbursement policies.

IV Discussion and Conclusion

Past theoretical research has shown how uncertainty about the broader environment in which firms operate can affect their behavior (Rodrik, 1991; Hassett and Metcalf, 1999). In this paper, we provide evidence on the relevance of policy risks for this kind of decision-making. There are theoretical grounds for expecting these micro factors to have aggregate implications (Friedman, 1968; Bernanke, 1983), and recent empirical evidence appears to support these theories' relevance (Bloom, 2009; Shoag and Veuger, 2015).

Myriad's exposure to the policy risks we analyze has implications, for example, for the organization of medical innovation across firms. For both of the events we analyze, Myriad could have smoothed out the associated risks by expanding its scope to diversify across product lines. Indeed, "Diversifying Our Portfolio" made column 1 of the "Dear Shareholders" letter in Myriad's 2014 Annual Report (Myriad Genetics, Inc., 2014). Such diversification would benefit Myriad's stakeholders if they are unable to fully insure against the costs of internal financial distress.

Because the institutional uncertainties we analyze are primarily downside risks, they depress expected returns and may thus reduce aggregate levels of technology development (Scherer, 2001; Grabowski, 2004; Cockburn and Stern, 2010). On the other hand, there is evidence that privately held intellectual property sometimes reduces innovation by other parties (e.g., Williams, 2013). These competing forces imply that increasing the strength of intellectual property rights may either increase or decrease innovative activity. Whether one thinks medical innovation is sub-optimally slow (Murphy and Topel, 2003), or worries about its costs (Weisbrod, 1991), its responsiveness to incentives highlights the surrounding policy environment's importance.

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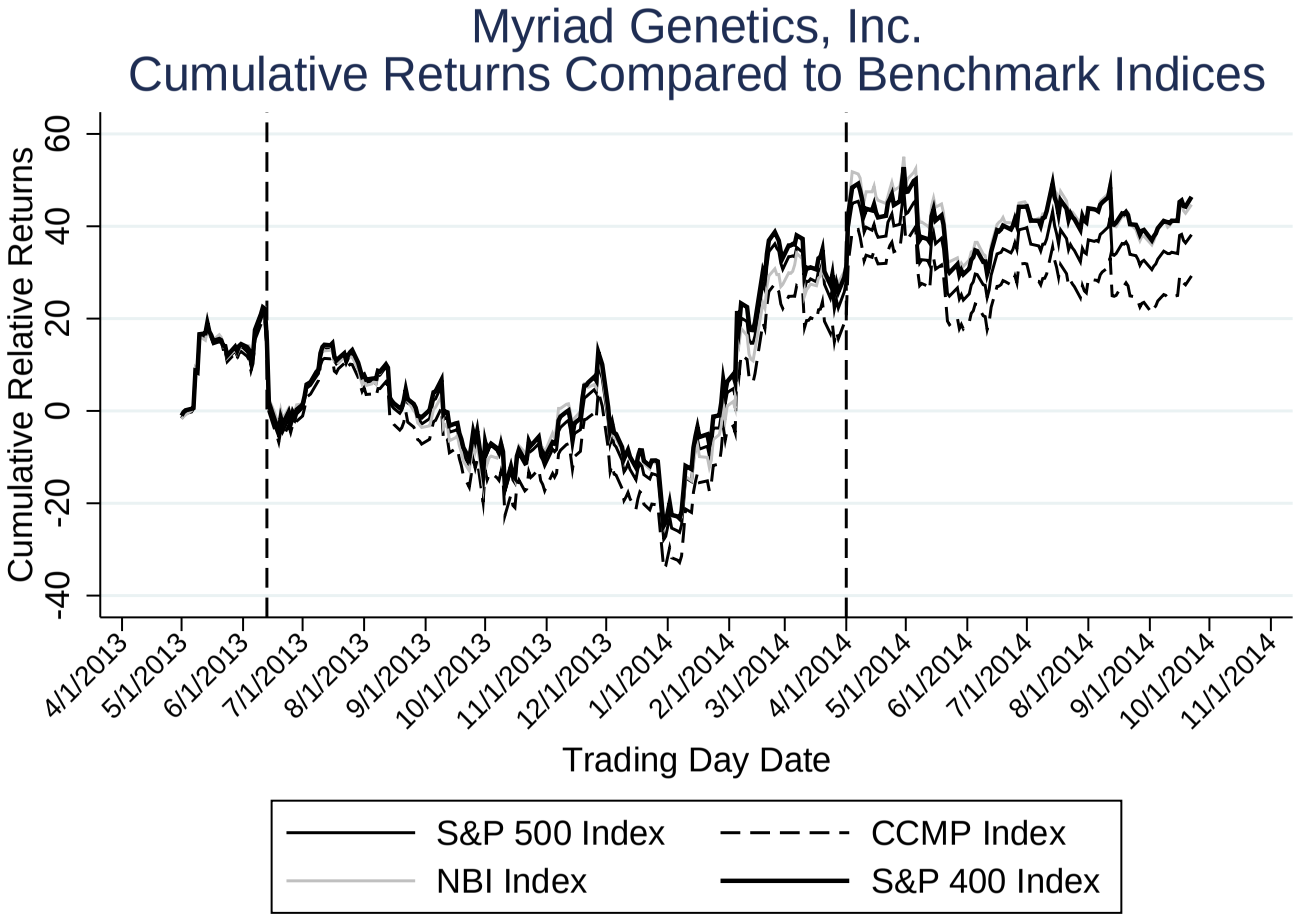

Figure 1. **Myriad Genetics, Inc., Cumulative Returns Relative to Benchmark Indicies**

This figure shows the cumulative relative returns to Myriad Genetics common stock for the period from April 2013 till November 2014, compared to the S&P 500 Index, the NBI Index, the CCMP Index, and the S%P 400 Index. The dashed vertical lines indicate the two events on which our empirical analysis focuses: the Supreme Court's decision in Association for Molecular Pathology v. Myriad Genetics, Inc., and Medicare's reimbursement re-determination decision. Data are from Bloomberg.

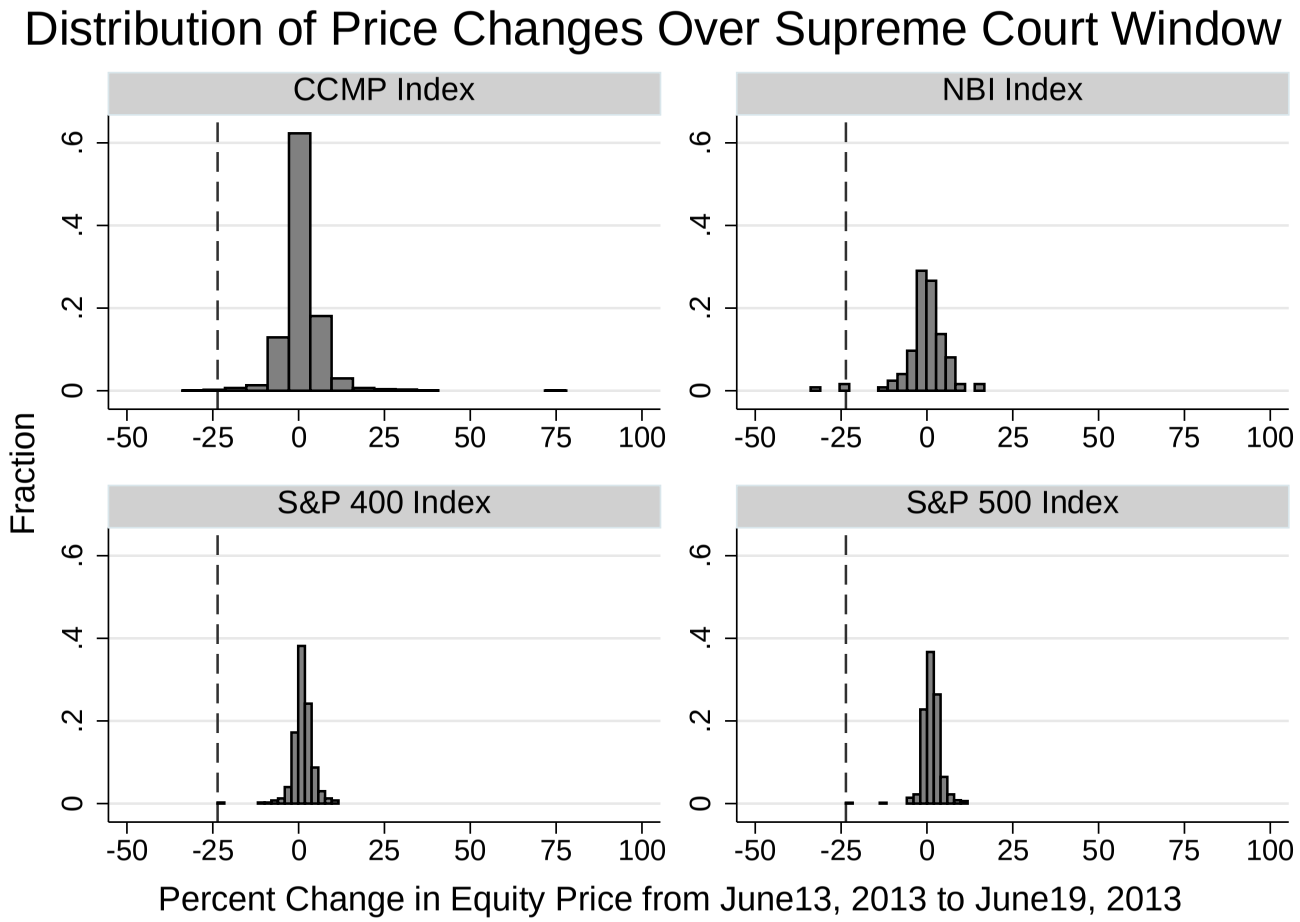

Figure 2. **Distribution of Price Changes over Supreme Court Window**

These histograms present the price change for each stock in four benchmark indices (the S&P 500 Index, the NBI Index, the CCMP Index, and the S&P 400 Index) from June 13th to June 19th, 2013. The interval thus covers the week following the Supreme Court's decision in Association for Molecular Pathology v. Myriad Genetics, Inc. The change in Myriad's stock price is represented in each panel by a dashed vertical line. Data are from Bloomberg.

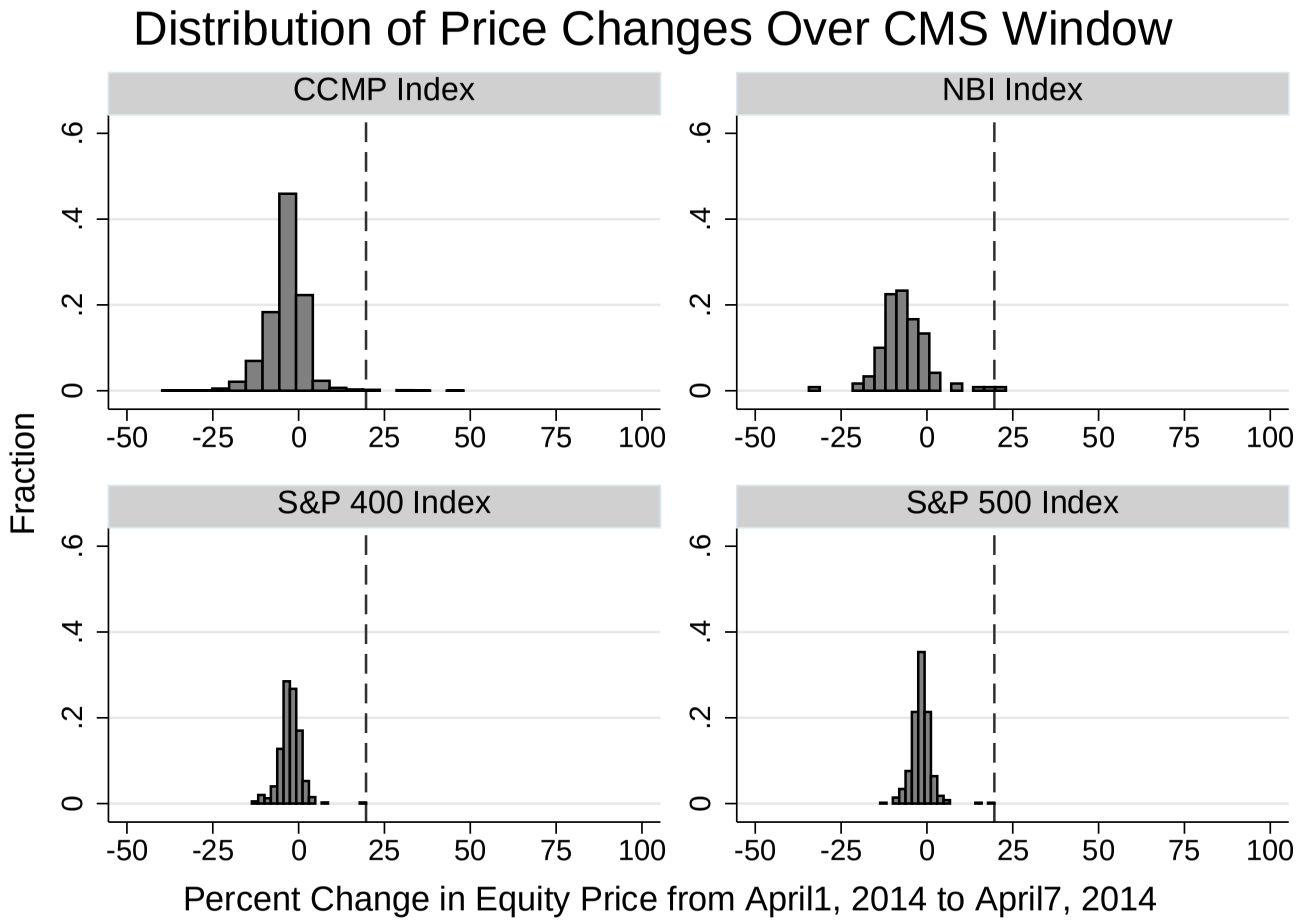

Figure 3. **Distribution of Price Changes over Medicare Reassessment Windows**
These histograms present the price change for each stock in four benchmark indices (the S&P 500 Index, the NBI Index, the CCMP Index, and the S&P 400 Index) from April 1st to April 7th, 2014. The interval thus covers the week following Medicare's reimbursement re-determination decision. The change in Myriad's stock price is represented in each panel by a dashed vertical line. Data are from Bloomberg.

Table 1. **Supreme Court and CMS Event-Study Analyses**

	Event Period		
	1	2	3
	0 to 1	0 to 4	-2 to +2
Panel A: Supreme Court Decision			
S&P 500 Index	-20.00	-26.35	-23.04
	(-4.58)	(-3.82)	(-3.34)
CCMP Index	-19.85	26.50	22.88
	(-4.59)	(-3.87)	(-3.34)
NBI Index	-19.69	-24.96	-21.63
	(-4.83)	(-3.88)	(-3.36)
S&P 400 Index	-20.27	-26.44	-22.96
	(-4.71)	(-3.89)	(-3.38)
Panel B: CMS Pricing Decision			
S&P 500 Index	13.63	18.50	18.04
	(2.77)	(2.38)	(2.32)
CCMP Index	13.48	18.78	18.29
	(2.77)	(2.44)	(2.38)
NBI Index	13.38	19.48	19.21
	(2.93)	(2.70)	(2.66)
S&P 400 Index	13.74	18.38	18.21
	(2.81)	(2.38)	(2.36)

Note: Cumulative abnormal returns are calculated using the standard "market model"; normal returns, R_{it}, are calculated by estimating $R_{it} = \alpha_i + \beta_i R_{mt} + \varepsilon_{it}$, under the assumption that $E[\varepsilon_{it}] = 0$ and $Var[\varepsilon_{it}] = \sigma^2_{\varepsilon i}$, where R_{mt} is the return of a given market index. The abnormal return, AR_{it}, is then computed as the difference between the actual return, A_{it}, and the normal return predicted by the model: $AR_{it} = A_{it} - (\alpha_i + \beta_i R_{mt})$. The sum of these abnormal returns over select trading days is then the cumulative abnormal return. Abnormal returns are given relative to four benchmark indices (the S&P 500 Index, the NBI Index, the CCMP Index, and the S&P 400 Index). The estimation window runs from 150 to 30 trading days before the event. T-statistics appear in parentheses beneath each point estimate. The Data is from Bloomberg.

A Appendix

This appendix provides further information regarding important legal and business events in the recent history of Myriad Genetics, Inc. The event listings serve two purposes. First, they further flesh out the context within which our asset market analyses take place. Second, in some instances they characterize Myriad's responses to the business and legal environment it faced.

I.a Supreme Court Time Line

The list below summarizes major events in the case *Association for Molecular Pathology v. Myriad Genetics, Inc.*. The content is marginally adapted from the timeline provided by the American Civil Liberties Union (ACLU) at https://www.aclu.org/timelines/association-molecular-pathology-v-myriad-genetics-timeline-events:

- March 29, 2010: NY Federal Court Rules BRCA1 and BRCA2 gene patents invalid
- July 29, 2011: Federal Appeals court ruled that companies can obtain patents on genes
- March 26, 2012: The Supreme Court vacates the decision of the appeals court
- August 16, 2012: Federal Appeals court reaffirms its prior ruling
- September 25, 2012: The plaintiffs petition the Supreme Court
- November 30, 2012: The Supreme Court grants a writ of certiori
- April 15, 2013: The Supreme Court hears oral arguments
- June 13, 2013: The Supreme Court unanimously invalidates gene patents

I.b Post Supreme Court Competitor Entry

Following the Supreme Court's decision, several competitors immediately entered the markets in which Myriad had previously enjoyed exclusivity. Additional competitors entered at later dates. Cost information provided by the earliest entrants would have contributed to CMS's subsequent reimbursement decisions. The number of potential entrants illustrates the high relevance of intellectual property protections for the revenue streams of medical technology innovators.

- Ambry Genetics Corporation on June 13, 2013
- GeneDx, Inc., on June 13, 2013
- DNA Traits on June 13, 2013
- Quest Diagnostics Incorporated and Quest Diagnostics Nichols Institute on October 15, 2013
- Invitae Corporation on December 11, 2013
- Laboratory Corporation of America Holdings on Dec 2, 2013
- Counsyl, Inc., on May 9, 2014
- Pathway Genomics Corporation on June 3, 2014

I.c Post Supreme Court Legal Action

Following the Supreme Court's decision, a series of further legal actions were taken by both Myriad and its competitors (Myriad Genetics, Inc., 2014). These legal actions support two conclusions regarding the intellectual property uncertainties associated with new

medical technologies. First, they illustrate that intellectual property uncertainties are not easily resolved. Following the Supreme Court's decision, further legal determinations were needed to flesh out what the Supreme Court's decision would mean in practice. In matters involving new technologies, it may be too much to expect legal rulings to provide sufficient specificity and be sufficiently broadly applicable to fully resolve either the matter at hand or a broader class of issues. Second, the actions taken by Myriad provide a window into Myriad's business strategy following the Supreme Court's ruling. To initial analysts' surprise, Myriad determined that it had sufficient legal grounds to continue enforcing intellectual property claims associated with BRCA1 and BRCA2. The limits of its enforceable intellectual property claims would not be settled for another year.

Suits filed by Myriad:

- Ambry Genetics Corporation on July 9, 2013
- GeneDx, Inc., on October 16, 2013
- Quest Diagnostics Incorporated and Quest Diagnostics Nichols Institute on October 22, 2013
- Invitae Corporation on November 25, 2013
- Laboratory Corporation of America Holdings on December 3, 2013
- Counsyl, Inc., on June 13, 2014
- Pathway Genomics Corporation on June 16, 2014

Suits filed against Myriad:

- Counsyl, Inc., on September 30, 2013

- Invitae, Inc., on November 26, 2013
- Quest on October 10, 2013

I.d Major Business Events in Myriad's Recent History

Below are brief descriptions of several major business events in Myriad's recent history. Notably, it has engaged in significant merger-and-acquisition activity, as reported in its annual report (Myriad Genetics, Inc., 2014). It has also forwarded product lines distinct from BRAC*Analysis*. We take both sets of activities to be illustrative of Myriad's effort to diversify and reduce its exposure to fluctuations in the revenues generated by BRAC*Analysis*.

- February 2014: Acquisition of Crescendo Bioscience for $270 million.
- May 2011: Purchase of Rules-Based Medicine, Inc. for $80 million cash.

Below are additional events relevant for understanding developments in Myriad's market capitalization over the period we study. One of the most prominent features of Figure 1 is the steady, significant rise in Myriad's market capitalization during January and February of 2014. The events below underlie at least a portion of this rise.

- January 28, 2014: Myriad publishes positive data regarding a new product line (myVision).
- February 4, 2014: Myriad's second quarter earnings report significantly exceeds expectations.
- February 7, 2014: Myriad and Gene-by-Gene settle their lawsuit.