Essays on the effects of intellectual property rights on economic growth and production fragmentation, and the effects of unions on workplace safety

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Dedication

To my parents for their endless love, patience, and encouragement

Abstract

The first essay entitled "What are the Effects of Intellectual Property Rights on Economic Growth? Empirical Analysis of East Asia, TRIPs and Development" estimates the effects of IPRs on economic growth in country level in four ways. First, I consider the growth effects of IPRs across all countries. Second, I consider whether the growth effects of IPRs are different for East Asia than for the rest of the world. Third, I consider whether the 1995 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) altered the growth effects of IPRs. Fourth, I assess whether there is a tipping point in the relationship between IPRs and growth that is related to the development level of countries. I find that there is a (net) positive relationship between IPRs and economic growth across the countries of the world while the effect is ambiguous in East Asia. Also, the findings show evidence that growth in the post-TRIPs period deviates from that of the entire period in a positive way; yet these positive effects are more modest for East Asia. Finally I find there is a break point that alters the effects of IPRs before and after the TRIPs.

The second essay, "Effects of Strengthening Intellectual Property Rights on Global Value Chain", studies the effects of IPRs on exports especially, exports embodying exchange of intermediate inputs. First I consider how stronger IPRs affect exports in sectoral level in generalized factor-proportions framework. To consider an exchange of intermediate inputs, I construct a measure of value added contents of exports and gross exports using global input-output data from World Input-Output Database (WIOD). Second, I investigate how IPRs affect production fragmentation estimated as VAX ratio which represents production fragmentation. I employ the empirical approach in which exports at the industry level are explained as a function of country factor endowment and interactions with industry factor intensities. The evidence shows that a high level of patent protection

is associated with high value added exports and gross exports in patent-intensive industries. Second, I find that higher patent protection leads less international fragmentation in patent-intensive industries.

In the third essay entitled "Effects of Unionization on Workplace-Safety Enforcement: Regression-Discontinuity Evidence", I study how union certification affects the enforcement of workplace-safety laws. To generate credible causal estimates of certification effects, I employ regression discontinuity. I compare changes in outcomes in establishments where unions barely won representation elections to changes in outcomes in establishments where union barely lost such elections. The study combines two main datasets: the census of National Labor Relations Board (NLRB) representation elections and the Occupational Safety and Health Administrations (OSHA) enforcement database since 1985. From the results, I find evidence of positive effects of union certification on establishments rate of OSHA inspection, the share of inspections carried out in the presence of a labor representative, violations cited, and penalties assessed.

Contents

List of Tables

List of Figures

Chapter 1

Introduction

This dissertation consists of three chapters. The first two chapters examine the impact of strengthening intellectual property rights (IPRs) on economic growth and exports. The thirds chapter addresses labor unions and their effect on workplace safety.

IPRs are laws that provide protections for creations of the mind. Since 1990 there have been major reforms in patent laws throughout the world. However, there always have been debates on effects of IPRs on economic growth and exports due to their conflicting effects. First, IPRs reduce the risk that protected technologies will be imitated and thus ensure a return to investors on their R&D. As a consequence, IPRs are believed to affect economic growth positively by creating an incentive for innovation and by increasing transfers of intellectual property across countries via trade, foreign direct investment (FDI) and licensing arrangements. At the same time, strong IPRs are believed to increase the cost of innovation by increasing the price of technological inputs used in innovation. This later effect occurs because IPRs provide the owner of the rights with a monopoly on their protected technologies. This effect can result in monopoly pricing of technological inputs which reduces access to these inputs, and can negatively affect economic growth. Thus, the net direction of the relationship between IPRs and economic growth depends on whether the negative effects outweigh the positive effects.

The first essay co-authored with Pamela Smith estimates the effects of IPRs on economic growth in country level in four ways. First, I consider the growth effects of IPRs across all countries. Second, I consider whether the growth effects of IPRs are different for East Asia than for the rest of the world. Third, I consider whether the 1995 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) altered the growth effects of IPRs. Fourth, I assess whether there is a tipping point in the relationship between IPRs and growth that is related to the development level of countries.

The second essay studies the effects of IPRs on exports especially, exports embodying exchange of intermediate inputs. First I consider how stronger IPRs affect exports in sectoral level in generalized factor-proportions framework. To consider an exchange of intermediate inputs, I construct a measure of value added contents of exports and gross exports using global input-output data from World Input-Output Database (WIOD). Second, I investigate how IPRs affect production fragmentation estimated by VAX ratio which represents production fragmentation. I employ the empirical approach in which exports at the industry level are explained as a function of country factor endowment and interactions with industry factor intensities.

The third essay deals with different topic. Since 1970, the federal Occupational Safety and Health Act has defined federally-protected rights for American, private-sector workers to safe and healthy workplaces. The Occupational Health and Safety Administration (OSHA) works to uphold these rights through enforcement and education using its own agency resources directly and by leveraging partnerships with other organizations including state governments, research institutes, employers, and labor unions. Under the Act, workplaces must meet specific standards and employees have rights to initiate OSHA inspections. Union activities may serve as a complement to OSHAs direct expenditures and enforcement efforts. If unions are effective, declining unionization in the private-sector workforce can make the Department of Labor's (DOL) job more difficult. Labor unions tend to share the DOL's interests in ensuring safe and healthy workplaces. In the third essay, coauthored with Aaron Sojourner, I study how union certification affects the enforcement of workplace-safety laws. To generate credible causal estimates of certification effects, I employ regression discontinuity. I compare changes in outcomes in establishments where unions barely won representation elections to changes in outcomes in establishments where union barely lost such elections. The study combines two main datasets: the census of National Labor Relations Board (NLRB) representation elections and the Occupational Safety and Health Administration's (OSHA) enforcement database since 1985.

This dissertation is organized as follows. Chapter 2 estimates the effect of IPRs on economic growth across world, East Asia, and also analyzes the effect of TRIPs. Chapter 3 studies how IPRs affect exports, especially on value added exports, gross exports, and VAX ratio. Chapter 4 presents the effect of labor union certification on workplace safety. Chapter 5 concludes.

Chapter 2

What are the Effects of Intellectual Property Rights on Economic Growth? Empirical Analysis of East Asia, TRIPs and Development

2.1 Introduction

This paper examines the effects of intellectual property rights (IPRs) on the economic growth of countries. We consider four related questions. First, do IPRs have a positive growth effect across countries globally? Second, are the growth effects of IPRs different for East Asia than for the rest of the world? Third, did the 1995 Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs) alter the growth effects of IPRs for the world and also for East Asia? Fourth, is there a tipping point in the relationship between IPRs and growth that is related to the development level of countries? [Antrás and Staiger, 2012]

The motivation and contributions of this paper follow the four themes identified in these questions. We summarize each theme below.

First, IPRs are laws that provide protections for creations of the mind.[1] IPRs reduce the risk that protected technologies will be imitated and thus ensure a return to investors on their R&D. As a consequence, IPRs are believed to affect economic growth positively by creating an incentive for innovation and by increasing transfers of intellectual property across countries via trade, foreign direct investment (FDI) and licensing arrangements. At the same time, strong IPRs are believed to increase the cost of innovation by increasing the price of technological inputs used in innovation. This later effect occurs because IPRs provide the owner of the rights with a monopoly on their protected technologies. This effect can result in monopoly pricing of technological inputs, which reduces access to these inputs, and can negatively affect economic growth. Thus, the net direction of the relationship between IPRs and economic growth depends on whether the negative effects outweigh the positive effects. The literature shows that the net effect of IPRs on growth is ambiguous because it depends on the relative importance of the channels that link intellectual property with growth.[2] Thus, our first goal is to empirically examine the direction of the (net) effects of IPRs across all countries of the world.

Second, the countries of East Asia provide a unique case for considering the relationship between IPRs and economic growth. East Asian countries have achieved

[1] Forms of IPRs include patents, copyrights, trademarks, service marks, plant breeders rights, and trade secrets.

[2] For studies of various channels that link intellectual property with growth, see [Aitken et al., 1997], [Aitken and Harrison, 1999], [Branstetter, 2001], [Carr et al., 2001], [Chin and Grossman, 1990], [Coe and Helpman, 1995], [Coe et al., 1997], [Cohen and Levinthal, 1989], [Deardorff, 1992], [Dinopoulos and Syropoulos, 2008], [Diwan and Rodrik, 1991], [Eaton and Kortum, 1999, Eaton and Kortum, 1996], [Edwards, 1998], [Glass and Saggi, 2002], [Gould and Gruben, 1996], [Grossman and Helpman, 1991, Grossman and Helpman, 1990], [Grossman and Lai, 2004], [Helpman, 1993], [Kanwar and Evenson, 2003], [Keller, 2004], [Kwan and Lai, 2003], [Lai, 1998], [Lai and Qiu, 2003], [Lerner, 2002], [Mansfield, 1986], [Maskus, 2004, Maskus, 2000], [Nelson and Phelps, 1966], [Rivera-Batiz and Romer, 1991], [Segerstrom, 1991], [Smith, 2014, Smith, 2001, Smith, 1999], [Taylor, 1994, Taylor, 1993], [Xu and Chiang, 2005], and [Yang and Maskus, 2001].

rapid economic growth, and inward FDI and trade have contributed to this growth. Concomitantly, East Asian countries have also benefited from imitating and replicating foreign innovations, and weak IPRs have made this behavior possible. What makes East Asian countries distinctive relative to other regions (such as Africa) is their strong capacity for imitation combined with weak institutions for protecting intellectual property. Prior to the 1995 TRIPs Agreement, the strength of IPRs in East Asia was particularly weak relative to the rest of the world. Thus, while the popular wisdom is that stronger IPRs stimulate economic growth, East Asias growth was initially strong in the presence of weak IPRs. The literature on the growth effects of IPRs in East Asia is scant despite the unique characteristics of this region.[3] Thus, our second goal is to determine whether the growth effects of IPRs are different for East Asia relative to the rest of the world.

Third, the 1995 TRIPs Agreement of the World Trade Organization (WTO) brought about a major change in the strength of IPRs globally, and for East Asia in particular where IPRs were initially relative weak. IPRs are national laws and their protections extend to the geographic boundaries of countries. To secure protection in other countries, innovators must file for protection in the other countries. Prior to 1995, national intellectual property laws varied considerably across countries in terms of the technologies covered, duration of protection, enforcement mechanisms, etc. TRIPs brought about a reduction in this variation by requiring minimum standards for protection among WTO members, and by providing a dispute settlement mechanism for adjudicating complaints. One of the arguments set forth by proponents of the agreement (e.g., industrialized countries) was that strengthening IPRs would have positive growth effects. However, developing countries raised concerns that the negative effects of adopting strong IPRs could outweigh the positive benefits. The literature on the role of the TRIPs

[3] For studies that link intellectual property with growth in Asia, see [Kim, 2002], [Kumar, 2003], [Maskus et al., 2005], [Maskus and McDaniel, 1999], [Nelson and Phelps, 1966] and [Bank, 1993].

agreement in effecting growth has been constrained by data limitations.[4] However, the commonly used IPR measure (developed by Walter Park) is now updated to 2010 making it feasible to empirically examine the 15 years following the agreement. Thus, our third goal is to determine whether the TRIPs agreement altered the growth effects of IPRs.

Fourth, the incentives for adopting strong IPRs vary considerably across countries at different levels of development. Countries that are the source of intellectual property (e.g., industrialized countries) prefer that recipient countries (e.g., developing countries) have strong IPRs, either to reduce risk of imitation or to allow for monopoly behavior in the recipient countries markets. In contrast, recipients of intellectual property (e.g., developing countries) have mixed incentives. Developing countries prefer to adopt relatively weak IPRs to allow for domestic imitation and to improve access to technological inputs at more competitive prices. However, developing countries also want to create an incentive for inward technology transfers via trade, FDI and licensing arrangements; and also for domestic innovation, which can be stimulated by stronger IPRs. These mixed incentives explain why developing countries have resisted adopting stronger IPRs, despite the pressures of industrialized countries. Developing countries argue that the negative effects of adopting stronger IPRs exceed the positive effects for their economies. The existing literature suggests that the relationship between IPRs and economic growth may depend on the *level of development of countries*.[5] Indeed, there is some empirical evidence suggesting that less developed countries benefit from relatively weak IPRs, while industrialized countries benefit from relatively strong IPRs. This is consistent with the intuition that weak domestic IPRs stimulate economic growth primarily via imitation (and lower priced technology inputs) for less developed countries, while strong domestic IPRs stimulate economic growth

[4] For studies related to TRIPs, see [Co, 2004], [McCalman, 2005, McCalman, 2002, McCalman, 2001], [Taylor, 1994, Taylor, 1993].

[5] For studies of IPRs in developing countries, see [Cepeda et al., 2010], [Chen and Puttitanun, 2005], [Eicher and Garca-Pealosa, 2008], [Kim et al., 2012], [Primo Braga et al., 2000], [Rapp and Rozek, 1990], [Rodríguez-Clare, 1996], [Schneider, 2005] and [Smarzynska, 2004].

primarily via innovation (and stronger monopoly power over technology inputs) for more highly developed countries. Our fourth goal is to determine whether there is a development threshold that alters the growth effects of IPRs. If so, this would help explain national policy decisions to support stronger IPRs at higher levels of development.

In summary, this paper empirically examines the relationship between IPRs and economic growth with a focus on features that may alter this relationship *across regions* (Asia relative to the world), *across time* (pre and post-TRIPs), and *across the development levels* of countries. Our theoretical framework is a growth model that distinguishes capital as physical capital, human capital, and intellectual property. The empirical method includes estimating growth specifications using panel data for 115 countries over the period 1980 to 2010. We use a variety of econometric techniques including fixed effects and threshold regression methods. The findings show that there is a positive relationship between IPRs and economic growth across the countries of the world, and these positive growth effects are stronger following the 1995 TRIPs agreement. The findings also show that there is an ambiguous relationship between IPRs and economic growth across the countries of East Asia. However, there is a threshold level of development that once exceeded turns on the positive growth effects of IPRs in East Asia during the post-TRIPs period.

The remainder of the paper is organized as follows. Section 2 provides a discussion of the theoretical foundations and empirical specifications. Section 3 describes the data and method. Section 4 reports the results. Section 5 provides concluding remarks.

2.2 Model and Specification

The theoretical framework comes from the economic growth literature. Seminal research by [Barro, 1991], [Romer, 1990], [Mankiw et al., 1992] and others provides the grounding for a rich body of research on economic growth over the past two decades.[6] One of the distinguishing features of the theoretical literature is that is explores the characteristics of knowledge inputs, and distinguishes the rival and non-rival components. This approach can be applied to explore the effects of IPRs since such rights are designed to convert what would otherwise be rival knowledge into non-rival knowledge.

The empirical research that has evolved from the theoretical literature typically begins with a common growth equation, and then extends and adapts the equation to explore alternative hypotheses. A familiar expression of the growth equation used in cross-countries studies is:

$$\ln(Y_{i,t+1}) - \ln(Y_{it}) = \beta \ln(Y_{it}) + X_{it}\delta + \rho_i + \varphi_t + \varepsilon_{i,t} \tag{2.1}$$

where $Y_{i,t+1}$ is GDP per capita of country i in period $t+1$, Y_{it} is GDP per capita of country i in period t, X_{it} is a vector of determinants of growth, ρ_i is country-specific effects, φ_t is period-specific effects, and ε_{it} is a randomly distributed error term for country i in period t. Equation (2.1) says that growth in GDP per capita is a function of the initial level of GDP per capita at the beginning of the period, determinants of growth that vary across countries and time, country-specific characteristics and period-specific characteristics.

Empirical cross-country studies have defined the vector of determinants of economic growth (X_{it}) is a variety of ways.[7] We begin with a familiar baseline specification which we then extend to examine the role of IPRs. Our baseline specification is:

$$\Delta Y_{it} = \beta_0 + \beta_1 Y_{i0} + \beta_2 \Delta K_{it} + \beta_3 \Delta L_{it} + \beta_4 \Delta H_{it} + \beta_5 O_{it} + \beta_6 \pi_{it} + \rho_i + \varphi_t + \varepsilon_{it} \tag{2.2}$$

where ΔY_{it} is growth in GDP per capita (i.e., $\Delta Y_{it} = \ln(Y_{i,t+1}) - \ln(Y_{it})$); Y_{i0} is initial GDP per capita (i.e., $Y_{i0} = \ln(Y_{it})$); ΔK_{it} is growth in physical capital;

[6] For other foundational growth studies, see [Aghion and Howitt, 1992], [Backus et al., 1992], [Barro and Sala-i Martin, 1995], [Bosworth and Collins, 2003], [De Long, 1988], [Frankel and Romer, 1999], [Jones, 1995], and [Lee et al., 2004].

[7] For examples, see [Caselli et al., 1996], [Falvey et al., 2006], [Park and Ginarte, 1997] and [Kim et al., 2012].

ΔL_{it} is growth in labor; ΔH_{it} is growth in human capital; O_{it} is openness to trade; π_{it} is inflation (or economic stability); ρ_i and φ_t are country-specific and time-specific effects, respectively; and ε_{it} is a randomly distributed error term. In equation (2.2), i indexes the country and t indexes the growth period.

Equation (2.2) say that the economic growth of a country is a function of their GDP per capita at the beginning of the period; growth in physical capital, labor, and human capital over the period; trade openness and inflation (or economic instability); and country and time fixed effects.

Table 2.1 summarizes the expected parameter signs of equation (2.2), as well as those for the extensions (described below). We expect the signs on the parameters to conform with the underlying theory. Specifically, we expect the parameter on initial GDP per capita to be negative indicating that countries with relatively high initial values are closer to their steady states and thus have lower growth. We expect the parameters on growth in physical capital, labor, and human capital to be positive or negative depending on the contribution of these core inputs. We expect the parameter on trade openness to be positive suggesting that trade contributes to growth. And, we expect the parameter on inflation to be negative suggesting that economic instability adversely affects growth.

We extend this baseline in several ways to examine the role of IPRs. First, we distinguish capital to include physical capital and human capital (as above) as well as intellectual property. As noted earlier, IPRs convert what would otherwise be rival knowledge into non-rival knowledge (or excludable intellectual property). Also, the relationship between IPRs and economic growth may be non-linear. Thus, we extend equation (2.2) in two ways:

$$\Delta Y_{it} = \beta_0 + \beta_1 Y_{i0} + \beta_2 \Delta K_{it} + \beta_3 \Delta L_{it} + \beta_4 \Delta H_{it} + \beta_5 O_{it} + \beta_6 \pi_{it} + \beta_7 I_{it} + \rho_i + \varphi_t + \varepsilon_{it} \tag{2.3}$$

$$\Delta Y_{it} = \beta_0+\beta_1 Y_{i0}+\beta_2\Delta K_{it}+\beta_3\Delta L_{it}+\beta_4\Delta H_{it}+\beta_5 O_{it}+\beta_6\pi_{it}+\beta_7 I_{it}+\beta_8 I_{it}^2+\rho_i+\varphi_t+\varepsilon_{it} \tag{2.4}$$

where I_{it} is the IPRs of country i and I_{it}^2 is the square of this same term. We expect the parameter on IPRs to take a positive or negative sign depending on whether stronger IPRs contribute positively or negatively (in net) to economic growth. We expect the parameter on the squared term to take a positive signs if the rate of change in the effects of IPRs on growth is increasing and negative if it is decreasing.

Second, we extend equation (2.3) to consider whether the effects of IPRs are different for East Asia relative to the rest of the world. We add an interaction term as follows:

$$\begin{aligned}\Delta Y_{it} =&\beta_0 + \beta_1 Y_{i0} + \beta_2\Delta K_{it} + \beta_3\Delta L_{it} + \beta_4\Delta H_{it} + \beta_5 O_{it}+\\ &\beta_6\pi_{it} + \beta_7 I_{it} + \beta_8 I_{it} * DUMA_{it} + \rho_i + \varphi_t + \varepsilon_{it}\end{aligned} \tag{2.5}$$

where $I_{it} * DUMA_{i,t}$ is the interaction of IPRs and a dummy variable for East Asian countries. We expect the parameter on this term to be negative if weaker IPRs contribute positively to economic growth in East Asia (relative to the world). This would be consistent with the popular wisdom that East Asian countries have benefited from the ability to imitate non-rival knowledge given their relatively weak IPRs regimes.

Finally, we extend equation (2.3) to consider the effects of the TRIPs agreement for the global economy and for East Asia relative to the global economy. The specifications are:

$$\begin{aligned}\Delta Y_{it} =&\beta_0 + \beta_1 Y_{i0} + \beta_2\Delta K_{it} + \beta_3\Delta L_{it} + \beta_4\Delta H_{it} + \beta_5 O_{it}+\\ &\beta_6\pi_{it} + \beta_7 I_{it} + \beta_8 I_{it} DUMT_{it} + \rho_i + \varphi_t + \varepsilon_{it}\end{aligned} \tag{2.6}$$

$$\begin{aligned}\Delta Y_{it} =&\beta_0 + \beta_1 Y_{i0} + \beta_2\Delta K_{it} + \beta_3\Delta L_{it} + \beta_4\Delta H_{it} + \beta_5 O_{it}+\\ &\beta_6\pi_{it} + \beta_7 I_{it} + \beta_8 I_{it} DUMT_{it} * DUMA_{it} + \rho_i + \varphi_t + \varepsilon_{it}\end{aligned} \tag{2.7}$$

where $DUMT_{it}$ is a dummy variable for the period following the TRIPs agreement and $DUMT_{i,} * DUMA_{it}$ is the interaction of the dummy variables for TRIPs and East Asia. We expect the parameter on the TRIPs dummy to be significant if the growth effects of IPRs deviate during the post-TRIPs period relative to the entire period. A positive parameter would be consistent with the arguments set forth by proponents of strengthening IPRs and a negative parameter would be consistent with the arguments of adversaries to TRIPs. Finally, we expect the parameter on the interaction of the TRIPs and East Asia dummies to be significant if the growth effects of IPRs post-TRIPs are different for East Asia than for the global economy.

2.3 Method and Data

2.3.1 Method

Our first method involves estimating equations (2.2) to (2.7) using fixed effects and random effects regression techniques. We adopt these approaches to account for the country and time-specific effects. In this paper, we report the fixed effects results only, as the null hypothesis that the effects are random is rejected (using the Hausman test).

We also address two related econometric issues. The first issue is that we find evidence of heteroskedasity using Whites test. Thus, we apply standard methods to generate heteroskedasticity-corrected standard errors. The second issue is that IPRs could be endogenous with respect to contemporaneous economic growth. We address this possibility by using the common approach of lagging the measure of IPRs. The intuition for lagging is that current growth does not determine past IPRs policy choices.

Our second method involves estimating a variant of equation (2.3) using a *threshold regression technique* (see [Chan, 1993] and [Hansen, 2000, Hansen, 1999]). This technique allows us to determine whether there is a tipping point in economic growth that is related to the development level of countries. Specifically, we assess whether there is a development level that turns on or alters the growth effects of IPRs. The threshold regression technique allows us to endogenously determine the threshold and test for its significance.

The following equations describe the threshold approach:[8]

$$y_i = \theta_1^{'} x_i + e_i, \qquad q_i \leq \gamma \tag{2.8}$$

$$y_i = \theta_2^{'} x_i + e_i, \qquad q_i > \gamma \tag{2.9}$$

where y_i is economic growth, q_i is the threshold variable which is used to split the sample of countries into two groups, x_i includes control variables, γ is the threshold level, e_i is a regression error; and i indexes the country. In our application, the threshold variable is the development level of countries and the control variable is their IPRs. These two equations allow the parameters on the control variable (IPRs) to differ above and below the threshold (development level). The idea is that for development levels above and below the threshold, the relationship between IPRs and growth is different.

To implement the threshold approach, we combine equations (2.8) and (2.9) as suggested by [Hansen, 2000]. This gives the single equation:

$$y_i = \theta^{'} x_i + \delta_n^{'} x_i(\gamma) + e_i \tag{2.10}$$

where $\theta = \theta_2$ and $\delta = \theta_1 - \theta_2$, and $x_i(\gamma) = x_i d_i(\gamma)$. The term $d_i(\gamma) = \{q_i \leq \gamma\}$ where $\{\cdot\}$ is the indicator function. In our application, the term $d_i(\gamma)$ is a dummy variable that depends on whether the development level of the given country is above or below the threshold.

Using this equation, it is possible to generate an endogenously determined threshold (development level) and then to test for the statistical significance of

[8] For applications of the threshold regression method in growth studies, see [Falvey et al., 2006], [Mohtadi and Ruediger, 2014], and [Thompson and Rushing, 1996, Thompson and Rushing, 1999].

the threshold. The threshold in equation (2.10) is the value of that minimizes the sum of squared errors. To show this, we rewrite equation (2.10) in matrix notation as

$$Y = X\theta + X_{\gamma}\delta + e \tag{2.11}$$

where all terms are as defined above. The sum of squared errors can then be written as:

$$S_n(\theta.\delta, \gamma) = (Y - X\theta - X_{\gamma}\delta)'(Y - X\theta - X_{\gamma}\delta) \tag{2.12}$$

The least squares estimators $\hat{\theta}, \hat{\delta}, \hat{\gamma}$ jointly minimize the standard error function shown in equation (2.12). The sum of square errors function conditional on the threshold (γ) is

$$S_n(\gamma) = S_n(\hat{\theta}(\gamma), \hat{\delta}(\gamma), \gamma) = Y'Y - Y'X_{\gamma}^{*}(X_{\gamma}^{*\prime}X_{\gamma}^{*})^{-1}X_{\gamma}^{*\prime}Y \tag{2.13}$$

where $\hat{\gamma}$ is the value that minimizes $S_n(\gamma)$, or

$$\hat{\gamma} = \operatorname*{argmin}_{\gamma \in r_n} S_{\gamma} \tag{2.14}$$

where $r_n = r \cap \{q_1, \ldots\ldots q_n\}$, which requires less than n function evaluations.

Using the approach, the slope estimates of equation (2.11) can be computed as a function of the endogenously determined threshold (i.e., $\hat{\theta} = \hat{\theta}(\hat{\gamma})$ and $\hat{\delta} = \hat{\delta}(\hat{\gamma})$). We apply this approach to equations (2.3). The corresponding specification is:

$$\begin{aligned} \Delta Y_{it} = &\beta_0 + \beta_1 Y_{i0} + \beta_2 \Delta K_{it} + \beta_3 \Delta L_{it} + \beta_4 \Delta H_{it} + \beta_5 O_{it} + \beta_6 \pi_{it} + \\ &\beta_7 (I_{it} * DUMY_{i0} \leq \gamma) + \beta_8 (I_{it} * DUMY_{it} > \gamma) + \rho_i + \varphi_t + \varepsilon_{i,t} \end{aligned} \tag{2.15}$$

where is the endogenously determined threshold development level; $DUMY_{i0} \leq \gamma$ is the dummy variable for development levels less than or equal to the threshold; $DUMY_{i0} > \gamma$ is the dummy variable for development levels greater than the threshold; and all other terms are as previously defined.

To test for the threshold, we use a bootstrapping technique to derive the asymptotic distribution for a likelihood ratio (LR) test, which obtains p-values for this test. The null hypothesis is that no threshold exists (i.e., $H_0 : \delta = 0$ or $\theta_1 = \theta_2$). The LR statistic is:

$$LR = \frac{s_n(\gamma) - s_n(\hat{\gamma})}{\hat{\sigma}^2} \quad where \quad \hat{\sigma}^2 = \frac{1}{n(t-1)} S_n(\hat{\gamma}) \tag{2.16}$$

where $S_n(\gamma)$ is the residual sum of squares under the null hypothesis, $S_n(\hat{\gamma})$ is the residual sum of squares under the alternative hypothesis, and $\hat{\sigma}^2$ is the residual variance under the alternative hypothesis. Larger values correspond with a rejection of the null hypothesis of no threshold.

Applying this test to equation (2.15), the null hypothesis is $H_0 : \beta_7 = \beta_8$. A rejection of the null would indicate that there is a threshold development level that serves as a tipping point, changing the growth effects of IPRs.

2.3.2 Data

The data are detailed by country and year. We pool cross-country data over time to create a panel dataset. The data cover 115 countries for the period from 1980-2010. Thus, the data spans the majority of countries, and the 15 years pre-TRIPs and 16 years post-TRIPs for a total of 31 years. The countries in the sample are those for which comparable data are available. We divide the sample into six sub-periods including: 1980-84, 1985-89, 1990-94, 1995-99, 2000-04, and 2005-10. We calculate five-year averages over these sub-periods to measure the variables in the specifications described above. The use of period averages provides a smoothing of business cycle effects.[9] Appendix A describes all of the data and their sources, with the exception of intellectual property rights which we describe below.

Intellectual property rights provide a measure of the component of capital that is non-rival. We use the index value constructed by Walter Park to measure

[9] All periods are five years long with the exception of the period of 2005-10 which is six years.

this component.[10] This index measures the strength of countries patent policies including: (1) extent of coverage in eight technology areas; (2) length of protection; (3) membership to five international treaties that address patents; (4) provisions for loss of protection including working requirement, compulsory licensing and revocation of patents; and (5) enforcement mechanisms including preliminary pre-trial injunctions, contributory infringement, and burden of proof. Countries are assigned a score from 0 to 1 in each category based on the strength of their laws. The overall index is the un-weighted sum of the scores in these categories. The index takes values from 0 to 5 with higher values indicating stronger protections. Park constructed this index on a five-year basis from 1960 to 2010.

We use the IPRs index from 1980 to 2005 to match our dataset. We use the values for the initial years of each period to ensure that our measure is exogenous with respect to economic growth (as discussed earlier). Appendix A reports the IPRs measure for all countries in our sample, including the East Asian countries. The appendix also reports averages and standard deviations for the world and for East Asia. As shown, the average strength of IPRs is weaker and more variable across East Asian countries relative to the world. However, almost all countries have strengthened their IPRs over time, with the largest changes in the years following the 1995 TRIPs agreement.[11] In East Asia, Japan is the leader in adopting and maintaining strong IPRs throughout the pre and post-TRIPs periods. Others with relatively strong IPRs include Korea, Hong Kong, and the Philippines. Several others have substantially strengthened their IPRs over time including China, Papua New Guinea and Indonesia. For the later countries, IPRs were exceptionally weak in the earlier years and have strengthened over time as they have moved toward compliance with TRIPs.

[10] See [Park, 2008] and [Ginarte and Park, 1997].

[11] Iran and Iraq are exceptions where IPRs have either remained unchanged or weakened over time.

2.4 Results

We organize our discussion of the findings around the four themes of this study.

2.4.1 World

First, we consider whether IPRs have a positive (or negative) growth effect across countries globally. Table 2.2 reports estimates of equations (2.2) - (2.4) for the full sample of countries during the period 1980-2010. The results show a positive relationship between IPRs and economic growth across the countries of the world. This finding is indicated by the positive and significant estimates on the IPRs variable in equations (2.3) and (2.4). The findings also show a non-linear relationship between IPRs and economic growth. That is, while growth increases with the strength of IPRs, it increases at a decreasing rate. This finding is indicated by the negative and significant estimate on the squared IPRs variable in equation (2.4).

These findings suggest that for the global economy, the positive effects of stronger IPRs on economic growth (e.g., increased inward technology transfers and innovation) outweigh the negative effects (e.g., decreased domestic imitation and access to technological inputs). However, the magnitude of the *net positive effect* increases at a decreasing rate suggesting a tapering off of benefits.

The estimates on the remaining variables are consistent with expectations. These estimates show that capital growth and trade openness both contribute positively to economic growth, while inflation (or economic instability) contributes negatively to growth. The finding also show that initial growth is negatively related to economic growth as suggested by the underlying theory, where countries close to their steady states experience a slowdown in growth.

2.4.2 East Asia

Next, we consider whether the growth effects of IPRs differ for East Asia relative to the world. We report results corresponding with two approaches. The first approach uses the sample of East Asian countries, and the second approach uses the full sample for the world and considers how East Asia deviates from the world. Table 2.3 reports the results with the former the columns corresponding with equations (2.2) - (2.4), and the later in the column corresponding with equation (2.5).

The results show a statistically insignificant relationship between IPRs and economic growth across the countries of East Asia in equations (2.2) - (2.4). That is, the positive effects of IPRs on economic growth (e.g., increased inward technology transfers and innovation) do not appear to outweigh the negative effects (e.g., decreased domestic imitation and access to technological inputs). In other words, the *net effect* is ambiguous. This finding is consistent with the mixed incentives for IPRs experienced by developing countries (see Section 1).

These ambiguous findings for the effects of IPRs in East Asia (in Table 2.3) contrast with the stronger positive findings for the world (in Table 2.2). To assess statistically whether the growth effects of IPRs for East Asia deviate from those of the world, we consider our second approach. These results are reported in the column for equation (2.5). in Table 2.3. The deviation effect for East Asia is reflected in the estimate on the interaction term ($I * DUMA$). This estimate is insignificant suggesting that the growth effects of IPRs for East Asia are not statistically different than those for the world, at least not for the full time period from 1980-2010.

The estimates on the remaining variables do indicate that East Asia is unique in one specific way. Labor growth in East Asia is negatively related to economic growth. In other words, East Asian countries with higher labor growth rates have relatively lower economic growth rates. The remaining baseline results for East Asia are consistent with those for the world. Countries in East Asia with higher initial growth have lower economic growth, countries with higher capital growth have higher economic growth, and countries with economic instability have lower growth rates.

2.4.3 TRIPs

Next, we consider whether the 1995 TRIPs agreement altered the growth effects of IPRs for the world, and for East Asia. To this end, we use two alternative approaches. The first approach involves dividing the sample into pre-TRIPs and post-TRIPs periods, and estimating equation (2.3) for the world and for East Asia separately. The pre-TRIPs period is defined as 1980-1994 and the post-TRIPs period is 1995-2010. Table 2.4 reports these results in the columns corresponding with equation (2.3). The estimates of equation (2.3) show a negative effect of IPRs in the pre-TRIPs period for both the world (insignificant) and East Asia (significant). In contrast, the results show a positive effect of IPRs for the world (significant) and for East Asia (significant) in the post-TRIPs period.

These results suggest that the TRIPs agreement played an important role in altering the *net effects* of IPRs on economic growth. In the pre-TRIPs period, countries with relatively weak IPRs had higher economic growth, particularly in East Asia. This is consistent with the argument that weaker IPRs stimulate economic growth by allowing for imitation and access to technological inputs. In the post-TRIPs period, this pattern reversed such that countries with relatively strong IPRs had higher economic growth, globally and in East Asia. This pattern is consistent with the argument that strong IPRs stimulate economic growth by encouraging technology transfers (via trade, FDI and licensing) and innovation. These results describe the experiences of the average country in the world and in East Asia during these time periods.

The second approach involves using the full sample for the entire period (1980-2010) and all countries, and considering whether TRIPs altered the growth effects for the world and for East Asia (relative to the world). Table 2.4 reports the deviation effect for the world in the column for equation (2.6), and the deviation effect for East Asia in the column for equation (2.7). The estimates of equation (2.6) show that growth in the post-TRIPs period deviates from that of the entire period in a positive way. That is, average growth rates across the countries of the world are higher during the *post*-TRIPs period. The estimates of equation (2.7) show that these effects are more modest for East Asia. Average growth rates across the countries of East Asia are smaller than those of the world during the post-TRIPs period. These results are consistent with the intuition that the net effects of IPRs on economic growth are more positive for the average country in the world than for the average country in East Asia where imitation and access to lower priced technological inputs remain important contributors to economic growth.

Finally, the baseline estimates for the pre and post-TRIPs periods provide one new insight. The findings show that human capital growth contributes positively to economic growth, while labor growth contributes negatively to economic growth, particularly during the post-TRIPs period. This is consistent with the intuition that human capital is an important contributor to a countrys capacity to innovate.

2.4.4 Development Thresholds

In this last section, we explore whether there is a tipping point in the relationship between IPRs and growth that is related to the development level of countries. Table 2.5 reports the results of estimating equation (2.15) using the threshold regression method. The first two columns report estimates for the world during the pre and post TRIPs periods. The last two columns report estimates for East Asia during these same periods. The results include estimates of the effects of IPRs above and below an endogenously determined threshold level of development.[12]

[12] In each regression, the p-values indicate a rejection of the null hypothesis at the one percent level. This means that there exists a threshold level of development that alters economic growth. The endogenously determined thresholds range from 7.612 for the world for the pre-TRIPs period to 6.150 for the post-TRIPs period. For East Asia, thresholds range from 7.341 for the pre-TRIPs period to 7.980 for the post-TRIPs period. These thresholds are generated

The results for the world show that IPRs have an insignificant effect on growth for countries below the threshold and a negative and significant effect on growth for countries above the threshold during the pre-TRIPs period (column 1). For the post-TRIPs period, IPRs again have an insignificant effect on growth for countries below the threshold; however for countries above the threshold, the effect of IPRs is now positive (column 2). These results are consistent with the earlier findings (in Table 2.4) that the TRIPs agreement altered the net effects of IPRs on growth from negative to positive for the average country in the world. However, the results also show that the affected countries are only those above the threshold level of development (e.g., highly developed countries).

Further, the results for East Asia show that IPRs have a mixed effect on growth both before TRIPs and after TRIPs. During the pre-TRIPs period, East Asian countries at lower development levels experience positive growth effects from weak IPRs, while those at higher development levels experience positive growth effects from strong IPRs (column 3). This is consistent with the intuition that weak domestic IPRs stimulate economic growth primarily via imitation (and lower priced technology inputs) for less developed countries, while strong domestic IPRs stimulate economic growth primarily via innovation (and stronger monopoly power over technology inputs) for more highly developed countries. In contrast, we find that this pattern reverses in during the post-TRIPs period for East Asia (column 4). On first blush, this last result appears to be anomalous. However, on further exploration, we find that the column 4 results (in Table 2.5) for IPRs are not robust, whereas the other results are robust. This sensitivity is related to the Asian financial crisis during the late 1990s. We report the results of the related sensitivity analysis in Section 2.5.

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using the sample for each period and each group.

2.4.5 Sensitivity Analysis

In this last section, we assess the sensitivity of our findings. First we consider the robustness of results with respect to the measure of IPRs. To this end, we evaluate six alternative measures that combine the Park and Fraser indexes. The Park index (I) is described in Section 3.2 and provides the basis for the results reported in the paper. The Fraser index (F) measures the degree of economic freedom of countries. This index is based on multiple variables including the legal structure and security of property rights, and freedom to trade internationally. This index has been used in recent studies to capture the enforcement of laws, which is positively correlated with enforcement. The index takes values from 0 to 10 with higher values indicating stronger economic freedom (or legal enforcement). We examine the joint effects of the Park and Fraser indexes to account for the combined effects of IPR laws and their enforcement. Specifically, we consider the combinations: I; F; $I * 2 * F$; $I + F$; $I * F$; $I^2 * F$. Tables 2.6 reports the effects of these measures on world growth (eq. (2.3)), and Table 2.7 reports the effects on East Asia relative to the world (eq. (2.5)). As shown in both tables, the signs and significance of the estimates on the IPRs variables are robust across measures. Further, as shown in Table 2.6, the magnitudes of the estimates are smaller when we account for enforcement, suggesting that the growth effects of strong IPR laws are moderated by their weak enforcement. As shown in Table 2.7, the negative effects for East Asia (relative to the world) are strongest when we consider enforcement alone (F) and the sum of laws and their enforcement ($I + F$). These results are consistent with our earlier findings, but provide additional evidence that enforcement (or lack thereof) reinforces the effects of IPR on economic growth.

Second, we assess the robustness of our results with respect to the potential impact of the Asian financial crisis during the late 1990s. To this end, we re-estimate equation (2.3)) for the post-TRIPs period for East Asia. Recall, the post-TRIPS period (1995-2010) includes the three sub-periods 1995-1999, 2000-2004 and 2005-2010. We consider whether the results vary across these sub-periods. Table 2.8

reports the estimates of equation ((2.3)) for each of the sub-periods (columns 1-3) as well as for the overall post-TRIPs period (column 4). As expected, we find a negative relationship between economic stability (Π) and growth in East Asia during the financial crisis (1995-1999) and a positive relationship during the subsequent period (2000-2004). In other words, economic instability did indeed contribute to lower growth during the financial crisis. Further, we find that IPRs contribute positively to East Asias economic growth over the entire post-TRIPs period (1995-2010), and this is driven primarily by the significant positive effects during the most recent period (2005-2010). These results are consistent with earlier findings, but provide further evidence of the strong recent contributions of IPRs to economic growth as Asia emerged from the financial crisis.

2.5 Concluding Remarks

In this paper, we empirically examine the relationship between IPRs and economic growth with a focus on features that may alter this relationship across regions (Asia relative to the world), across time (pre and post-TRIPs), and across the development levels of countries. We consider four questions. First, do IPRs have positive growth effects across countries globally? Our results show a (net) positive relationship between IPRs and economic growth across the countries of the world. However this relationship is non-linear. That is, while growth increases with the strength of IPRs, it increases at a decreasing rate. These findings suggest that for the global economy, the positive effects of stronger IPRs on economic growth (e.g., increased inward technology transfers and innovation) outweigh the negative effects (e.g., decreased domestic imitation and access to technological inputs). However, there is a tapering off of net benefits.

Second, are the growth effects of IPRs different for East Asia than for the rest of the world? We find initially that IPRs have an insignificant effect on economic growth across the countries of East Asia, and these effects are not statistically different than those for the world. The positive effects of IPRs on economic growth appear to cancel out the negative effects, such that the net effect is ambiguous. This finding is consistent with the mixed incentives for IPRs experienced by developing countries. When we explore the pre and post-TRIPs periods and the role of development level, new insights emerge for East Asia (see below).

Third, did the 1995 TRIPs Agreement alter the growth effects of IPRs for the world and for East Asia? The results show that countries with relatively weak IPRs had higher economic growth, particularly in East Asia, during the pre-TRIPs period. In the post-TRIPs period, this pattern reversed such that countries with relatively strong IPRs had higher economic growth, globally and in East Asia. The results showed evidence that growth in the *post*-TRIPs period deviates from that of the entire period in a positive way; yet these positive effects are more modest for East Asia. These findings are consistent with the intuition that East Asia continues to benefit from imitation and access to lower priced technological inputs that is possible under less stringent IPRs regimes.

Fourth, is there a tipping point in the relationship between IPRs and growth that is related to the development level of countries? The results for the world show that IPRs have a negative effect on growth for countries above a threshold development level during the pre-TRIPs period, and have a positive effect for this same group during the post-TRIPs period. In contrast, countries below the threshold are insensitive to the strength of IPRs. These results suggest that there is a tipping point, and that highly developed countries do experience growth benefits from strong IPRs, particularly in the post-TRIP era. For East Asia, the results show that countries at lower development levels experience positive growth effects from weak IPRs, while those at higher development levels experience positive growth effects from strong IPRs during the pre-TRIPs period. This result is consistent with the intuition that weak domestic IPRs stimulate economic growth primarily via imitation (and lower priced technology inputs) for less developed countries, while strong domestic IPRs stimulate economic growth primarily via innovation (and stronger monopoly power over technology inputs) for more highly developed countries.

Finally, we note that the above finding are robust along several dimensions including consideration of the enforcement of intellectual property laws, the impact of the Asian financial crisis, and the lagged effects of IPRs on economic growth.

Table 2.1: Expected Signs of Parameter Estimates

Abbreviation	Variable	Eq. (2.2)	Eq. (2.3)	Eq. (2.4)	Eq. (2.5)	Eq. (2.6)	Eq. (2.7)	Eq. (2.15)
Baseline								
Y_0	Initial Growth	$-$	$-$	$-$	$-$	$-$	$-$	$-$
ΔK	Capital Growth	$+/-$	$+/-$	$+/-$	$+/-$	$+/-$	$+/-$	$+/-$
ΔL	Labor Growth	$+/-$	$+/-$	$+/-$	$+/-$	$+/-$	$+$	$+$
ΔH	Human Capital Growth	$+/-$	$+/-$	$+/-$	$+/-$	$+/-$	$+$	$+$
O	Openness to Trade	$+$	$+$	$+$	$+$	$+$	$+$	$+$
Π	Economic Instability/Inflation	$-$	$-$	$-$	$-$	$-$	$-$	$-$
IPRs								
I	IPRs		$+/-$	$+/-$	$+/-$	$+/-$	$+/-$	
I^2	IPRs Squared			$+/-$				
$I * DUMA$	IPRs $*$ East Asia Dummy				$-$			
TRIPs								
$DUMT$	TRIPs Dummy					$+/-$		
$DUMT{*}DUMA$	TRIPs Dummy $*$ East Asia Dummy						$+/-$	
Threshold								
$I * (Y <$ Threshold$)$	IPRs $*$ Development level (a)							$+/-$
$I * (Y >$ Threshold$)$	IPRs $*$ Development level (a)							$+/-$

Notes: The endogenous variable is economic growth measured as $\Delta Y = \ln(Y_i, t+1) - \ln(Y_i, t)$ in each equation. (a) Equation (2.15) is a variant of equation (2.3), where a threshold development level is determined endogenously.

Table 2.2: Cross-Country Estimates for the World, 1980-2010

Variables	World Growth		
	Equation (2.2)	Equation (2.3)	Equation (2.4)
Y_0	-0.055***	-0.059***	-0.056***
	(0.003)	(0.003)	(0.003)
ΔK	0.129***	0.135***	0.126***
	(0.012)	(0.011)	(0.012)
ΔL	0.212	0.235	0.327
	(0.205)	(0.210)	(0.207)
ΔH	0.003	-0.006	-0.009*
	(0.005)	(0.005)	(0.005)
O	0.023***	0.018***	0.018***
	(0.004)	(0.004)	(0.004)
Π	-0.002***	-0.002***	-0.002***
	(0.000)	(0.000)	(0.000)
I		0.010***	0.021***
		(0.001)	(0.006)
I^2			-0.002***
			(0.001)
Constant	0.412***	0.415***	0.388***
	(0.024)	(0.023)	(0.024)
Observations	$3,011$	$3,011$	$3,011$
Number of countries	115	115	115
Adjusted R^2	0.54	0.56	0.56

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.3: Cross-Country Estimates for East Asia, 1980-2010

Variables	East Asia Growth			World Growth
	Equation (2.2)	Equation (2.3)	Equation (2.4)	Equation (2.5)
Y_0	-0.050***	-0.052***	-0.054***	-0.059***
	(0.005)	(0.005)	(0.005)	(0.003)
ΔK	0.148***	0.149***	0.150***	0.135
	(0.022)	(0.022)	(0.022)	(0.011)
ΔL	-2.816***	-2.773***	-2.802***	0.235
	(0.377)	(0.387)	(0.390)	(0.211)
ΔH	0.010	0.007	0.014	-0.006
	(0.014)	(0.014)	(0.018)	(0.005)
O	-0.007**	-0.005	-0.005	0.018***
	(0.003)	(0.003)	(0.003)	(0.004)
Π	-0.103***	-0.098***	-0.091***	-0.002***
	(0.023)	(0.023)	(0.027)	(0.000)
I		0.004	0.001	0.010***
		(0.003)	(0.004)	(0.001)
I^2			0.001	
			(0.001)	
$I * DUMA$				-0.000
				(0.002)
Constant	0.434***	0.440***	0.444***	0.415***
	(0.043)	(0.041)	(0.040)	(0.025)
Observations	294	294	294	$3,011$
Number of countries	11	11	11	115
Adjusted R^2	0.80	0.80	0.80	0.56

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.4: Cross-Country Estimates for the World and East Asia, Pre-TRIPs (1980-1994) and Post-TRIPs (1995-2010)

Variables	World Growth		East Asia Growth		World Growth	
	Pre-TRIPs Equation (2.3)	Post-TRIPs Equation (2.3)	Pre-TRIPs Equation (2.3)	Post-TRIPs Equation (2.3)	Pre-TRIPs Equation (2.6)	Post-TRIPs Equation (2.7)
Y_0	-0.064***	-0.076***	-0.036**	-0.108***	-0.059***	-0.048***
	(0.007)	(0.006)	(0.017)	(0.018)	(0.003)	(0.003)
ΔK	0.188***	0.129***	0.206***	0.142***	0.135***	0.153***
	(0.024)	(0.014)	(0.038)	(0.039)	(0.011)	(0.011)
ΔL	0.408**	-0.997***	-0.990**	-3.755***	0.235	0.213
	(0.205)	(0.248)	(0.450)	(0.719)	(0.210)	(0.217)
ΔH	0.009	0.021***	-0.252***	0.162***	-0.006	0.006
	(0.014)	(0.006)	(0.028)	(0.025)	(0.005)	(0.005)
O	0.032***	0.035***	-0.004	0.010**	0.018***	0.016***
	(0.009)	(0.005)	(0.008)	(0.004)	(0.004)	(0.004)
Π	-0.002***	-0.010***	-0.192**	0.051	-0.002***	-0.002***
	(0.000)	(0.001)	(0.027)	(0.052)	(0.000)	(0.000)
I	-0.002	0.006***	-0.016***	0.010**	0.010***	0.004***
	(0.002)	(0.001)	(0.005)	(0.005)	(0.001)	(0.001)
$DUMT$					0.018***	
					(0.002)	
$DUMT{*}DUMA$						-0.001
						(0.001)
Constant	0.436***	0.551***	0.470***	0.731***	0.397***	0.341***
	(0.047)	(0.043)	(0.124)	(0.123)	(0.023)	(0.021)
Observations	1,345	1,666	135	159	3,011	2,971
Number of countries	105	114	11	11	115	115
Adjusted R^2	0.77	0.61	0.88	0.89	0.56	0.56

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.5: Threshold Regression Estimates of Equation (2.15)

Variables	World Growth		East Asia Growth	
	Pre-TRIPs (1980−1994)	Post-TRIPs (1995−2010)	Pre-TRIPs (1980−1994)	Post-TRIPs (1995−2010)
Y_0	-0.059***	-0.081***	-0.135***	-0.086***
	(0.007)	(0.005)	(0.016)	(0.015)
ΔK	0.189***	0.138***	0.292***	-0.002
	(0.023)	(0.014)	(0.036)	(0.035)
ΔL	0.418**	-1.045***	-3.451***	-6.191***
	(0.204)	(0.244)	(0.312)	(1.026)
ΔH	0.010	0.022***	-0.361***	0.114***
	(0.014)	(0.006)	(0.029)	(0.023)
O	0.033***	0.035***	-0.012**	0.016***
	(0.008)	(0.005)	(0.005)	(0.003)
Π	-0.002***	-0.010***	-0.914***	0.003
	(0.000)	(0.001)	(0.068)	(0.054)
$I * (Y \leq \text{Threshold})$	0.001	0.002	-0.490***	0.010**
	(0.002)	(0.002)	(0.035)	(0.005)
$I * (Y > \text{Threshold})$	-0.007***	0.008***	0.016***	-0.049***
	(0.002)	(0.001)	(0.005)	(0.013)
Constant	0.394***	0.581***	1.564***	0.724***
	(0.050)	(0.040)	(0.128)	(0.113)
Threshold	7.612	6.150	7.341	7.980
p-value	0.000	0.000	0.000	0.000
Observations	1,345	1,666	135	159
Adjusted R^2	0.767	0.614	0.947	0.903

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.6: Sensitivity Analysis: Measurement of Intellectual Property Rights, Equation (2.3)

Variables	World Growth					
	Equation (2.3)					
Y_0	-0.059***	-0.047***	-0.052***	-0.049***	-0.052***	-0.051***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ΔK	0.135***	0.181***	0.185***	0.179***	0.185***	0.188***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
ΔL	0.235	-0.637***	-0.746***	-0.627***	-0.746***	-0.821***
	(0.210)	(0.096)	(0.097)	(0.095)	(0.097)	(0.103)
ΔH	-0.006	0.004	-0.000	0.002	-0.000	0.003
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.004)
O	0.018***	0.026***	0.025***	0.025***	0.025***	0.024***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Π	-0.002***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
I	0.010***					
	(0.001)					
F		0.002***				
		(0.000)				
$I * 2 * F$			0.000***			
			(0.000)			
$I + F$				0.003***		
				(0.000)		
$I * F$					0.001***	
					(0.000)	
$I^2 * F$						0.000***
						(0.000)
Constant	0.415***	0.336***	0.375***	0.342***	0.375***	0.373***
	(0.023)	(0.022)	(0.023)	(0.022)	(0.023)	(0.023)
Observations	3,011	2,692	2,692	2,692	2,692	2,692
Adjusted R^2	0.556	0.597	0.606	0.602	0.606	0.602

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.7: Sensitivity Analysis: Measurement of Intellectual Property Rights, Equation (2.5)

Variables	World Growth					
	Equation (2.5)					
Y_0	-0.059***	-0.047***	-0.052***	-0.048***	-0.052***	-0.051***
	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
ΔK	0.135***	0.179***	0.184***	0.177***	0.184***	0.188***
	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
ΔL	0.235	-0.625***	-0.753***	-0.643***	-0.753***	-0.823***
	(0.211)	(0.095)	(0.099)	(0.097)	(0.099)	(0.105)
ΔH	-0.006	0.003	-0.000	0.001	-0.000	0.003
	(0.005)	(0.004)	(0.005)	(0.005)	(0.005)	(0.005)
O	0.018***	0.027***	0.025***	0.027***	0.025***	0.024***
	(0.004)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Π	-0.002***	-0.001***	-0.001***	-0.001***	-0.001***	-0.001***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
I	0.010***					
	(0.001)					
$I * DUMA$	-0.000					
	(0.002)					
F		0.002***				
		(0.000)				
$F * DUMA$		-0.007***				
		(0.002)				
$I * 2 * F$			0.000***			
			(0.000)			
$I * 2 * F * DUMA$			-0.000			
			(0.000)			
$I + F$				0.003***		
				(0.000)		
$I + F * DUMA$				-0.003**		
				(0.001)		
$I * F$					0.001***	
					(0.000)	
$I * F * DUMA$					-0.000	
					(0.000)	
$I^2 * F$						0.000***
						(0.000)
$I^2 * F * DUMA$						-0.000
						(0.000)
Constant	0.415***	0.344***	0.371***	0.333***	0.371***	0.372***
	(0.025)	(0.022)	(0.024)	(0.023)	(0.024)	(0.024)
Observations	3,011	2,692	2,692	2,692	2,692	2,692
Adjusted R^2	0.556	0.601	0.606	0.603	0.606	0.602

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** p<0.01, ** p<0.05, * p<0.1). All regressions include country and time fixed effects.

Table 2.8: Sensitivity Analysis: Asian Financial Crisis

	East Asian Growth			
Variables	1995-1999	2000-2004	2005-2010	1995-2010
	Eq. (2.3)	Eq. (2.3)	Eq. (2.3)	Eq. (2.3)
Y_0	-0.018***	0.000	-0.017***	-0.017***
	(0.001)	(0.002)	(0.002)	(0.001)
ΔK	0.306***	0.331***	0.118***	0.153***
	(0.026)	(0.022)	(0.021)	(0.021)
ΔL	-0.205	-0.839***	-2.507***	-1.873***
	(0.459)	(0.081)	(0.384)	(0.270)
ΔH	0.063***	0.008	-0.152***	0.013
	(0.017)	(0.028)	(0.016)	(0.019)
O	-0.001	0.011***	0.013***	0.012***
	(0.004)	(0.002)	(0.001)	(0.001)
Π	-0.080**	0.338***	-0.038	-0.049
	(0.038)	(0.028)	(0.028)	(0.045)
I	0.003	-(0.007)	0.032***	0.007*
	(0.004)	(0.004)	(0.002)	(0.004)
Constant	0.031	-0.046***	0.168***	0.094***
	(0.024)	(0.013)	(0.025)	(0.019)
Observations	55	50	54	159
Adjusted R^2	0.915	0.921	0.975	0.732

Note: Heteroscedasticity-adjusted standard errors are in parentheses. (*** $p<0.01$, ** $p<0.05$, * $p<0.1$). All regressions include country and time fixed effects.

Chapter 3

Effects of Strengthening Intellectual Property Rights on Global Value Chains

3.1 Introduction

Recently, the international fragmentation of production has attracted much attention. The second unbundling, or the fragmentation of production chain across borders is one of the most distinctive features of the last 30 years of globalization [Baldwin and Robert-Nicoud, 2014]. Production fragmentation occurs when different stages of production are divided among different suppliers in different countries. Firms in different countries trade intermediate inputs as well as final goods. For example, parts and components produced in one country may pass through a sequence of other countries that each adds value through different processing. Countries specialize in the particular stages of production in which they have comparative advantage in factor costs including labor and capital or locational advantage and intermediate goods are indirectly or reversely traded. As this production fragmentation deepens, the nature of trade has been changing from trade in final goods to trade in value added.

Participation in these global value chains generates economic benefits in terms of productivity, innovations, and variety of exports although the benefits do not accrue evenly across countries and industries. While endowment, size and location of a country are important factors in global value chain participation, trade-related policy factors also influence the pattern and type of integration into global value chains. Kowalski [Kowalski et al., 2015] finds that the most important factors for developing countries to participate in value chains are the logistics performance, IPRs protection, and infrastructure and institutions.[1]

There have been significant improvements in the standards of IPRs worldwide especially after the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs). The close relationship between patent protection and trade is found in numerous studies. Higher standards of intellectual property protection are likely to foster further innovation in the economy as a whole. There are numerous studies on the relationship between trade and patent protection: Some find positive effects ([Maskus and Penubarti, 1995]; [Rafiquzzaman, 2002]) while others show neither significant effect nor negative impact of stronger IPRs on exports. ([Ferrantino, 1993]; [Smith, 1999])

Increase in trade flows involving the exchange of intermediate inputs and differences in the level of patent protection between trade partners creates new forms of cross border policy effects when compared with situations where goods are produced in a single location. Raising the level of patent protection promotes more innovation activity, resulting in greater varieties of intermediate goods and lower cost of final goods. Meanwhile, a higher level of patent rights protection means that a greater fraction of these varieties is protected and therefore sold at monopoly prices. Therefore, increasing the level of patent rights protection on the costs of final goods depends on whether net variety effects dominate the

[1] Kowalski et. al. [Kowalski et al., 2015] finds that market size, level of development, industrial structure, location, tariff, inward FDI openness, logistics performance are the most important determinant of global value chains. However, trade and investment policy reforms as well as improvements of logistics and customs, intellectual property protection, infrastructure and institutions, can also play an active role in promoting further engagement.

market power effect. Higher patent protection may be a barrier for countries hoping to participate in global value chains due to the limited access to intermediate goods. On the other hand, it may promote a competitive environment of market, leading to lower price and increased varieties of intermediate goods. Therefore, it provides opportunities to add more value, especially for small and medium enterprises seeking to benefit from outsourcing by leading firms.

This paper studies whether a country's ability to protect patent rights is an important determinant of comparative advantage in global value chains. Particularly, I test whether countries with a better patent protection regime export more in industries with higher patent intensities, by constructing a measure of value added contents of exports and gross exports. Also, I construct an additional variable measuring production fragmentation, VAX ratio, and test if stronger patent protection of the country increases production fragmentation in patent-intensive industries.

Previous literature has focused on the relationship between patent protection and trade, and economic growth. [Gould and Gruben, 1996], [Lerner, 2002], [Kanwar and Evenson, 2003] find positive effects between strengthening IPRs and economic growth whearas [Kortum and Lerner, 1999], [Cohen et al., 2000], [Mowery et al., 2001], [Thompson and Rushing, 1996] show non positive effects on economic growth through technical innovations.

For the relationship between IPRs and trade, [Ferrantino, 1993] finds no significant impact between stronger IPRs and exports, and [Smith, 1999] shows a negative relationship. Co's [Co, 2004] results show that the relationship between patent protection and exports depends on R&D intensity. For the country with an average imitative ability, US R&D intensive exports increase when patent rights index increase while US non-R&D-intensive exports decrease with increase of patent rights index. [Ivus, 2010] estimates the impact of strengthening patent rights (PRs) in developing countries on developed countries' exports over 1962-2000. She finds that the increase in PRs after the TRIPs agreement increased about $35 billion (2000 US dollars) to the value of developed counties' patent-sensitive exports into 18 developing countries. [Ivus, 2015] also finds that strengthening IPRs from the ratification of TRIPs in developing countries increased exports of new products in patent-sensitive industries of the U.S.

The literature on the effects of intellectual property rights on production fragmentation is very scant. Glass [Glass, 2004] models outsourcing decisions when intellectual property rights are imperfectly protected to find possible reasons for expanded outsourcing. When firms in the North develop higher quality levels of existing products and shift some stages of production to the South, production in the South lowers cost but implies risk of imitation by Southern firms. Under these circumstances, lower risk of imitation or larger labor supplies can increase outsourcing, elevate rate of innovation, and lower the Northern relative wage. Vichyanond [Vichyanond, 2009] examines how countries' level of patent protection affect exports in industries with different degrees of reliance on innovation. Constructing a simple theoretical model, he shows that higher patent rights protection does not necessarily lead to specialization in industries that rely heavily on innovation and there may exist a threshold inherent in intellectual property rights protection.

Canals and Sener [Canals and ¸Sener, 2014] empirically estimates the responsiveness of US offshoring to intellectual property rights reforms in 16 countries. From the difference-in-difference analysis using IPR reform years, they find that intra-industry offshoring intensities do not change for typical US industries after IPR reform. However, high-tech (patent-sensitive) industries substantially expand their intra-industry offshoring activities, whereas low-tech (patent-insensitive) industries do not change their intra-industry offshoring activities in a statistically significant way.

Existing studies point out that patent protection affects trade in intermediate goods and offshoring. However, they do not account for embodied amount of intermediate goods trade flows in gross trade. This paper is distinctive in that it provides an empirical analysis on how intellectual property rights affect trade in value-added, gross trade, as well as production fragmentation. I calculate the value added portion of exports using input-output data from World Input-Output Database (WIOD) that combines time series data on trade, production, and factor use by country and industry. Value added exports measure the value added contents from source country to destination country in each industry. This is followed by estimation of the effect of strengthening IPRs on value added exports and production fragmentation based on conventional comparative advantage theory. This paper proceeds as follows. Section 2 articulates the theory prediction for trade including intermediate trade and IPRs and empirical framework. Section 3 then describes the data. Section 4 presents and interprets the results and discusses possible endogeneity as well as robustness check of the results. Section 5 concludes.

3.2 Theory predictions and empirics

Theoretically, the effects of IPRs on trade are not clear. [Maskus and Penubarti, 1995], [Glass and Saggi, 2002], [Carr et al., 2001], and [Vichyanond, 2009] provide theory that shows stronger IPRs may increase or decrease trade. Stricter patent protection has conflicting effects: market power effect and market expansion effect. First, the exclusive right provided by patent protection increases the price of the product and decreases exports. Second, the exclusive rights prevent imitation and exclude competitors, thereby increasing exports. Trade involving the exchange of intermediate inputs and differences in the level of patent protection between trade partners may have different policy effects.

Hypothesis 1. The market power effect predicts a negative relationship between stronger IPRs and exports. A higher level of patent rights protection lead to a greater fraction of intermediate varieties that are protected and therefore sold at monopoly prices. Therefore, I expect stronger IPRs to have negative effects on comparative advantage. I also expect this effect to be stronger in patent-intensive industries than less patent-intensive industries.

Hypothesis 2. The market expansion effect predicts a positive relationship between stronger IPRs and exports. I expect that raising the level of patent protection promotes more innovation activities resulting in greater varieties of intermediate goods and lower cost of final goods, thereby having a positive effect on comparative advantage. I also expect these effects are stronger in patent-intensive industries when compared to less patent-intensive industries.

Increasing the level of patent rights protection on the costs of final goods depends on whether net variety effects dominate the market power effect. I test hypothesis 1 and 2 using empirical method that accounts for patent protection and patent intensity. The empirical strategy employed in this paper follows and extends the specification used in previous literatures for estimating comparative advantage. Nunn [Nunn, 2007], Romalis [Romalis, 2004], and Vichyanond [Vichyanond, 2009] use cross-country export data, country-level factor endowment, and sector-level factor intensities. Nunn [Nunn, 2007] uses this equation to estimate the effect on contractual enforcement of industries' exports and Levchenko [Levchenko, 2007] employs this model to analyze the relationship between institutions and international trade. Romalis [Romalis, 2004] examines how factor proportions determine the structure of commodity trade using a similar functional form. Rajan and Zingales [Rajan and Zingales, 1998] show evidence that sectors that are relatively more in need of external finance grow disproportionably faster in countries with more developed financial markets.

Based on the empirical specification in this literature, I test whether a country's higher level of patent protection is an important determinant of comparative advantage. The higher level of patent protection promotes more innovation activities by securing return of investor's R&D and other innovative activities. Intermediate varieties increase and price lowers when this is the case. At the same time, a higher level of patent rights protection means that a greater fraction of these varieties is protected and therefore sold at monopoly prices. I test whether countries with higher patent protection have a comparative advantage in the exports of intermediate goods and final goods that use inputs requiring patent-intensive technologies by estimating the equation as follows:

$$\begin{aligned} \ln(y_{ikt}) = & \alpha_i + \alpha_k + \alpha_t + \beta_1 \ln(P_{it}) + \beta_2 \ln P_{it} p_k + \beta_3 \ln(H_{it}) + \\ & \beta_4 \ln(H_{it}) \ln(h_k) + \beta_5 \ln(K_{it}) + \beta_6 \ln(K_{it}) k_k + \varepsilon_{ikt} \end{aligned} \tag{3.1}$$

where y_{ikt} denotes three different outcomes: 1) value added exports; 2) gross exports; and 3) VAX ratio of industry k of country i at year t[2] ; P_{it} is the level of patent rights protection; p_k is the patent intensity of industry k; H_{it} is the human capital endowment of country i; h_k is the human capital intensity of industry k; K_{it} denotes the physical capital endowment of country i; k_k is physical capital intensity of industry k; α_i, α_k, α_t denote country, industry, and year fixed effects, and ε_{ikt} is the error term which is allowed to be heteroskedastic.

The empirical analysis in this study relies on country-industry level panel data from 1995 to 2010[3] . I estimate the equations on value added exports and endowments to test the effect of strengthening IPRs as follows[4] : In this equation three outcomes are explained by interactions of country characteristics with industry characteristics. The parameter of interest is β_2, which represents the effect of stronger IPRs by industry. A positive coefficient of β_2 indicates that countries with stronger protection regime exports relatively more in industries for which patent-intensity is higher. That is, countries with higher IPRs index specialize in patent-intensive industries. Therefore, the effects of patent rights protection on value added exports, gross exports and VAX ratio are greater for more patent-intensive industries with a positive β_2 while a negative coefficient implies smaller effects. Coefficients β_3, β_6 reports the effects of human capital and physical capital on the outcomes by country and industry. Then I expand the equation (3.1) by adding natural resources endowments and financial openness

[2] To measure country-industry level data, I sum up VAX ratio from country i to country j in sector k into the VAX ratio of industry k of country i.

[3] Although WIOD Input-Output data covers from 1995 to 2011, I restrict the period of study up to 2010 due to the availability of other data including human capital and IPRs index

[4] In order to precise semi-elasticity interpretation for the estimated coefficients, I take the log of dependent variable, and all independent variables.

and their intensities by industries to mitigate omitted variable bias;

$$\begin{aligned}\log(y_{ikt}) =& \alpha_i + \alpha_k + \alpha_t + \beta_1 \ln P_{it} + \beta_2 \ln P_{it} p_k + \beta_3 \ln H_{it} + \\ & \beta_4 \ln H_{it} h_k + \beta_5 \ln K_{it} + \beta_6 \ln K_{it} k_k + \beta_7 \ln N_{it} + \\ & \beta_8 \ln K_{it} n_k + \beta_9 \ln F_{it} + \beta_{10} \ln F_{it} f_i + \varepsilon_{ikt}\end{aligned} \tag{3.2}$$

where N_{it} denotes natural resources endowments of country i; n_k means natural resource intensity of industry k; F_{it} is the financial openness of country i; f_k denotes financial openness intensity of industry k. Coefficients are determined by relative factor rewards. The coefficient for the level of patent protection P_{it} and patent intensity p_k has same implication as in the equation (3.1).

Both equations estimate the effects of endowments on value added exports and gross exports separately to compare the results. As there are possibilities that what countries export may be very different from what they actually contribute to the production process, country and industry endowment may have different effects on value added exports and gross exports. Trade in value added may follow theories of comparative advantage more closely than gross trade as value-added flows capture where factors of production including labor and capital are used along the global value chain. Therefore, patent protection of source country of input may have strong positive or negative effects on value added trade.

Then, the effects of patent protection are estimated for the VAX ratio, which indicates production fragmentation. VAX ratio has a different trend for value added exports and gross exports. It has declined over time globally, which means that countries are increasingly using input stemming from outside the country and sector. For example, U.S.'s value added trade in the electrical appliance sector can be reduced while U.S.'s gross exports increases from using more imported intermediates that are assembled in the U.S. Strong patent protection of the country is expected to have different impacts by patent intensities of industries.

VAX ratio is explained in the same equations, Noting that $\ln(VAX_{ict}) = \ln(\textit{value added exports}_{ict}) - \ln(\textit{gross exports}_{ict})$, β_2 for VAX ratio will be the difference in β_2 between value added exports and gross exports. The positive coefficient

β_2 indicates that countries with stronger IPRs have higher VAX ratio in industries with higher patent intensity, which means that the effect of higher IPRs on the VAX ratio is greater for more patent-intensive industries.

3.3 Data

Value added exports Trade in intermediate goods accounts for almost two-thirds of the world trade. Since the conventional way of measuring trade counts the gross value of goods at border crossing, it overstates domestic value added and causes a double counting problem.[5] Fragmentation, or offshoring can be identified with new data sets that remove the double counting that arise when intermediates cross borders and are then embodied into further processed goods. These new trade numbers are called 'value added' trade to distinguish them from the 'gross' trade flows that are traditionally measured.

Using input-output tables rather than relying on trade data, we can track how much input is created from a source country that is used to produce which final good directly or indirectly and we can calculate the correct amount of international production fragmentation. The World Input-Output database has been developed to analyze the effects of globalization on trade patterns, environmental pressures and socio-economic development for 35 industries of 40 countries[6] for the period of 1995 to 2011. The WIOD is a combination of national input-output tables in which the use of product is broken down according to its origin. For each year, the WIOD has the standard I/O table (1435×1435 matrix). It shows value added content of bilateral trade, source countries and industries, as well as destination countries and industries.

[5] Koopman et al. [Koopman et al., 2008] estimates that the share of domestic content in China exports is about 50%.

[6] Countries in WIOD database includes Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Poland, Portugal, Romania, Slovak Republic, Slovenia, Spain, Sweden, United Kingdom, Canada, United States, Brazil, China, India, Japan, South Korea, Australia, Taiwan, Turkey, Indonesia, and Russia.

Johnson and Noguera [Johnson and Noguera, 2012] combined time series data on trade, production, and input use to compute the value added content of trade. This paper basically follows the methodology of Johnson and Noguera [Johnson and Noguera, 2012] for constructing value added trade. Focusing on that manufacturing sector, 14 sectors of WIOD data were used, which correspond to 23 industries in the ISIC revision 3 categorization.

Johnson and Noguera [Johnson and Noguera, 2012]'s framework of value added is consistent with Trefler and Zhu's [Trefler and Zhu, 2010] extended HOV model.[7]

Assume that there are K sectors and N countries in a year t. Also, output in each sector of each country is produced using domestic factors and intermediate inputs from domestic or foreign suppliers. Define i as the source country, j as the destination country, k as the source industry, and k' as the destination industry. Then market clearing in value is written as follows:

$$y_{it}(k) = \sum_j f_{ijt}(k) + \sum_j \sum_{k'} m_{ijt}(k, k') \tag{3.3}$$

where y_{it} is the value of total output in sector k of country i, $f_{ijt}(k)$ is the value of final goods shipped from country i to country j, and $m_{ijt}(k, k')$ is the value of intermediates from sector k in country i shipped to sector k' in country j. Define exports $x_{ijt}(k)$ as the total value of final goods and intermediate goods exported to country j: $x_{ijt}(k) = f_{ijt}(k) + \sum_{k'} m_{ijt}(k, k')$. Thus, referring to equation (3.3), market clearing condition states that total output is divided between gross exports, domestic final use, and domestic intermediate use. If one stacks the market clearing conditions, we have the total value of goods in each sector in the $K \times 1$ vector y_{it}, and final goods f_{it} also in the $K \times 1$ vector, and the intermediate goods $m_{ijt}(k, k')$ in $K \times K$ vector. Next, define $A_{ijt}(k, k')$ as the share of the intermediate inputs from i by country j where $A_{ijt}(k, k') = \frac{m_{ijt}(k,k')}{y_{it}(k)}$. Then rewrite

[7] See the Appendix:Data

the market clearing conditions as a $K \times N$ matrix where:

$$y_t = A_t y_t + f_{jt} \tag{3.4}$$

where

$$A_t \equiv \begin{pmatrix} A_{11t} & A_{12t} & \dots & A_{1Nt} \\ A_{21t} & A_{22t} & \dots & A_{2Nt} \\ \vdots & \vdots & \ddots & \vdots \\ A_{N1t} & A_{N2t} & \dots & A_{NNt} \end{pmatrix}, \; y_t = \begin{pmatrix} cy_{1t} \\ y_{2t} \\ \vdots \\ y_{Nt} \end{pmatrix}, \; f_t = \begin{pmatrix} \sum_j f_{1jt} \\ \sum_j f_{2jt} \\ \vdots \\ \sum_j f_{Njt} \end{pmatrix}$$

Then, one can write the total output vector as:

$$y_t = (1 - A_t)^{-1} f_t \tag{3.5}$$

where $(1 - A_t)^{-1}$ is the Leontief inverse of the global input-output matrix A_t. The Leontief inverse represents how much output from each country and sector is required to produce final goods, where the vector for final foods is the total world absorption of final goods f_t, which means that f_t includes the final goods themselves and the intermediate goods used in the production process. Then the total output vector can be decomposed into destination specific vectors as follows:

$$\begin{pmatrix} y_{1jt} \\ y_{2jt} \\ \vdots \\ y_{Njt} \end{pmatrix} = \sum_j (1 - A_t)^{-1} \tilde{f}_{jt} \qquad \text{where } \tilde{f}_{ji} = \begin{pmatrix} f_{1jt} \\ f_{2jt} \\ \vdots \\ f_{Njt} \end{pmatrix} \tag{3.6}$$

In equation (3.6), $(1 - A_t)^{-1} \tilde{f}_{jt}$ is the vector of output used directly and indirectly to produce final goods in country j. Using this equation and the proportion of intermediate inputs used to produce final goods $A_{ijt}(k, k')$, total value added from the origin country to the destination can be computed. If the ratio of value added to gross output in sector s of source country i is defined as:

$$r_{it}(k) = 1 - \sum_j \sum_{k'} A_{jit}(k, k') \tag{3.7}$$

Then, the amount of value added from sector k in country i is obtained by multiplying this ratio by the individual element of y_{ijt} as the following equation.

$$va_{ijt}(k) = r_{it}(k)y_{ijt}(k) \tag{3.8}$$

The total value added exports is estimated by summing up all value added amount of each sector as the following equation.

$$va_{ij} = \sum_k va_{ij}(k) \tag{3.9}$$

From the equations above, VAX ratio of sector k in country i is computed by dividing value added by total exports of each sector as:

$$[\text{VAX ratio}]_{ijk} = va_{ij}(k)/x_{ij}(k) \tag{3.10}$$

Value-added exports measure the amount of domestic value added embodied in final expenditure in each industry and destination country. I utilize this sector level data $va_{ij}(k)$ and $[\text{VAX ratio}]_{ijk}$ in two ways: 1) how much value added trade is occurred which is measured by value added exports; 2) and how individual sectors engage in trade which represent production fragmentation measured by VAX ratio.

First, the value added content of trade from country i to country j in industry k is captured by $va_{ij}(k)$. By summing up this value for the country i, I use this value as amount of intermediate goods trade of country i in industry k and estimate the effects of strengthening intellectual property rights on this value added trade.

Second, the sector level VAX ratio in multi-sector framework can be interpreted as international fragmentation of production. For example, assume that two countries, i and j and many sectors k. Under this circumstance, and from the equations above, VAX ratio can be written as: $\frac{va_{12}(k)}{x_{12}(k)} = \frac{r_1(k)y_{12}(k)}{x_{12}(k)}$. Then, this VAX ratio depends on three factors: the value added to output ratio in sector k, $r_1(k)$; the ratio of gross output produced in a sector k of country *1* and absorbed abroad country *2*, $y_{12}(k)$; and the gross exports from the sector k in country *1* to country

2, $x_{12}(k)$. Comparing the magnitudes of $x_{12}(k)$ and $y_{12}(k)$ is not straightforward in the multi-sector case.

Sectoral VAX ratio provides information on how each sector engages in trade. For example, an output of sector k in country 1 can be sold to as an intermediate input for the exporter in country 2. In this case the supplier of this intermediate good in country 1 is indirectly engaged in trade allowing his input to be embodied in the purchaser's exporting good. When this kind of transaction occurs across different sectors, the VAX ratio decreases while value added amount increases. Thus, a lower VAX ratio represents that production fragmentation has deepened. The ratio of value added to gross trade has declined over time, down from around 85 percent in early 1970 (Johnson and Noguera, 2014).

Patent index and patent intensity To measure the strength of IPRs into the model, Park's (2012) IPRs index is used. Two approaches are most commonly used in previous literatures assessing the effect of strengthening IPRs. First, the index of Rapp and Rozek [Rapp and Rozek, 1990] is based on the adherence of each country's patent laws in 1984 to the minimum standards proposed by the U.S. Chamber of Commerce. They rated the patent laws of 157 countries on a scale from 0 to 5. However, this index only considers patents and ignores trademarks and copyrights.

The other way of assessing IPRs of country is Ginarte and Park (1997)'s index, which is updated until 2010. Park's (2012) IPRs index measures the strength of countries' patent policies. This index incorporates five components of patent laws including: extent of coverage, duration of protection, membership to international patent agreements, provisions for loss of protection, and enforcement mechanisms. The index takes values from 0 to 5, with higher values indicating stronger levels of patent protection.

Branstetter et al. [Branstetter et al., 2006] identifies the year of patent reform of 16 countries and use dummy variables for assessing the effect of patent reform using difference in difference and Canals and Sener [Canals and ¸Sener, 2014] follows that measure. However, this year dummy variable is only available for 16 countries and my research begins from 1995, which does not cover the year before identified reform year. Ivus (2012) finds that changes in the strength of IPRs of countries are strongly correlated with their colonial origin and uses a colonial origin dummy for difference in difference estimation.

Since Park's index covers most recent years and also reflects enforcement of a country's patent law as well as allowing analysis over time, this paper employs Park's IPRs index as a measure of IPRs protection.

For measuring patent intensity, I use patent citation data from the NBER U.S. patent citations data, which utilizes USPTO (United Stated Patent and Trademark Office) data. The data comprises detailed information on almost 3 million U.S. patents granted between 1976 and 2006. Based on the assumption that the high number of patents submitted to and granted implies that the industry heavily relies on innovation, the ratio of the number of citations of each industry to the whole manufacturing sector is calculated. Since simple patent count may skew the measure of innovation in terms of economic importance, significance or value, capturing forward and backward spillover effect of patents more precisely captures the reliance on innovation of each industry.[8] Patent intensity of industry i in this study is calculated as the total number of citations in the industry divided by the total number of citations in the whole manufactures.

To match the patent data to value added exports, I use Algorithmic Links with Probabilities' (ALP) developed by Zolas and Lybbert (2012). Zolas and Lybbert (2012)'s ALP matching explicitly links patent and economic data via standard, widely-used product and industry classification systems such as Standard International Trade Classification (SITC) or International Standardized Industrial Classification (ISIC). This approach implicitly reflects differences in patent usage across

[8] Although patents awarded are good indicator of innovation, the value of innovation is not accurately measured by patent count. (Qian, 2007) It has long been known that innovations vary enormously in their technological and economic importance, significance or value, and moreover, that the distribution of such values is extremely skewed. Thus, simple patent counts are seriously and inherently limited in the extent to which they could faithfully capture and summarize the underlying heterogeneity. Encouraged by the finding that citations are correlated with the value of innovations (Trajtenberg, 1990), citations are used

economic sectors. This linkage was utilized as a probability that indicates the likelihood of the matching. Since this study focuses on manufacturing industries, patent citation data is also restricted to the manufactures.

Table 3.2 presents calculated patent intensity. Industries in Machinery and equipment, Medical, precision and optical instruments, Fabricated metal products and chemicals and chemical products have higher patent intensities. On the other hand, tobacco products industry, tanning and dressing of leather, manufacture of luggage, handbags, saddlery, harness and footwear, recycling, and other transport equipment industries have lower patent intensity.

Other data

The human capital data are from the Barro-Lee dataset [Barro and Lee, 2010]. They provide average years of schooling for different age groups of each country. I use the logarithm of the average years of schooling on the population over 25 years old to measure human capital endowment. Since Barro-Lee data is available every five years, I interpolate the variable for every year by linear projection. For estimating physical capital endowments, the logarithm of physical capital per worker from the Global Development Network Growth Database is used.

Since Heckscher-Ohlin model assumes that there are no factor intensity reversals, the share of factor in each industry is fixed. Industry level factor intensity including human capital, physical capital, natural resource, and external finance intensities are measured by using U.S. data for consistency. Human capital intensity and physical capital intensity are calculated using U.S. Census of Manufactures. Following Braun [Braun, 2003], human capital intensity is measured as the industry's average wage of that of the whole manufacturing sector. Physical capital intensity corresponds to each industry's ratio of gross fixed capital formation to that of the whole manufactures.

To expand the empirical model, data on financial openness and natural resources are included. Financial openness is from Chinn-Ito index (KAOPEN) which is an index measuring a country's degree of capital account openness. KAOPEN is based on the binary dummy variable that codifies the tabulation of restrictions on cross-border financial transactions reported in the IMF's Annual Report on Exchange Arrangements and Exchange Restrictions (AREAER). External finance dependence by industry comes from [Rajan and Zingales, 1998] and Klingebiel et. al. [Kroszner et al., 2007]. They define the industry-level tendency of external finance as the ratio of investment minus internal cash flows from operations to capital investments based on data of U.S. firms in COMPUSTAT. Table 3.3 shows the ranking of industry human capital intensities and physical capital intensities.

Data on natural resources are from the World Bank's total natural resources rent data as percentage of GDP and includes sum of oil rents, natural gas rents, goal rents (hard and soft), mineral rents, and forest rents. Natural resources' intensity is reflected in the dummy variable that has a value of 1 for the industries including food; tobacco; wood products except furniture; paper and products; petroleum refineries; miscellaneous petroleum and coal products; other nonmetallic mineral products; iron and steel; chemicals; and metal products.

3.4 Analysis

3.4.1 Results

If a high level of protection is associated with high value added exports in patent-intensive industries, the coefficient of the patent interaction term should be positive. Table 3.4 shows the results for the logged amount of value added contents of export for all manufacturing sectors in 40 countries during the 1995-2010 period. The first column shows the basic regression results only with the IPRs interaction terms of IPRs index and patent intensity in the industry. The second column presents the results of equation (3.1) and the third column presents the results of extended equation (3.2). I focus on the coefficients of the interaction term of IPRs index and patent intensity to measure industry-specific effects.

When only an interaction term of IPRs and patent intensity is considered for the log of value added exports, the estimated effect (SE) is 3.889 (0.546), which is significant and has a 95 percent confidence interval of +2.819 to +4.960. The second column adds an interaction term of human capital intensity and human capital endowments, and of physical capital intensity and physical capital endowments. The estimated coefficient reduces to 1.354 (0.508). The third column adds the vector of interaction terms associated with natural intensity and financial market openness. With these control variables, the estimated effect falls slightly to 0.975 (0.527) and significantly at 10% level. Because it contains the richest set of control variables, I compare the estimate of value added exports to gross exports based on this specification.

The estimates of the interaction term of IPRs and patent intensity on the logged amount of gross exports in Table 3.5 is similar, 0.863 (0.374) with a 95% CI of +0.132 to +1.594. The mean of gross exports is 9.42 with a standard deviation of 1.84. As expected, the estimated effects of factors are greater in value added exports than in gross exports. Both estimated coefficients of the interaction term between IPRs index and patent intensity are positive suggesting that strong protection of IPRs have positive effects on the value added exports and gross exports of patent-intensive industries. From the results, we can see that the effect of patent rights protection is biased positively towards patent-intensive industries both in value added exports and gross exports.

Next, I present the results for the VAX ratio in determining the effects of stronger patent protection in the industry on international fragmentation of production. Table 3.6 shows the same specification as Table 3.4. The first column includes only estimates of IPRs index and patent intensity of industries. The estimated coefficient of an interaction term of the IPRs index and patent intensity is 0.309 (0.080) with a 95% CI of +0.152 to +0.466. When human capital intensity and physical capital intensity are added, the estimated coefficient reduces to 0.148 (0.080). When all control variables are included, the estimated coefficient reduced to 0.102 (0.083), which is the same as the difference between the coefficient for value added exports and coefficient for gross exports, but it is not significant.

The results suggest that high levels of patent protection are associated with a high VAX ratio in patent-intensive industries, indicating lower production fragmentation. Stronger IPRs lead less fragmentation in patent-intensive industries. In other words, countries with higher patent protection have less fragmentation of production in patent-intensive industries. That is, patent-intensive industries in countries with high patent protection tend to participate much in their trade by utilizing their own innovations. Strong IPRs regime in the high-tech industries promotes internal innovation leading to greater varieties of intermediate goods, therefore lowering the price of inputs.

3.4.2 Robustness

I assess the robustness of the main results in two ways: 1) varying IPRs measure; and 2) employing alternative measure of patent intensity; 3) and applying the model into bilateral trade framework.

First, I employ an additional measure of IPRs to verify the results. While Park's IPRs index measures the strengthening of patent protection laws, it does not capture the actual implementation of the laws in the real world. For example, in case of China, it is said that there is large discrepancy between patent laws and implementation although China's IPRs index has been raised over time. Therefore I use the Fraser index[9] complementally to reflect implementation of patent protection as Hu and Png [Hu and Png, 2013] and Zhang et. al [Zhang et al., 2015]. Table 3.7 presents results by employing varied IPRs measures. The estimated coefficients for value added exports are still positive but are not significant. Also,

[9] Legal system and property rights part of the economic freedom index of Fraser Institute focuses on rule of law, security of property rights, an independent and unbiased judiciary, and impartial and effective enforcement of the law. The nine components in this area are indicators of how effectively the protective functions of government are performed. These components are from three primary sources: the International Country Risk Guide, the Global Competitiveness Report, and the World Bank's Doing Business project [Gwartney et al., 2015]. Fraser index in this paper is used to include implementation of patent law of each country. Since this index is released every 5 year until 2000, index for the period from 1995 and 1999 is interpolated every year by linear projection.

the magnitude of estimate is smaller suggesting that the effects of strong IPR laws are moderated by their weak enforcement as results in Chapter 2. Also, the estimated coefficients for the gross exports are smaller but positive and mostly significant. The estimated coefficients for the VAX ratio are still positive but significant in variation 2 and 3 which deviates from the baseline estimation.

Second, I replace patent intensity with Hu and Png's [Hu and Png, 2013]. The patent intensity used in this study is the ratio of the number of citations of one industry to the number of citations of all manufacturing industries. Hu and Png [Hu and Png, 2013] uses USPTO data as well. However, they obtained the ratio of patents granted to sales among US publicly listed companies reported in Compustat and the NBER Patent Database. The difference from the measure used in this study is that Hu and Png's [Hu and Png, 2013] uses patent grant data and reflects the size of industry by combining sales data. Table 3.8 reports estimates of the variables of main interest using alternative measures of patent intensity. Since the alternative measure of patent intensity is smaller, the estimated coefficient of the interaction term between IPRs index and patent intensity gets larger. The results are all positive and close to the main estimates in Table 3.3 and Table 3.4. However, the estimated coefficient for the VAX ratio is more significant than the main estimate.

Third, I estimate the same specification based on bilateral trade equation using the gravity model. Romalis's [Romalis, 2004] specification employed this study is valued for both bilateral trade and multilateral trade. Eaton and Kortum (2002) and Chor (2010) constructed theoretical framework of bilateral trade and this model is adopted into the widely used gravity equation. Bilateral trade flows are determined by country-endowments and industry factor intensities and institutional factors. I employ (i) Heckscher-Ohlin forces, as picked up by the interaction between country factor endowment and industry factor intensities; (ii) IPRs forces, through the interaction between country IPRs strength and industry measure of dependence; (iii) bilateral distance variable; (iv) exporter fixed effects; (v) importer-industry fixed effects. Standard errors are clustered by country pairs.

The basic specification is as the equation below:

$$\ln(y_{ijk}) = \sum_{f=1}^{F} \theta\beta_f(\ln\frac{V_{if}}{V_{i0}})s_{fk} + \theta\beta_{ipr}IPR_{iI} * p_k - \beta_d D_{ij} + I_i + I_{jk} - \theta\zeta_{ij} - \theta\upsilon_{ijk} \quad (3.11)$$

where $\frac{V_{if}}{V_{i0}}$ denotes country factor endowments; s_{fk} is industry factor intensities; $IPR_{iI} * p_k$ is an interaction term of IPRs index and patent intensity; D_{ij} is bilateral distance variables; I_i is exporter fixed effects; I_{jk} is importer-industry fixed effects; and $-\theta\zeta_{ij} - \theta\upsilon_{ijk}$ reflects standard errors clustered by country pair. Using the richest specification as equation (3.2), equation (3.11) can be rewritten as equation equation (3.12):

$$\begin{aligned}\ln(y_{ijk}) = &\sum_{f=1}^{F} \theta\beta_f(\beta_h \ln\frac{H_i}{H_{i0}}h_k + \beta_k \ln\frac{K_i}{K_{i0}}k_k + \beta_f \ln\frac{F_i}{F_{i0}}f_k + \beta_n \ln\frac{N_i}{N_{i0}}n_k) + \\ &\theta\beta_{ipr}IPR_{iI} * p_k - \beta_d D_{ij} + \beta_{RTA}RTA_{ij} + I_i + I_{jk} - \theta\zeta_{ij} - \theta\upsilon_{ijk}\end{aligned} \quad (3.12)$$

where H_i, K_i, F_i and N_i denote country endowment for human capital, physical capital, financial openness and natural resources respectively; h_k, k_k, f_k and n_k denotes industry level intensities; and RTA_{ij} denotes whether trading partners conclude regional trade agreement.

Table 3.9 presents the results. The first and the second columns present the results for the value added exports and gross exports respectively. The third column displays the results of the VAX ratio. The estimated effects of IPRs and patent intensity are stable and significant. Also, the estimated effect of IPR and patent intensity on value added exports is greater than that on gross exports, similar to the aggregated estimation above.

3.5 Concluding Remarks

In this chapter, I considered two questions. First, are stronger IPRs an important determinant of comparative advantage in value added exports? Also, does it have a different effect compared to the case of gross exports? The results show that stronger patent protection has a positive effect on both value added exports and gross exports in patent intensive industries. The effect is bigger in value added exports. Countries with high levels of patent protection specialize in high-tech industries while countries with low levels of protection specialize in low-tech industries. That is, the effect of stronger patent protection is biased positively towards patent-intensive industries in both value added exports and gross exports.

Second, what effect does strong IPRs have on production fragmentation estimated by VAX ratio? The results suggest that high levels of patent protection are associated with a high VAX ratio in patent-intensive industries indicating lower production fragmentation, which means stronger IPRs lead to less fragmentation in patent-intensive industries. In other words, countries with higher patent protection have less fragmentation of production in patent-intensive industries.

To check the robustness of the results, I employ variation of IPRs measure, alternative measure of patent intensity as well as alternative empirical estimation including gravity. All estimates support the baseline results providing evidence that countries' strong patent protection is an important determinant of comparative advantage in patent intensive industries.

Table 3.1: Descriptive Statistics

Variable	**Mean**	**Std. Dev.**	**Min**	**Max**
VAX ratio	0.63	0.42	0.00	3.84
Value added exports	$39,516$	$94,428$	0.18	$1,719,281$
Gross exports	$47,438$	$90,423$	39.64	$1,514,821$
ln(VAX ratio)	0.45	0.26	0	1.58
ln(Value added exports)	8.61	2.31	0	14.49
ln(Gross exports)	9.42	1.84	3.68	14.38
Year of Schooling	9.74	2.20	3.51	13.42
ln(Gross fixed capital)	25.19	1.61	20.55	28.74
IPR Index	4.02	0.70	1.23	4.88
Rent for natural resources (% of GDP)	2.58	5.19	0.00	42.96
ITO-CHINN financial openness Index	0.74	0.34	0.00	1.00
Human capital intensity	0.07	0.03	0.01	0.14
Physical capital intensity	0.08	0.05	0.00	0.19
Patent intensity	0.04	0.04	0.00	0.17
Natural resources intensity	0.43	0.49	0.00	1.00
Financial market openness intensity	0.11	0.10	0.01	0.31

All variable are averaged for 1995-2010. Number of observation is 7,627.

Table 3.2: Patent Intensity by Industry

ISIC rev. 3	Patent Intensity	Descriptions
29	0.174	Machinery and equipment. e.c.
33	0.093	Medical, precision and optical instruments, watches and clocks
28	0.084	Fabricated metal products except machinery and equipment
24	0.082	Chemicals and chemical products
32	0.075	Radio, television and communication equipment and apparatus
30	0.068	Office, accounting and computing machinery
17	0.066	Textiles
26	0.058	Other non-metallic mineral products
18	0.055	Wearing apparel; dressing and dyeing of fur
27	0.039	Basic metals
22	0.030	Publishing, printing and reproduction of recorded media
31	0.027	Electrical machinery and apparatus n.e.c.
15	0.025	Food products and beverages
36	0.025	Furniture; manufacturing n.e.c.
25	0.022	Rubber and plastics products
20	0.017	Wood and products of wood and cork, except furniture
21	0.017	Paper and paper products
23	0.014	Coke, refined petroleum products and nuclear fuel
34	0.013	Motor vehicles, trailers and semi-trailers
35	0.007	Other transport equipment
37	0.004	Recycling
19	0.003	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear
16	0.001	Tobacco products

Note: Calculated by author from NBER patent citation data (http://www.nber.org/patents/). Industry descriptions are from UN Statistics Division (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2). IPC Code in NBER patent data is converted into ISIC revision 3 using ALP concordance with the propensity [Lybbert and Zolas, 2012]. Despite of different method of calculating patent intensity, the ranking is similar to [Vichyanond, 2009].

Table 3.3: Table 3.6: Industries with Extreme Factor Intensities

Most Labor-intensive Industries		
Rank	**ISIC rev. 3**	**Descriptions**
1	15	Food products and beverages
2	21	Paper and paper products
3	27	Basic metals
4	29	Machinery and equipment
5	24	Chemicals and chemical products
6	23	Coke, refined petroleum products and nuclear fuel
7	34	Motor vehicles, trailers and semi-trailers
8	20	Wood and products of wood and cork, except furniture
9	22	Publishing, printing and reproduction of recorded media
10	26	Other non-metallic mineral products
Most Capital-intensive Industries		
Rank	**ISIC rev. 3**	**Descriptions**
1	15	Food products and beverages
2	16	Tobacco products
3	24	Chemicals and chemical products
4	27	Basic metals
5	29	Machinery and equipment
6	32	Radio, television and communication equipment and apparatus
7	21	Paper and paper products
8	34	Motor vehicles, trailers and semi-trailers
9	23	Coke, refined petroleum products and nuclear fuel
10	33	Medical, precision and optical instruments, watches and clocks

Note: Calculated by author from US Census Manufacturing Data (http://www.census.gov/econ/manufacturing.html). Industry descriptions are from UN Statistics Division (http://unstats.un.org/unsd/cr/registry/regcst.asp?Cl=2). NAICS 2002 and 2007 are converted into ISIC revision 3 with the propensity using concordance table of UN Statistics Division.

Table 3.4: Effects of Country Endowment and Factor Intensities on Value Added Exports (1995-2010)

Variables	ln(Value added exports)	ln(Value added exports)	ln(Value added exports)
PR index∗patent intensity	3.889***	1.354***	0.975*
	(0.546)	(0.508)	(0.527)
IPR index	0.496***	0.985***	0.936***
	(0.086)	(0.097)	(0.099)
Skill∗skill intensity		7.167***	6.815***
		(0.710)	(0.711)
Skill		-3.343***	-3.056***
		(0.270)	(0.272)
Capital∗capital intensity		0.880*	1.257***
		(0.454)	(0.468)
Capital		0.294***	0.240***
		(0.055)	(0.056)
Natural resources∗natural resources intensity			0.327***
			(0.045)
Natural Resources			-0.308***
			(0.035)
Financial openness∗financial market intensity			-1.445***
			(0.386)
Financial Openness			0.633***
			(0.082)
Constant	7.326***	1.717*	1.919**
	(0.082)	(0.897)	(0.910)
Year fixed effect	Yes	Yes	Yes
County-Industry fixed effect	Yes	Yes	Yes
Adjusted R^2	0.971	0.973	0.974

Notes: Estimate (Tow way clustered robust standard errors by country-industry pair). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 7,627. Year, country, and industry fixed effects are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Table 3.5: Effects of Country Endowment and Factor Intensities on Value Added Exports and Gross Exports (1995-2010)

Variables	ln(Value added exports)	ln(Gross exports)
IPR index∗patent intensity	0.975*	0.863**
	(0.527)	(0.374)
IPR index	0.936***	0.655***
	(0.099)	(0.058)
Skill∗skill intensity	6.815***	0.796**
	(0.711)	(0.385)
Skill	-3.056***	-1.209***
	(0.272)	(0.146)
Capital∗capital intensity	1.257***	0.577*
	(0.468)	(0.295)
Capital	0.240***	0.367***
	(0.056)	(0.030)
Natural resources∗natural resources intensity	0.327***	0.091***
	(0.045)	(0.025)
Natural Resources	-0.308***	-0.126***
	(0.035)	(0.020)
Financial openness∗financial market intensity	-1.445***	0.202
	(0.386)	(0.240)
Financial Openness	0.633***	0.488***
	(0.082)	(0.046)
Constant	1.919**	0.090
	(0.910)	(0.570)
Year fixed effect	Yes	Yes
County-Industry fixed effect	Yes	Yes
Adjusted R^2	0.974	0.986

Notes: Estimate (Tow way clustered robust standard errors by country-industry pair). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 7,627. Year, country, and industry fixed effects are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Table 3.6: Effects of Country Endowment and Factor Intensities on VAX ratio (1995-2010)

Variables	ln(VAX ratio)	ln(VAX ratio)	ln(VAX ratio)
IPR index∗patent intensity	0.309***	0.148*	0.102
	(0.080)	(0.080)	(0.083)
IPR index	-0.024*	0.012	0.013
	(0.014)	(0.015)	(0.015)
Skill∗skill intensity		0.476***	0.487***
		(0.098)	(0.098)
Skill		-0.154***	-0.146***
		(0.042)	(0.042)
Capital∗capital intensity		0.153**	0.184**
		(0.075)	(0.075)
Capital		-0.033***	-0.036***
		(0.010)	(0.010)
Natural resources∗natural resources intensity			0.041***
			(0.008)
Natural Resources			-0.034***
			(0.006)
Financial openness∗financial market intensity			-0.178***
			(0.055)
Financial Openness			0.048***
			(0.013)
Constant	0.454***	1.050***	1.062***
	(0.013)	(0.156)	(0.155)
Year fixed effect	Yes	Yes	Yes
County-Industry fixed effect	Yes	Yes	Yes
Adjusted R^2	0.943	0.944	0.944

Notes: Estimate (Tow way clustered robust standard errors by country-industry pair). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 7,627. Year, country, and industry fixed effects are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Table 3.7: Effects of Country Endowment and Factor Intensities on All Outcomes using Variation of IPRs index (1995-2010)

Variables	ln(Value added exports)	ln(Gross exports)	ln(VAX ratio)
Baseline			
IPR index×patent intensity	0.975*	0.863**	0.102
	(0.527)	(0.374)	(0.083)
IPR	0.936***	0.655***	0.013
	(0.099)	(0.058)	(0.015)
Variation1			
IPR index×Fraser index×patent intensity	0.011	0.189*	0.043
	(0.188)	(0.113)	(0.031)
IPR index×Fraser index	0.660***	0.471***	-0.004
	(0.097)	(0.051)	(0.015)
Variation2			
(IPR index×Fraser index)$^{\frac{1}{2}}$×patent intensity	0.168	0.276**	0.067*
	(0.226)	(0.138)	(0.037)
(IPR index×Fraser index)$^{\frac{1}{2}}$	0.621***	0.472***	-0.005
	(0.085)	(0.045)	(0.013)
Variation3			
(IPR index+0.5×Fraser index)×patent intensity	0.143	0.108	0.233***
	(0.576)	(0.341)	(0.097)
(IPR index+0.5×Fraser index)	1.614***	1.388***	-0.033
	(0.169)	(0.086)	(0.027)

Notes: Estimate (Tow way clustered robust standard errors by country-industry pair). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 7,627. Year, country, and industry fixed effects are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Table 3.8: Effects of Country Endowment and Factor Intensities on All Outcomes using Alternative Patent Intensities (1995-2010)

Variables	ln(Value added exports)	ln(Gross exports)	ln(VAX ratio)
IPR index∗patent intensity	15.047***	13.148***	0.800***
	(1.971)	(1.463)	(0.302)
IPR index	0.493***	0.270***	0.000
	(0.100)	(0.059)	(0.018)
Year fixed effects	Yes	Yes	Yes
Country-Industry fixed effects	Yes	Yes	Yes
Adjusted R^2	0.974	0.987	0.944

Notes: Estimate (Tow way clustered robust standard errors by country-industry pair). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 7,627. Year, country, and industry fixed effects are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Table 3.9: Effects of country endowment and factor intensities on all outcomes using bilateral specification (1995-2010)

Variables	ln(Value added exports)	ln(Gross exports)	ln(VAX ratio)
IPR index∗patent intensity	1.048***	0.111***	0.417***
	(0.060)	(0.036)	(0.012)
Human capital∗human capital intensity	3.226***	1.508***	0.200***
	(0.107)	(0.056)	(0.016)
Physical capital∗physical capital intensity	0.214***	0.021**	0.078***
	(0.019)	(0.011)	(0.003)
Financial openness∗	-2.326***	0.068	-0.642***
financial openness intensity	(0.143)	(0.084)	(0.022)
Natural resources∗natural resources intensity	0.152***	0.074***	0.012***
	(0.022)	(0.008)	(0.004)
ln(Distance)	-1.320***	-1.421***	-0.021***
	(0.037)	(0.055)	(0.002)
RTA	0.098**	0.069	-0.004
	(0.048)	(0.077)	(0.004)
Common language	0.208**	0.245	-0.003
	(0.104)	(0.180)	(0.006)
Constant	7.178***	17.076***	-1.533***
	(0.504)	(0.557)	(0.074)
Exporter fixed effects	Yes	Yes	Yes
Importer-industry fixed effects	Yes	Yes	Yes
Adjusted R^2	0.729	0.857	0.272

Notes: Estimate (Two way clustered robust standard errors by exporter and importer). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. The number of observation is 210,112. Exporter fixed effects and importer-industry fixed are included in the regression. Logged amount of average years of schooling age over 25, gross fixed capital, rent for natural resources as % of GDP, and Ito-Chinn financial openness index are used for estimation.

Chapter 4

Effects of Union Certification on Workplace-Safety Enforcement: Regression-Discontinuity Evidence

4.1 Introduction

Since 1970, the federal Occupational Safety and Health Act has defined federally-protected rights for American, private-sector workers to safe and healthy workplaces. The Occupational Health and Safety Administration (OSHA) works to uphold these rights through enforcement and education using its own agency resources directly and by leveraging partnerships with other organizations including state governments, research institutes, employers, and labor unions. Under the Act, workplaces must meet specific standards and employees have rights to initiate OSHA inspections, to participate in inspections and in pre- and post-inspection meetings, and in administrative proceedings. Union activities may serve as a complement to OSHA's direct expenditures and enforcement efforts. If unions are effective, declining private-sector unionization may make the Department of

Labor's (DOL) job more difficult.

Labor unions tend to share the DOL's interests in ensuring safe and healthy workplaces. In collective bargaining and labor-management relations at unionized firms, they often push to increase health and safety along with improvements in other terms and conditions of employment. To some extent, unions educate workers about the nature of their legal rights, facilitate exercise of these rights, and work to ensure such rights are protected by encouraging vigorous enforcement against violations. Unionized workers may also be more likely to understand their rights under OSHA and to report potential health and safety violations, request inspections, and participate directly or through a labor representative in the inspection process.

Smith [Smith, 1986] and Weil [WEIL, 1991] pioneered study of these processes. They provide thoughtful, thorough discussion of ways that unions can promote enforcement of workers' OSHA rights.[2] Morantz [Morantz, 2013] provides a more recent look focused on the coal mining industry and the Mine Safety & Health Administration (MSHA), which has a much more intensive regulatory regime than OSHA. To develop empirical evidence, Smith studies data at the industry-year level from 1977-1979 and observes a positive association between the unionization rate and the rate of worker-initiated complaint inspections controlling for a few other industry-year characteristics. Weil studies OSHA enforcement data combined with business-census data from the manufacturing industry in the year 1985. He compared union to nonunion establishments in a broad cross-section with respect to their inspection probabilities, probability of having a labor-representative participate in inspections, level of violations cited, and level of penalties. In each case, he found large differences between union and nonunion establishments. We extend the analysis beyond manufacturing to the whole private economy and beyond a single year of data to 27 years. Morantz controls for more observable factors than Smith or Weil could and also finds evidence of more intensive enforcement in unionized workplaces.

[2] This is an example of a *rights-facilitating* effect of unions, a term coined by Budd & McCall

Interpreting those observed differences is a challenge given the prior data's limited ability to support tight comparison across otherwise-similar establishments. Perhaps unions do cause stricter enforcement through the mechanisms described above and, thereby, create the differences observed. Or, omitted variables that are correlated with both union status and outcomes could drive the outcome differences while unionization *per se* has no effect. For example, in establishments that are more dangerous, workers may be more likely to unionize and OSHA may be more likely to inspect, cite, and penalize. Without an ability to compare tightly-similar establishments with respect to their underlying safety levels and propensities to unionize, it is difficult to credibly isolate the causal effect of unions.

To overcome this obstacle, regression discontinuity design (RDD) compares establishments where unions barely won National Labor Relations Board (NLRB) union-certification elections to establishments where unions barely lost such elections ([DiNardo and Lee, 2004],[Sojourner et al., 2015]; [Frandsen, 2013]). Rather than comparing union to nonunion establishments generally and relying on statistical controls and untestable identifying assumptions vulnerable to selection bias, we restrict attention only to establishments where employees indicated an interest in unionizing such that the NLRB held a union-certification election. At the time of the election, establishments where the union just won narrow elections are very similar to establishments where the union just lost such elections. After the election, unions are certified as collective-bargaining agents in the former set of establishments but not in the latter set. Around the 50% vote-share threshold, this generates a quasi-random assignment of union certification to establishments and helps overcome the omitted-variables problem. Each establishment experiencing an NLRB election in the last three decades is connected to any relevant OSHA inspection records from the OSHA enforcement database covering 1985 to 2011.

In the years after the election, did the two sets of establishments experience

[John W. Budd, 1997] where they develop evidence unions help workers exercise their rights to access unemployment-insurance benefits.

different inspection probabilities, probabilities of having a labor-representative present on inspections, levels of violations cited, and levels of penalties assessed? These comparisons provide credible estimates of the local average treatment effects of union certification on the margin. This is related to, but different than, the effect of unionization *per se*. About half of establishments where unions are certified sign first contracts. In the other half, unionization tends not to follow certification. Furthermore, RDD is most informative about the effects of unionization on the margin of certification, rather than their effects of unionization where unions have overwhelming worker support ([Sojourner et al., 2015],[DiNardo and Lee, 2004]). This is the most relevant margin to understand the effects of policy changes that would make it marginally easier or harder to get union certification, such as card check or faster elections. Further, we do the best the OSHA enforcement data allow to construct measures of occupational injury in each establishment and to analyze effects on reported injuries, though the data have substantial limitations for this purpose.

An important advantage of RDD over designs that simply try to adjust for observed differences in control variables is that the assumptions needed for RDD imply falsifiable conditions [DiNardo and Lee, 2010]. Our data fail one type of falsification test: that the distribution of vote shares should be smooth, rather than displaying sharp jumps or drops, at the 50% threshold. However, it passes a second falsification test. Like an experiment, there should not be any difference in the distribution of observable characteristics between the "treatment" and "control" groups *prior* to treatment. In our context, this means there should be no difference *prior* to the election between establishments where unions later barely win and those where they later barely lose. Analysis of the pre-election versions of the OSHA outcomes and characteristics of the establishments observed from the NLRB elections yields no evidence of differences, supporting the validity of the RDD assumptions. Rather than rely simply on the RDD design, we also harness the longitudinal nature of the data to build in a difference-in-differences (DiD) logic to the analysis as well. In predicting each establishment's post-election outcomes, we study if establishments where unions barely won elections have different outcomes than those where they barely lost *controlling for each establishment's own lagged outcomes and characteristics*. Either RDD or DiD is strong alone but each makes different identifying assumptions. Combining them provides some insurance against violations of the assumptions of either [Frandsen, 2013].

4.2 Design and Data

Index establishments by $i = 1, 2I$ and suppose each has only one union-certification election. Interest centers on the average effect of the union winning an election, indicated by D_i. The forcing variable that which governs selection into union certification is the election's pro-union vote-share (X_i).[3] As in Lee & Lemieux [Lee and Lemieux, 2010] and Sojourner et al [Sojourner et al., 2015], the basic model for any given outcome (Y_i) is:

$$Y_i = D_i\tau + f(X_i) + W_i\delta + \varepsilon_i \tag{4.1}$$

Union certification, D_i, depends deterministically on vote share, $D_i = 1[X_i > 0]$ and f is assumed to be continuous at 0. Other pre-election observable determinants of the outcome (W_i), including lagged outcomes, can serve as control variables.

The causal effect of union certification near the certification threshold is identified as τ under the following continuity assumption on unobservable influences (ε_i):$lim_{x\uparrow 0}E[\varepsilon_i|W_i, X_i = x] = lim_{x\downarrow 0}E[\varepsilon_i|W_i, X_i = x]$. This assumes that unobserved factors influencing the outcome do not jump in a discontinuous manner at the election-victory threshold. Because the only factor that can shift discontinuously at the threshold is union certification (D), any observed differences in

[3] We transform raw vote shares following DiNardo & Lee [DiNardo and Lee, 2004]. We create 20 bins of width 5 percent and consider each establishment to have the vote share of the mid-point of its bin so that the possible values of X do not vary with the number of votes cast in the election. We also re-center so that the union-victory threshold has the value zero.

outcomes across the threshold after the election can be interpreted as the causal effect of union certification on the margin.

The study population is all U.S. private-sector establishments on the margin of unionization between 1985 and 2009 as measured by the establishment experiencing at least one NLRB certification election during this period. The study starts with January 1985 because this is the first year any occupational fatalities are recorded in the OSHA enforcement database [U.S. Department of Labor, 2014]. Over this time, the NLRB election database contains 79,390 elections with a valid election month, election year, industrial classification code, state, establishment name, and counts of employees voting in favor of and against unionization. In some cases, the data contain establishment street address. We integrate two databases that compile and standardize NLRB election records: one from Holmes (2006) that includes elections during 1977 to 1999 and which includes many establishments' street address and a second provided by Hank Farber covering 1962 to 2009 but lacking street address.

Because any establishment can have multiple NLRB elections over time, a matching algorithm is used to construct longitudinal, unique-establishment identifiers within the NLRB elections database. Across the set of elections in establishments in the same state, city, and industry (strict match after cleaning), the algorithm links elections in establishments with similar names and addresses (fuzzy match after cleaning). This identifies 72,187 unique establishments. Appendix C.1 provides additional detail on the records-matching process.

Next, establishments with NLRB elections are linked to records in the OSHA enforcement database. The OSHA database records all the administrative enforcement actions carried out by the federal OSHA and federally-approved state OSH agencies covering U.S. private sector establishments from 1985 to 2012. This period includes 3,246,794 inspection records across the U.S. private-sector economy. For each inspection, the establishment's name, address, city, state, and industry are observed. The database also contains records of Fatality and Catastrophe Investigation summaries (OSHA Form 170), which are developed after an inspection triggered in response to a reported fatality or catastrophe [U.S. Occupational Safety and Health Administration, 2016]. These are the source of our establishment level data on reported fatal and nonfatal injuries.

Our focus is only on OSHA records from establishments that experienced NLRB elections. For each OSHA record, we look for a match among all the NLRB election records using strict matching of establishment's city, state, and industry along with fuzzy-matching on name and address. Using the NLRB-based establishment identifiers, this yields a longitudinal database of unique establishments each linked to any associated NLRB elections and OSHA enforcement data. This procedure produces links 48,671 OSHA records to 16,166 unique establishments that underwent NLRB certification elections, implying that 22.4 percent of such establishments are linked to any OSHA record. The other 77.6 percent of establishments with NLRB elections are measured to have no OSHA enforcement actions during the study period.

Analysis focuses on the subsample of NLRB elections meeting the following criteria:

1. *At least 20 individuals voted*: a vote-total floor minimizes the risk that the exact outcome could be manipulated by the company, the union, or workers, which would somewhat undermine the quasi-randomization across the vote-share threshold [Frandsen, 2012].

2. *Election occurs between 1985 and 2009*: before 1985, records of fatal injuries are almost completely absent from the OSHA database (Appendix Figure C.1). Even after 1985, the OSHA fatality data is highly incomplete. The OSHA data includes only about two-fifths as many fatal occupational injury reports as the more-complete Census of Fatal Occupational Injuries (CFOI) across the years both are available (Appendix Figure C.2). However, focusing on elections occurring after 1985 ensures a positive probability of observing occupational fatalities prior to the election, giving a meaningful pre-election injury measure for use as a control variable and in testing for

valid RD conditions. Our NLRB election data end in 2009.

3. *First such election observed in an establishment* : Considering multiple elections for the same establishment raises a number of conceptual questions about whether an establishment should be considered as treated (union wins) or control (union loses). Focusing on only the first election meeting criteria 1) and 2) in each establishment sidesteps these thorny issues. This election is termed the establishment's focal election [Sojourner et al., 2015]. This is a conservative standard that may attenuate estimated effects. If a subsequent election has the same result as the focal election, this does not introduce measurement error. If a subsequent election has the opposite result, we are less likely to find an effect because the establishment then truly has a mix of certified and not-certified units rather than having the pure status measured by the focal-election result. Another issue raised by multiple elections is the possibility that unions or management learn enough through recently-past elections to manipulate the outcome of the election in such a way as to introduce systematic differences across the threshold in unobservables and, thereby, invalidate the RD identifying assumption. This concern diminishes as the time between elections extends. Therefore, any establishment that experienced an NLRB election, regardless of outcome, in the 5 years immediately prior to the focal election is excluded.

4. *No evidence of prior unionization*: Using the NLRB data back to 1962, any establishment where any union was certified prior to the focal election is excluded. This clarifies the interpretation of the treatment as a contrast between establishments with no unions previously certified as bargaining agents and those with any union so certified [Sojourner et al., 2015]. However, our rules would fail to exclude establishments certified or unionized prior to the focal election if workers voted prior to 1962 or unionized outside the NLRB process, or if our linking process missed a longitudinal match to a prior union election victory.

5. *Valid number of votes*: the number of total recorded votes must not exceed the number of eligible voters (bargaining-unit size).

Filtering on criteria 1 and 2 reduces the number of unique establishments and focal elections to 42,430. After implementing criteria 3, 4 and 5, the number of unique establishments shrinks to our analytic sample is 31,052 establishments. As described at the top of Table 4.1, the average raw vote share was 49 percent, a union won a majority in 44 percent of focal elections, and the average number of eligible voters was 107. In the analytic sample, 26.2 percent of establishments have at least one linked OSHA record from between January 1985 to December 2011, similar to the link rate in the overall NLRB sample. The other 73.8 percent have no linked OSHA record.

4.3 Outcome measures

Five outcome variables are measured for each establishment. Relative to each establishment's unique focal election, a post-election and a pre-election measure of each variable is constructed. Post-election measures serve as outcomes, contrasted across the certification threshold to estimate the union-certification effect. Pre-election measures serve three purposes. First, they allow for falsification testing. The assumptions of RDD imply the testable prediction that there should be no discontinuity in the distribution of pre-election observables across the threshold. Second, they serve as control variables to reduce bias that may arise from violations of the RDD conditions. Third, they increase estimates' precision by helping explain post-election outcomes and, thereby, reducing the role of unobservable influences.

We develop three measures of the intensity of OSHA enforcement activity at each establishment in the post-election period and one measure of labor's active involvement in the inspection process. First, to measure each establishment's post-election inspection rate, count the number of post-election inspections, those between the focal-election month and the end of the study period (December

2011). Compute the length of the establishment's post-election period in years: post-election months/12. The post-election inspection rate is the count of inspections over the length of the period or, equivalently, the average number of inspections per year post-election. We measure pre-election inspection rates analogously using January 1985 as the start. In the pre-election period, the average annual inspection rate is 0.04 with standard deviation 0.21, implying an average of 4 inspections performed annually per 100 establishments in our sample. Post-election, the annual inspection rate is 3 per 100 establishments. For 2014, OSHA reports a total of 83,380 federal or state-plan inspections. The Bureau of Labor Statistics reports 9.1 million private-sector establishments in 2014Q3, implying an annual inspection rate of 0.9 inspections per 100 establishments overall. Establishments in our sample appear more likely to be inspected than establishments in general.

Second, the exercise of walkaround rights [WEIL, 1991] at each establishment in each period is measured by the share of inspections attended by a labor representative. In the pre-election period, an average of 2 percent of inspections were attended by labor representatives. For research purposes, it is heartening that this share is so low because we construct the sample to focus on establishments with no union representation in the pre-election period. For program purposes, it is sobering evidence that workers rarely exercise their rights to participate in OSHA inspections absent a union. Pre-election labor-representative share also serves to control for differences in pre-election unionization across establishments that our sample-construction rules miss. Analyzing the effect of certification on post-election exercise of walk-around rights also generates empirical evidence on the extent to which certification drives unionization *per se*. Evidence that certification lifts the share of inspections attended by labor representatives would give validity to interpreting certification effects as informative about unionization effects. Finally, this provides an estimate of certification effects on exercise of federal walkaround rights, the most credible evidence on a union rights-facilitation effect in the literature.

Third, combining multivariate data on each establishment's OSHA violations yields a single index measuring the establishment's degree of OSHA violations cited. For each inspection at an establishment, OSHA assigns a number of current violations for each of 5 types of violations: Serious, Willful, Repeated, Other, and Unclassified. Figure 4.1 displays an example of the kind of violation and penalty data available from each inspection. We focus on Serious, Willful, and Repeated violations because Other and Unclassified violations are extremely rare. For each establishment and each of the three types of violation, sum the number of violations across all post-election inspections and divide through by years at risk. Do the same for the pre-election period. This measures the average annual number of violations of each type in each period. The distribution of these are highly-skewed with large masses at zero violations. Log-transform using log(1+average number of violations per year) to reduce the influence of outliers. Motivated by the idea that the three types of violations are all generated by a single, latent establishment propensity to violate, we factor analyze the three pre-election log-violation-rates across establishments to find the single latent factor that explains the most variance in violation rates, obtain scoring coefficients, and score each establishment based on its three, measured pre-election log-violation-rates. The top of Table 4.2 provides summary statistics for log-violation rates across establishments in the sample. Column 1 (2) presents pre-election (post-election) establishment averages and standard deviations. Column 3 presents scoring coefficients from the factor analysis. These coefficients imply that each establishment's violations score in each period is $0.328 * log$(1+average serious violations per year)$+0.201*log$(1+average willful violations per year)$+0.319*log$(1+average repeated violations per year). We score each establishment in the post-election period using its three, measured post-election log-violation-rates with the same, pre-election scoring coefficients because the sets of establishments are more homogeneous prior to the election than afterwards. To give the score a meaningful scale, we standardize in the post-election control group. We compute the mean and standard deviation (SD) of the score in this subsample and then use these moments to standardize all pre- and post-election observations. Effects will be measured relative to the SD of outcomes where unions lose the focal election. There is little difference between average violation indexes pre- versus post-election (Table 4.1). The minimum of -0.24 and maximum of 71.06 post-election shows that, even with log-transformations, the standardized index remains highly skewed. It has a large mass at the minimum corresponding to those with no inspections or with inspections without violations.

This measurement approach has many advantages. It pools information across three highly-correlated violation measures to produce a single, low-noise, post-election measure for use as an outcome. It provides a single pre-election control variable, rather than three that would likely suffer from multicollinearity. By reducing both measurement error in the outcome and multicollinearity in the predictors, this approach should boost the precision of estimated certification effects ($\hat{\tau}$). Finally, it allows the observed correlation structure between the three measures to determine the optimal way to weight them into a single factor rather than using *ad hoc* weighting as is conventional when the sum of violations of all types is used.

A disadvantage is that the units of this violations index are not easily comparable to the conventional, count-of-violations measure. To address this, we divide the set of establishments in the post-election control group into percentiles based on values of the violation index. Each percentile contains about 175-180 establishments with tightly-similar values of the index. Within each percentile, we compute the average total number of post-election violations across the establishments. The percentile containing the mean violation-index value ($z = 0$) has an average number of violations equal to 1.1. The percentile containing the establishments with violation-indices two SD above the mean ($z = 2$) has an average number of violations of 10.2 violations. So, moving two SD up from the mean is equivalent to moving up 9.1 total violations over the post-election period. Considering the difference between the $z = 0$ and $z = 1$ ($z = 1$ and $z = 2$) bins implies a difference of 3.6 (5.5) violations. We average these by considering a two

SD difference. Our sample's average post-election period is 16.5 years, so one way to understand an SD of the index is as 0.28 violations per post-election year. The robustness section also presents alternative estimates based on more-conventional measures.

Fourth, to measure OSHA penalties, we use a similar approach to pool information across multiple penalty types. For each establishment in each period, after inflating penalty amounts to 2014 dollars, we measure the average annual penalties assessed of six types: {Serious, Willful, Repeated}×{Initial, Current}. An analogous log-transformation, factor analysis, scoring, and standardization process gives pre-election and post-election penalty index levels for each establishment. The middle of Table 4.2 provides summary statistics for log-penalty rates across establishments in the sample and the scoring coefficients obtained from the pre-election period. Pre-election penalties are 12 percent of a post-election control-group SD lower than the post-election control-group mean. Because violations and inspections did not change much over the same period, this suggests penalties per violation increased over time. Using the same approach as with violations to get a more conventional measure of penalties in dollar terms, moving up two SD of the penalty index from the percentile containing $z = 0$ is equivalent, on average, to moving up by $62,379 in post-election penalties. Therefore, one SD is $1,890 per year.

Fifth and finally, we construct an index of occupational injury risk that pools available data on the average number of workers at each establishment per year reportedly experiencing three types of occupational injuries: fatal, non-fatal but requiring hospitalization, and non-fatal and not requiring hospitalization. These data derive from OSHA's Fatality and Catastrophe Investigation Summaries (OSHA Form 170), as archived in the OSHA Enforcement Database [U.S. Occupational Safety and Health A and are generated only after OSHA conducts an investigation in response to a fatality or catastrophe. The underlying data on occupational injuries is far from perfect. Many injuries are missing and injury presence may be driven by a reporting propensity generated by union certification. Dissatisfaction with OSHA's accounting for fatal occupational injuries spurred the creation of the well-regarded Census of Fatal Occupational Injuries (CFOI) in 1992 but which, unfortunately, does not allow establishment-level matching. We do not use the survey-based injury measures that some prior studies have used because the survey is non-representative and because we limit ourselves to the very small share of establishments that experience NLRB elections (under 2,000 per year among 9.5 million establishments implies less than 0.1%) and the intersection of these two samples would be tiny. Over 1992 to 2011, the OSHA data contains information on about a quarter to a third of the occupational fatalities included in the CFOI (Appendix Figure C.2). The bad news is that our OSHA data misses a large share of injuries. The good news is that the OSHA trend moves with the CFOI trend, so it may contain some useful, if imperfect, information. The motivation and approach are the same as described for violations and penalties above. We use information on bargaining-unit size to convert injury counts of each type into annual injury rates per 100,000 workers.[4] The three injury rates are then factor analyzed, scored, and standardized, as with penalties and violations. We treat the resulting injury index as a proxy for each establishment's underlying occupational injury propensity. One SD in the injury index can be understood as 0.03 injuries per 100,000 employees per year. This seems very small but, at the establishment-year level, the vast majority of establishments have no reported injuries.

Use of the post-election injury index as an outcome is problematic. Suppose that unionization leads to more accurate reporting of injuries to OSHA; measurement error in the injury index would be correlated with the treatment variable.

[4] Over a similar period, Frandsen [Frandsen, 2013] linked NLRB election data to the Census Longitudinal Business Database, which gives a measure of each establishment's number of employees. In establishments with elections, the average number of voters is 93 and average number of employees is 254. He does not report the number of eligible voters nor turn-out rates. In our very-similar sample, among focal elections with more than 20 voters, the average turnout rate #voters/#eligible = 0.89. To estimate the number of establishment employees at the time of the focal election from the number of eligible voters, we compute a scaling factor as #employees/#eligible = #employees∗(turnout rate/#voters) = 254∗(.89/93) = 2.43. So, for each of the three types of injury counts, we construct an injury rate per 100,000 employees per year as (100,000∗#count)/(2.43∗#eligible∗#years).

In a regression of post-election injuries on a union-certification indicator, unionization would appear to lead to more injuries, when actually it may lead to higher reporting conditional on the same (or lower) injury rates. We include the analysis for completeness but do not vest it with much credibility.

4.4 Control variables

Knowing each establishment's history of OSHA inspection frequency, violations, penalties, occupational injuries, and union-representation provides a rich characterization of establishment propensity to have future inspections, violations, penalties, and injuries. For each post-election outcome variable, the most important explanatory factor conceptually is each establishment's own pre-election level on the variable, which we observe. Each establishment's own pre-election levels for the other four outcome variables also serve as predictors.

Each establishment's industry can help explain outcomes and enable more-credible, narrower comparisons. We include a set of indicators of the establishment's major industry division (Appendix Table C.1) and construct a measure of minor industry (2-digit) occupational fatal injury risk using the best data available from all establishments in the U.S. economy and completely external to the OSHA data. We measure the occupational fatality rate for each minor industry each year by the ratio of a) fatal occupational injuries from the Census of Fatal Occupational Injuries (CFOI) per b) thousands of employees in the industry from the BLS Current Employment Statistics [U.S. Bureau of Labor Statistics, 2013]. To reduce measurement error, eleven annual rates, from 1992 to 2002, are averaged within minor industry to construct a cross-section of rates across industries. We similarly construct a measure of minor-industry nonfatal injury and illness rate using the BLS Injuries, Illnesses, and Fatalities data, which was available from 1994 to 2002 [U.S. Bureau of Labor Statistics, 2016]. Across establishments in our sample, the average minor-industry fatal injury risk level is 7.61 fatalities per 100,000 full time equivalent employees (FTE) with SD of 9.45 (Table 4.1). The average annual occupational fatality rate in the U.S. economy broadly fell from 5.0 in 1992 to 4.2 in 2002. The average annual nonfatal injury and illness rate in 2014 was 3.4 per 100 employees, compared to 8.2 in our sample. Establishments in our sample, those experiencing certification elections, are in industries that are about half-again to double as risky as the average among all establishments. Including these industry variables as controls allows our analysis to compare outcomes across establishments in the same industry division controlling for differences in minor-industry risks along with establishment-level pre-election measures of inspections, violations, penalties, labor-representation, and injuries.

4.5 Analysis

4.5.1 Assessing validity of identifying assumption

We present evidence from three falsification tests of the validity of the RD identifying assumption. First, there should be no discontinuity in density of vote-shares across the 50% threshold. Figure 4.2 presents a histogram of binned vote-shares across the sample of establishment focal NLRB elections. Most elections are close, giving a large share of the sample close to the threshold. However, we reject the null of no discontinuity in the density of vote shares across the threshold (t=4.14) [McCrary, 2008]. This result implies a significant discontinuity in the distribution of vote-share values, raising concern about possible post-election manipulation and some degree of violation of the RD identifying condition. If we had only post-election data, violations of the RD condition would be very troubling. However, as Frandsen [Frandsen, 2013] and Sojourner et al [Sojourner et al., 2015] point out, the availability of panel data makes possible a more robust design that combines the logic of difference-in-difference and RD design.

Second, we plot how the pre-election conditional mean of each outcome variable varies as a function of vote-share bin. Consider the left-side of each of the 5 panels of Figure 4.2. Panel (a) displays estimates from a regression of pre-election inspection rates on a set of indicators for each vote-share bin computed with robust standard errors. The left-most estimate is the mean pre-election inspection rate for establishments that went on to have a pro-union vote share between 0 and 5 percent. The 95 percent confidence interval for each conditional mean estimate is also displayed. The other 19 estimates correspond to conditional means in the other 19 vote-share bins. There does not appear to be a discontinuity in the conditional mean at the certification threshold, demarked by the vertical line. If the RDD assumption holds, there should not be. Consider the other 4 pre-election, left-side panels. In each, there is no evidence of a significant difference across the threshold. This is consistent with the validity of the RDD identifying conditions.

Third, we formally test for discontinuity across the threshold in the distribution of pre-election observables. Close to the threshold, there should be none. A "union certification effect" prior to the election would be evidence of systematic differences leading up to the election between establishments where unions will go on to win versus where unions will go on to lose, a violation of the identifying assumption ([Lee and Lemieux, 2010];[Sojourner et al., 2015]). The possibility that such differences might exist far from the threshold is the motivation for an RDD. We implement the test with a seemingly-unrelated regression (SUR) model with 8 pre-election observables as dependent variables: inspection rate, labor-representative share, violations index, penalty index, and injury index, bargaining-unit size in the focal election and its square, and minor-industry (SIC 2-digit) fatal and non-fatal injury rates. Each dependent variable depends on a piecewise linear function of vote-share allowing for different intercepts and slopes on either side of the certification threshold, including a certification indicator. After estimating the SUR system, we test the joint hypothesis that the certification effects for all the dependent variables equal zero and report the p-value.

We perform this test in different subsamples, starting only with establishments that had vote-shares very close to the threshold and expanding the bandwidth for inclusion and sample incrementally. Table 4.3 reports the estimated discontinuity coefficients for each dependent variable, with each column reporting results from a different bandwidth. The joint null of no pre-election differences is not rejected at 10 percent significance at any bandwidth up to 0.325 (which includes focal elections with vote shares between 15-85 percent), consistent with no significant discontinuity in the distribution of pre-election characteristics and with the validity of the RD design using close elections.

4.5.2 Union-certification effects

To start the analysis of effects, inspect the right-side graphs in Figure 4.3's panels. Panel (a) plots the mean post-election inspection rate for each vote share bin. The effect of certification would appear as a discontinuous change in the conditional mean across the certification threshold. Restricting attention to establishments with close elections, there appears to be a slightly higher inspection rate where unions just won compared to where they just lost but the difference appears small in magnitude.

Panel (b) plots the conditional mean of labor-representative share. Here the certification effect is clear. The outcome increases smoothly with vote-share below the certification threshold and also moves relatively smoothly with vote-share above the threshold. However, there is a large, positive discontinuity apparent when the threshold is crossed. The magnitude of the effect appears to be about 0.07. Interpreted causally, this implies that certification causes a 7 percentage point increase in the share of inspections attended by a labor representative. However, accounting for the fact that this outcome is defined only for 26 percent of the sample with any linked OSHA inspections, this could be interpreted as consistent with a 27 percent increase in union-inspection share if all establishments had been inspected.[5] This result provides clear evidence that certification triggers enduring unionization.

In the other figures, effects on violations, penalties, and injuries appear small

[5] For the 74 percent of establishments with no linked OSHA records, "share of inspections attended by labor representatives" is not defined; the denominator is 0. In these cases, we set the measured share to 0. Because the effect of union certification in this 74 percent is 0 by construction, any observed non-zero effect of certification must be driven by the contrast among

or null. Any effects appear to be generated by variations immediately around the threshold, particularly in the (50%,55%] percent pro-union vote-share bin.

To formalize this analysis and to allow for controls, we use regression analysis. We estimate the effect of union certification on each outcome among establishments with NLRB election vote shares within a certain range, a bandwidth, of the certification threshold. We use first-order local-linear regression with a uniform kernel. The bandwidth for each outcome is chosen using the optimality criterion of Imbens & Kalyanaramang [Imbens and Kalyanaraman, 2012]. For each outcome, we estimate 4 specifications, with increasingly rich sets of control variables. Table 4.4 displays the estimated coefficient (SE) on the won-certification indicator (D) from four specifications in columns for each of the 5 outcomes, in panels from top to bottom. The top panel contains estimates of the effect of certification on establishments' annual rate of OSHA inspection. Specification 1 includes only a certification indicator and a piece-wise linear function of vote-share. The estimated certification effect (SE) is 0.00825 (0.0038), which is significant at 5 percent and has a 95 percent confidence interval of +0.001 to +0.016.

Specification 2 adds establishment pre-election inspection rate as a control variable. The estimated certification effect remains similar, 0.00860 (0.00363). The establishment's own lagged outcome is a strong predictor, which raises the adjusted R^2 from 0.0002 to 0.0566. To save space, Table 4.4 only presents estimated coefficients for the 1(union-certified) variable. For the inspection-rate outcome, estimated coefficients for all control variables are in Appendix Table C.2. Most estimates appear sensible. For instance, the establishment's own pre-election inspection rate is a strong predictor of post-election inspection rate. Appendix Table

the 26 percent with linked OSHA records. To approximate the effect if all establishments experienced inspections, one might scale up the estimated effect by a factor of 3.8 (=1/0.26), which implies that certification would cause a 27-percentage point increase in union-representation share. This is plausible given that only about half of certifications lead to enduring unionization [Ferguson, 2008] and not every OSHA inspection in an establishment with any union workers has a labor representative participate. DiNardo & Lee [DiNardo and Lee, 2004] Figure IIIb reports evidence that the probability of reaching first contract is not correlated with vote share, conditional on the union winning.

C.3 to Table C.6 present full estimates for other outcomes.

Specification 3 adds the vector of the other four lagged-outcome variables, size of the bargaining unit, and its square as controls. With these strong control variables, the estimated effect falls slightly to 0.00693 (0.00343) but remains significant. Specification 4 adds the set of industry-division indicators and the minor-industry fatality risk measure as predictors. Because it contains the richest set of control variables, we prefer to focus on specification 4. The estimate is similar, 0.00722 (0.00339) with a 95% CI of +0.0006 to +0.0139. Taken together, this evidence is consistent positive effect of union certification on the probability of OSHA inspection such that, in 1,000 establishments at risk, unionization causes an additional 7.2 inspections per year.

To understand the magnitude, consider a few points of reference. In the private-economy broadly, about 9 establishments per 1,000 were inspected in 2014. The effect would almost double that. In the analytic sample of establishments, the mean post-election inspection rate is 30 per 1,000 with an SD of 110 per 1,000. The estimated effect is about a quarter of the mean level and about 7 percent of an SD.

The second panel of panel of Table 4.4 presents estimates of union-certification effects across the analogous four specifications on labor-representative share. The only difference is that in specification (2), adding the lagged-outcome control here means adding lagged labor-representative share rather than adding lagged inspection rate as we did in the first panel. Across the four specifications, the estimated effect is very stable, the standard error does not rise, and adjusted R2 does. In specification (4), the estimated effect of certification on labor-representative share is 0.0710 (0.00918) with a 95% CI of +0.053 to +0.089. The mean (SD) in the post-election period is 0.06 (0.23) suggesting that the effect exceeds the mean and implies a 0.31 effect size. The estimates' stability as strong control variables are added is consistent with the validity of the research design, as in an experiment. Scaling this up by 3.8 to approximate the effect if all establishments were inspected implies a 0.27 labor-representative share effect. That is, conditional on being inspected, certification raises the probability of having a labor representative accompany the inspector by 27 percent.

The third panel reports the certification effect on the violation index. Again, the estimated effects are stable as more controls are added. In the richest specification, union certification is estimated to cause an increase in cited violations equivalent to 7.88 percent of an SD with a 95% CI of +1.0 percent to +14.8 percent. Recall that increasing the violation index by an SD is, on average, equivalent to having 0.28 additional violations per establishment annually in the post-election, control group. Therefore, a +7.88 percent of a SD effect of union certification on the violation index implies an increase of 2.2 violations per year per 100 establishments.

The fourth panel reports the certification effect on the OSHA penalties index. Estimated effects are again stable but significant at the 10 percent level, not 5 percent. The richest specification yields a point estimate of +7.35 percent of an SD with a 95% CI of -0.002 percent to +15.0 percent. This is similar in magnitude to the effect on violations. Certification causes an additional $139 in penalties per year per establishment on average.

Finally, the fifth panel reports the estimated certification effect on the injury index. Point estimates are stable across specifications. The preferred specification yields a point estimate of +12.0 percent of an SD but is not significant at the 10 percent level. A positive effect here is consistent with some combination of two mechanisms. Certification may actually cause more injuries, a real effect, or it may raise the probability of any injuries being reported to OSHA, a spurious result. The injury index is categorically different than the other outcomes: inspection rate, labor-representative share, violations, and penalties. These are outcomes for which the OSHA data represents a reliable and complete census. In contrast, for injuries, this OSHA data are incomplete. In any case, the estimate is not statistically significant, a null result.

OSHA conducts two types of inspections: programmed and complaint-initiated.

Programmed inspections depend on establishment characteristics other than unionization status and are scheduled centrally by OSHA staff looking across the whole universe of establishments. If analysis found a large effect of union certification on programmed inspection rates, it would be a red flag that the design is flawed, though increased exercise of walkaround rights during programmed inspections could lead to additional violations and penalties. Worker, union, or others' complaints or reported accidents trigger these non-programmed inspections. Union certification should have effects on inspection rates via complaint-initiated inspections. To check whether mechanisms are operating as expected, two separate versions of each outcome are constructed, one based solely on programmed inspections and the other on complaint-initiated ones. To keep units stable, Table 4.2 scoring coefficients are used to construct penalty, violation, and injury indices. [6]Union certification effects are estimated on each.

Table 4.7 displays results. First, the effect of certification on inspection rate operates completely through complaint-initiated inspections, as expected. Second, there are significant increases in the exercise of walkaround rights in both types of inspections, consistent with certification leading to unionization which increases general labor representation in the enforcement process. The effect is stronger for complaint-initiated inspections, consistent with unionization driving these reports. There is weak evidence of an increase in violations and penalties during programmed inspections, suggesting that having labor representatives during inspections increases enforcement intensity somehow. The certification effect does not appear to operate simply through increasing the probability of inspection, although that does happen too. There is also strong evidence for increases in violations and penalties during complaint-initiated inspections. Labor representation somehow also leads to stricter enforcement.

Evidence that certification causes increases in inspection rates, exercise of

[6] There are generally no injuries in programmed inspections so we cannot construct measures there.

walkaround rights, violations, and penalties raises further questions about mechanisms. To give evidence, we measure the share of inspections with any violations at the establishment-level and analyze the effect of certification on this outcome. We get a tight null result an estimated effect of +0.04 percent with 0.85 percent standard error. Certification increases complaint-initiated inspection probability and increases the share of all inspections attended by labor representatives but not the share of inspections finding any violations. This is a null result on the extensive margin of violations. Next we look at the intensive margin of violations: does certification cause more violations or more-severe violations to be found conditional on being inspected and having any violations? Here we start with our baseline estimator of the effect of certification on the violation index (Table 4.4: Spec. 4) and add two additional control variables: an indicator of whether the establishment experienced any post-election inspections to dummy out the no-inspection case and the post-election inspection rate. We want to understand the extent to which an establishment's post-election inspection rate absorbs the certification effect on the violation index. After controlling for post-election inspection rate, the estimated certification effect on the violation index is 0.050 (0.028) with p=0.076. So, this is some evidence that certification increases the intensive margin of violation intensity.

4.5.3 Robustness

We assess the robustness of the main results to four threats to internal validity: misspecification of the longitudinal-matching algorithm to define establishments, alternative choices in the bias-variance tradeoff using alternative bandwidths, strategic manipulation in very close elections, and the use of alternative measures of penalty, violation, and injury propensity. In all this analysis, we use the richest specification, (4), as our baseline and deviate from that baseline in various ways. For compactness, only the estimated union-certification coefficient is presented in each case.

First, we assess the robustness of the main results to misspecification of the longitudinal-matching algorithm to define establishments. The entire analysis is dependent on the algorithm that we used to measure records that belong to the same establishment within and across the NLRB and OSHA datasets. Within state and industry, the matching algorithm penalizes mismatched string values in establishment name, address, and city. Matches with quality above a given threshold are retained. We constructed two alternative measures of which NLRB records belong to the same establishment by varying the threshold up and down. Each defines a somewhat different set of establishments and, consequently, a different set of focal elections. A more-strict, matching criterion generates fewer matches and so more unique establishments and focal elections; less strict implies fewer establishments. The more-strict, baseline, and less-strict criterion imply 31,151, 31,052, and 30,728 unique establishments, respectively. Consequently, all variables defined at the establishment level and the effect estimates vary somewhat. Table 4.5 presents estimates based on the two alternative match-quality thresholds, along with baseline estimates. Across all outcomes, results are stable.

A limitation of our design is inability to distinguish whether an establishment does not show up in the OSHA enforcement data because they are not operating or if they are operating but not inspected. Ideally, we would link to business registry data to distinguish these cases. However, given the nature of our measures and results, under reasonable assumptions, this inability would create a negative bias in estimated certification effects. Outcome measures are attenuated down because an establishment may fail before the end of our observation window. In those cases, we divide through by too many years before standardizing. If certification does not affect survival rates ([Richard B. Freeman, 1999]; [Sojourner et al., 2015]), this measurement error in outcomes is uncorrelated with certification but does diminish the contrast between establishments across the certification threshold, leading the estimator to be attenuated to zero. If certification lowers survival rates, as found in Frandsen [Frandsen, 2013], then the attenuation is stronger in establishments where certification occurs than in those where it does not. This would lead to more negative bias in the estimator of certification effects. Given that our lack of registry data may cause negative bias in our estimator, our estimated positive effects are conservative and consistent with true effects that are larger.

Third, Frandsen [Frandsen, 2013] reports evidence that, in very close elections, post-election legal maneuvering may undermine the key identifying assumption of the RDD. In the elections with the narrowest margins of victory (the smallest difference between the number of pro-union votes cast and the number of pro-union votes necessary for the union to win certification), incentives for manipulation are strongest and there is compelling evidence that management and unions are able to manipulate final vote counts in the elections with the narrowest margins of victory (MOV). As discussed earlier and displayed in Figure 4.2, evidence from the McCrary test is consistent with this kind of violation in our data. To deal with this, in the main analysis, we exploit the panel nature of the data by conditioning on pre-election lagged outcomes and covariates. Here, we use a second approach. Because concern about manipulation is greater when MOV is smaller, we use a donut-RD approach [Barreca et al., 2011], excluding establishments with the smallest MOV and assessing how results change. Results, displayed and discussed in Appendix 15, are qualitatively similar.

Fourth, we use more-conventional measures of violations, penalties, and injuries. For violations, instead of using factor analysis to aggregate across the multiple types of violations, we (1) compute the sum of violations within establishment across types within period, (2) divide by the number of years to produce total violations per year, and then (3) use $log(1+\text{total})$ as the establishment outcome. We do the same for penalties. For injuries, we do the same but apply the scaling factor in step (1) to convert from injury counts to injury rates per 1,000 establishment employees. We use post-election versions as outcomes and pre-election versions as controls. Table 4.6 presents specification (4) results using these alternative measures. Inspection rates and labor-representative have the same outcomes; these estimates differ only slightly from the main result, due only to using alternative measures as controls. Estimated effects on violations, penalties, and injuries all have the same sign and significance levels as in the main results though the magnitudes differ somewhat and there is greater divergence in violations' and penalties' magnitudes than in the main results.

4.6 Conclusion

Union victory in close NLRB certification elections evidently lead to increased occupational-safety law-enforcement activity and increased worker representation in the enforcement process. Union certification increases the share of inspections that have a labor representative participating by 27 percentage points conditional on having any OSHA inspection. This provides the strongest evidence in the literature documenting a rights-facilitation effect of unions. These results imply that falling unionization rates nationally are reducing workers' exercise of their rights to participate in the occupational safety enforcement process and weakening a private actor that may co-produce law enforcement along with agency staff.

Union certification appears to increase OSHA activity inspection rates, violations cited, and penalties assigned each by about 8 percent of a standard deviation. The results are remarkably consistent across outcomes. The rise is partly due to an increase in the rate of complaint-initiated inspections and, conditional on inspection, to the intensive margin of violations more violations and more-extreme violations are found. It does not appear that certification affects the extensive margin of violations, the probability of finding any violations conditional on inspection.

The enforcement effects are driven by a spike in enforcement activity in establishments after unions win very-close elections where the union got more than 50% but not more than 55% of the vote share, not after they win by larger shares. This could be, but is unlikely to be, just a statistical anomaly. However, it does suggest a very localized effect a close certification effect rather than a general certification effect on enforcement activity. It is possible that unions that win by higher votes shares have recourse to alternative means of producing safety or alternative strategies for advancing members' interests and that a strategy of initiating OSHA complaints and advocating for the finding of more severe violations and penalties has appeal particularly to these marginal units.

Despite union effects in increasing OSHA enforcement activity, we do not see evidence of a substantial reduction in occupational injury though we have access only to a flawed measure of injuries.[7] This result is consistent with two basic interpretations. On its face, a na'ive interpretation suggests that increased enforcement activity does not increase safety and that the marginal enforcement activity is wasteful. This is consistent with the finding of Gray and Mendeloff [Wayne B. Gray, 2005] that the effects of OSHA inspections on workplace safety in manufacturing fell to nothing over 1987 to 1998, the first decade of our study period. Other interpretations also merit consideration. First, there may a real effect of unionization in increasing injury risk. Suppose unionization raises hourly pay and fringe benefits and management responds to this pressure on profits by seeking to reduce costs on other margins, including reducing job safety [Fairris, 1995]. In that case, OSHA may become more active either on its own or via increased worker and union reporting. We would observe a positive effect of unionization on OSHA enforcement activity. These enforcement efforts may succeed in holding the line on safety levels, producing a null effect on safety. That is, the enforcement activity may raise safety above what would have been observed if workers unionized, got raises, and did not have recourse to OSHA. Second, certification may raise the likelihood each injury is reported to OSHA. Even if unionization causes injury rates to fall, it may also cause *reported* injuries to rise.

Our result that unionization increases enforcement activity are qualitatively

[7] "Studies of unionism and occupational safety are surprisingly few and disappointingly inconclusive." Morantz makes a related point, "The empirical literature on the relationship between unionization and workplace safety presents a curious puzzle. On the one hand, scholars have documented numerous ways unions help to promote safe work practices. Yet most empirical studies of the relationship between unionization and important safety outcomes, such as injuries and fatalities, have failed to find statistically significant evidence of a 'union safety effect.' " We add to this body of work.

consistent with the results of Weil [WEIL, 1991] and Morantz [Morantz, 2011] but derive from different evidence in important ways. First, our sample looks across all private-sector industries and across all years from 1985 to 2011. Second, we are better able to separate causal effects from associated omitted-variables through strong research design drawing on establishment-level panel data. Third, we estimate the local average treatment effect across the certification threshold rather than an average treatment effect for union versus non-union broadly.

Table 4.1: Summary statistics

Variable	Mean	Std. Dev.	Min	Max
Vote share	0.49	0.23	0.0	1.00
1(Union won election)	0.44	0.5	0.0	1.00
Number of eligible voters	107.06	212.47	20	17195
Post-election				
Inspection rate	0.03	0.11	0.00	6.28
Labor-representative share	0.06	0.23	0.00	1.00
Violation index	-0.006	1.05	-0.24	50.78
Penalty index	-0.006	1.03	-0.27	20.18
Injury index	0.01	1.35	-0.08	121.84
Pre-election				
Inspection rate	0.04	0.21	0.00	12.00
Labor-representative share	0.02	0.15	0.00	1.00
Violation index	-0.03	1.34	-0.24	71.06
Penalty index	-0.12	0.73	-0.27	22.58
Injury index	0.02	2.53	-0.08	220.55
Establishments narrow industry				
Fatal injury rate	7.16	9.45	0.65	40.43
Nonfatal illness and injury rate	8.18	3.11	0.60	14.09

Notes: for each variable, these are summary statistics across the 31,052 establishments meeting sample inclusion criteria. Establishment narrow industry is defined by 2-digit SIC code. Fatal injury rate is per 100,000 employees per year. Nonfatal illness and injury rate is per 100 employees per year.

Table 4.2: Summary statistics for OSHA variables and factor construction

Variable	(1) Pre-election	(2) Post-election	(3) Index-scoring coefficients
Log of Violations; annual number of			
Serious violations	0.034 (0.162)	0.041 (0.156)	0.328
Willful violations	0.001 (0.028)	0.0004 (0.013)	0.201
Repeated violations	0.002 (0.038)	0.002 (0.023)	0.319
Log of Penalty measures; annual averages			
Initial Penalties for:			
Serious violations	0.430 (1.544)	0.733 (2.034)	0.275
Willful violations	0.010 (0.290)	0.021 (0.419)	0.189
Repeated violations	0.041 (0.484)	0.072 (0.669)	0.261
Current Penalties for:			
Serious violations	0.401 (1.449)	0.672 (1.881)	0.267
Willful violations	0.009 (0.260)	0.019 (0.379)	0.191
Repeated violations	0.037 (0.447)	0.065 (0.610)	0.262
Injuries; annual number of			
Fatal injuries	0.398 (15.387)	0.334 (5.169)	0.123
Hospitalizations	0.547 (19.088)	0.581 (10.869)	0.323
Non-hospitalizations	0.225 (9.248)	0.16 (4.884)	0.305

Notes: Annual rates of violations and penalties were calculated by dividing each count by number of years. The number of observation of each variable is 31,052.

Table 4.3: Coefficients on union certified in Seemingly Unrelated Regression at varied bandwidth

Specification:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Bandwidth:	0.025	0.075	0.125	0.175	0.225	0.275	0.325	0.375
Vote-share range included:	(45,55]%	(40,60]%	(35,65]%	(30,70]%	(25,75]%	(20,80]%	(15,85]%	(10,90]%
Pre-election observables								
Pre-election inspection rate	-0.000148	0.00667	-0.00318	-0.00542	-0.00542	-0.00864	-0.00652	-0.00370
	(0.00478)	(0.00972)	(0.00782)	(0.00656)	(0.00585)	(0.00522)	(0.00479)	(0.00451)
Pre-election union-rep share	0.00599	0.00293	0.00661	0.00715	0.00627	0.00607	0.00639*	0.00553
	(0.00410)	(0.00654)	(0.00497)	(0.00419)	(0.00378)	(0.00340)	(0.00315)	(0.00302)
Pre-election violations index	0.0388	0.0796	0.0128	0.0298	0.0296	0.0250	0.0256	0.0237
	(0.0498)	(0.0726)	(0.0581)	(0.0464)	(0.0403)	(0.0359)	(0.0335)	(0.0314)
Pre-election penalty index	0.0244	0.0414	0.0168	0.0377	0.0328	0.0191	0.0187	0.0152
	(0.0233)	(0.0357)	(0.0282)	(0.0237)	(0.0211)	(0.0191)	(0.0177)	(0.0167)
Pre-election injury index	-0.0360	-0.0269	-0.0246	-0.108	-0.0710	-0.0951	-0.0659	-0.0317
	(0.0418)	(0.0712)	(0.0839)	(0.0830)	(0.0701)	(0.0685)	(0.0616)	(0.0587)
Eligible voters	1.616	6.336	14.22	9.746	4.530	-2.273	-5.511	-11.24*
	(6.029)	(8.420)	(7.313)	(6.061)	(5.383)	(4.895)	(5.157)	(4.788)
Eligible voters squared	17867.3	29865.2	43914.1	20061.6	3792.9	1244.9	33254.2	17283.3
	(17753.7)	(20447.0)	(41673.8)	(31627.1)	(26253.4)	(23575.5)	(47978.3)	(44209.8)
Industry fatal injury rate	0.0236	0.0222	0.251	-0.0755	-0.177	-0.0777	-0.0736	0.00631
	(0.282)	(0.447)	(0.343)	(0.291)	(0.261)	(0.240)	(0.224)	(0.213)
Industry nonfatal injury rate	-0.0759	0.0173	-0.0138	-0.106	-0.0802	-0.121	-0.128	-0.166*
	(0.0938)	(0.149)	(0.114)	(0.0969)	(0.0866)	(0.0792)	(0.0740)	(0.0700)
Observations	4,318	9,237	13,830	18,053	21,513	24,420	26,592	28,205
χ^2	7.23	4.42	7.49	13.81	10.81	14.12	18.54	25.00
p-value	0.6129	0.8820	0.5858	0.1294	0.2888	0.1180	0.0294	0.0030

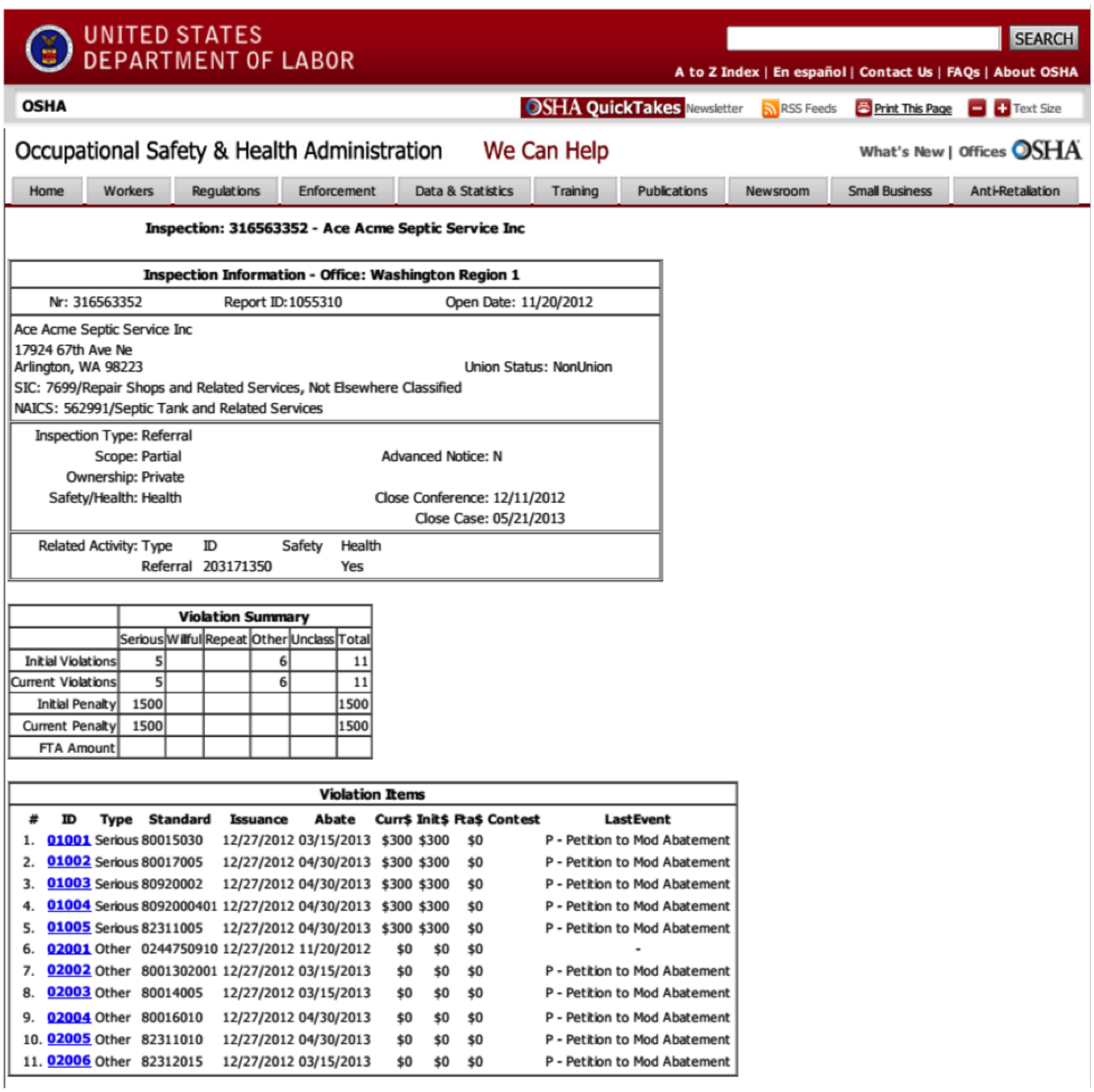
Note: Estimate (SE). Significant at *** 1%, ** 5%, * 10% level. All estimates show coefficients for 1(union certified) in seemingly unrelated regressions. and p-value are from the joint hypothesis test of null discontinuity effects across all pre-election variables.

Table 4.4: Effects of union certification on various outcomes with piece-wise linear function of vote share using uniform kernel with IK-optimal bandwidth for each outcome

Specification:	1	2	3	4
	Outcome: inspection rate			
Certification effect	0.00825**	0.00860**	0.00693**	0.00722**
	(0.00376)	(0.00363)	(0.00343)	(0.00339)
Adj. R^2	0.000195	0.0566	0.115	0.129
	Outcome: union-rep share			
Certification effect	0.0732***	0.0711***	0.0705***	0.0710***
	(0.00945)	(0.00930)	(0.00923)	(0.00918)
Adj. R^2	0.0261	0.0589	0.0711	0.0808
	Outcome: violation rate			
Certification effect	0.0788**	0.0746**	0.0668*	0.0788**
	(0.0370)	(0.0358)	(0.0354)	(0.0352)
Adj. R^2	0.000165	0.0352	0.0516	0.0776
	Outcome: penalty index			
Certification effect	0.0731*	0.0681*	0.0657*	0.0735*
	(0.0410)	(0.0396)	(0.0393)	(0.0388)
Adj. R^2	$8.71e-05$	0.0444	0.0544	0.0824
	Outcome: injury index			
Certification effect	0.121	0.122	0.117	0.120
	(0.0853)	(0.0852)	(0.0832)	(0.0839)
Adj. R^2	0.000312	0.00872	0.0153	0.0154
Piecewise linear in vote share	Yes	Yes	Yes	Yes
Pre-election outcome		Yes	Yes	Yes
Pre-election all outcomes and quadratic in number of eligible voters			Yes	Yes
Major-industry indicators and minor-industry risks				Yes

Notes: Estimate (Heteroskedasticity-robust SE). Significant at *** 1%, ** 5%, * 10% level. This displays estimated union certification effects on 5 outcomes (rows) using four specifications (columns) each. The full set of coefficient estimates for all variables and all specifications for the five outcomes are in Appendix Tables A6(a)- A6(e). The IK-optimal bandwidths for the outcomes are 0.128, 0.151, 0.197, 0.153, and 0.146, respectively. Given the definition of vote share into 5% bins, effective bandwidths are 0.125 for optimal bandwidth in (0.125, 0.175] and 0.175 for the one in (0.175, 0.225] implying 13,830 and 18,053 establishments included, respectively.

Figure 4.1: Example of OSHA enforcement data for a particular inspection



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Inspection: 316563352 - Ace Acme Septic Service Inc

Inspection Information - Office: Washington Region 1

Nr: 316563352 Report ID:1055310 Open Date: 11/20/2012

Ace Acme Septic Service Inc
17924 67th Ave Ne
Arlington, WA 98223 Union Status: NonUnion
SIC: 7699/Repair Shops and Related Services, Not Elsewhere Classified
NAICS: 562991/Septic Tank and Related Services

Inspection Type: Referral
Scope: Partial Advanced Notice: N
Ownership: Private
Safety/Health: Health Close Conference: 12/11/2012
Close Case: 05/21/2013

Related Activity: Type	ID	Safety	Health
Referral	203171350		Yes

	Violation Summary					
	Serious	Willful	Repeat	Other	Unclass	Total
Initial Violations	5			6		11
Current Violations	5			6		11
Initial Penalty	1500					1500
Current Penalty	1500					1500
FTA Amount						

Violation Items

#	ID	Type	Standard	Issuance	Abate	Curr$	Init$	Fta$	Contest	LastEvent
1.	01001	Serious	80015030	12/27/2012	03/15/2013	$300	$300	$0		P - Petition to Mod Abatement
2.	01002	Serious	80017005	12/27/2012	04/30/2013	$300	$300	$0		P - Petition to Mod Abatement
3.	01003	Serious	80920002	12/27/2012	04/30/2013	$300	$300	$0		P - Petition to Mod Abatement
4.	01004	Serious	8092000401	12/27/2012	04/30/2013	$300	$300	$0		P - Petition to Mod Abatement
5.	01005	Serious	82311005	12/27/2012	04/30/2013	$300	$300	$0		P - Petition to Mod Abatement
6.	02001	Other	0244750910	12/27/2012	11/20/2012	$0	$0	$0		-
7.	02002	Other	8001302001	12/27/2012	03/15/2013	$0	$0	$0		P - Petition to Mod Abatement
8.	02003	Other	80014005	12/27/2012	03/15/2013	$0	$0	$0		P - Petition to Mod Abatement
9.	02004	Other	80016010	12/27/2012	04/30/2013	$0	$0	$0		P - Petition to Mod Abatement
10.	02005	Other	82311010	12/27/2012	04/30/2013	$0	$0	$0		P - Petition to Mod Abatement
11.	02006	Other	82312015	12/27/2012	03/15/2013	$0	$0	$0		P - Petition to Mod Abatement

Figure 4.2: Histogram of vote-shares across focal NLRB elections with at least 20 votes cast

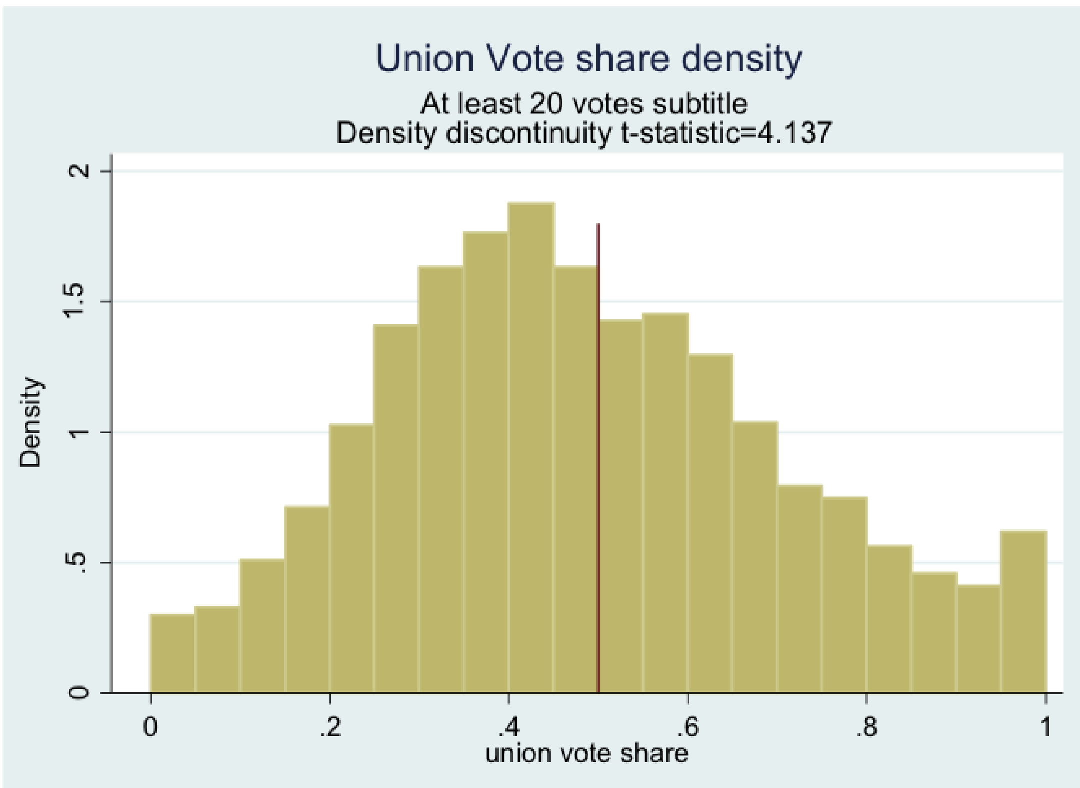
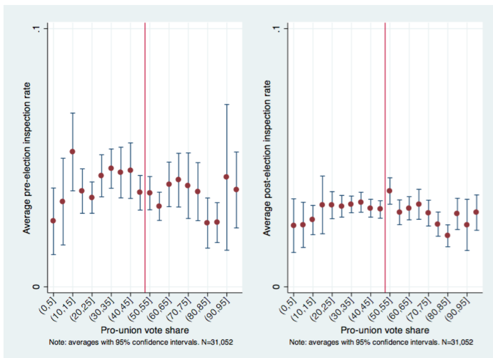
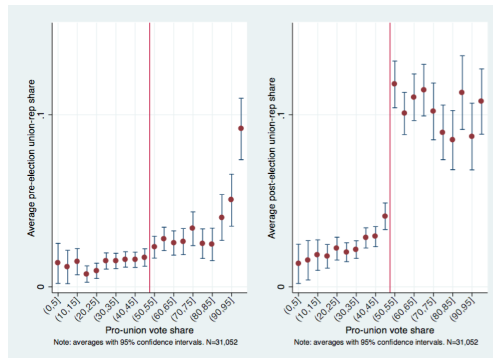


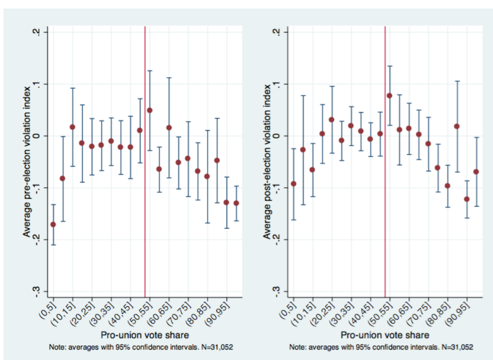
Figure 4.3: Average annual establishment **(a)** inspection rate, **(b)** labor-representative share, **(c)** violation index, **(d)** penalty index, and **(e)** injury index by vote-share bin in pre- and post-election periods



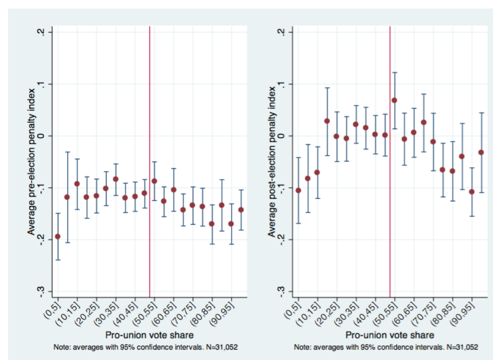
(a) Inspection rate



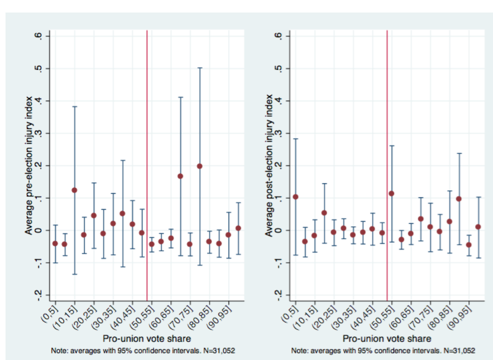
(b) Labor-representative share



(c) Violation index



(d) Penalty index



(e) Injury index

Table 4.5: Effects of union certification by strictness of matching-algorithm used to construct establishment panel

Matching algorithm:	More Strict	Baseline	Less Strict
	Outcome: inspection rate		
Certification effect	0.00735**	0.00722**	0.00656*
	(0.00338)	(0.00339)	(0.00336)
Adj. R^2	0.128	0.129	0.119
Obs.	13,871	13,830	13,678
	Outcome: union-representative share		
Certification effect	0.0710***	0.0710***	0.0738***
	(0.00913)	(0.00918)	(0.00922)
Adj. R^2	0.0791	0.0808	0.0798
Obs.	13,871	13,830	13,678
	Outcome: violation index		
Certification effect	0.0849**	0.0788**	0.0792**
	(0.0353)	(0.0352)	(0.0356)
Adj. R^2	0.0782	0.0776	0.0757
Obs.	18,110	18,053	17,856
	Outcome: penalty index		
Certification effect	0.0767**	0.0735*	0.0758*
	(0.0389)	(0.0388)	(0.0393)
Adj. R^2	0.0812	0.0824	0.0809
Obs.	13,871	13,830	13,678
	Outcome: injury index		
Certification effect	0.120	0.120	0.113
	(0.0834)	(0.0839)	(0.0776)
Adj. R^2	0.0154	0.0154	0.0210
Obs.	13,871	13,830	13,678

Notes: Estimate (Heteroskedasticity-robust SE). Significant at *** 1%, ** 5%, * 10% level. Establishments were matched using three different matching algorithms by strictness. All estimates based on specification (4) in Table 4.4. Baseline results are in the middle column (strgroup threshold 0.25). These are compared to results based on using stricter (0.2) and less strict (0.3) criterion. The total number of observations for all bandwidth for stricter criterion is 31,151, and 30,728 for less strict criterion. The IK-optimal bandwidths for the outcomes of stricter criteria are 0.133, 0.156, 0.189, 0.140, and 0.149, respectively. Also, IK-optimal bandwidths for the outcomes of less strict criteria are 0.133, 0.161, 0.206, 0.151, and 0.141 respectively.

Table 4.6: Estimated certification effects using alternative measures of violations, penalties, and injuries

Outcome	Inspect	Rep-share	Violations	Penalties	Injury
Certification effect	0.00820**	0.0714***	0.0161**	0.140*	0.0112
	(0.00345)	(0.00917)	(0.00810)	(0.0771)	(0.0185)
Observations	13,830	13,830	13,830	13,830	13,830

Notes: Estimate (Heteroskedasticity-robust SE). Significant at *** 1%, ** 5%, * 10% level. All estimates based on specification (4) in Table 4.4.

Table 4.7: Effects of union certification by inspection type

Outcome:	Inspection rate	Labor-rep. share	Violations	Penalties	Injury
Programmed					
Certification effect	-0.000281	0.0299***	0.0443	0.0947*	n/a
	(0.00155)	(0.00653)	(0.0409)	(0.0572)	
Optimal bandwidth	0.129	0.158	0.132	0.112	
Adj. R^2	0.0656	0.0416	0.0498	0.0382	
Obs.	13,830	13,830	13,830	9,237	
Complaint-initiated					
Certification effect	0.00744***	0.0636***	0.0859*	0.0658**	0.119
	(0.00277)	(0.00831)	(0.0445)	(0.0298)	(0.0839)
Optimal bandwidth	0.145	0.152	0.154	0.249	0.147
Adj. R^2	0.107	0.0673	0.0472	0.0602	0.0154
Obs.	13,830	13,830	13,830	21,513	13,830

Notes: Estimate (Heteroskedasticity-robust SE). Significant at *** 1%, ** 5%, * 10% level. All estimates based on specification (4) in Table 4.4. No injury reports from programmed inspections.

Chapter 5

Conclusion

In chapter 2 and 3, I present the results of empirical analysis that measures the effect of IPRs on economic growth and exports.

In chapter 2, I empirically examine the relationship between IPRs and economic growth with a focus on features that may alter this relationship across regions (Asia relative to the world), across time (pre and post-TRIPs), and across the development levels of countries. I consider four questions. First, do IPRs have positive growth effects across countries globally? Results show a (net) positive relationship between IPRs and economic growth across the countries of the world, however this relationship is non-linear. Second, are the growth effects of IPRs different for East Asia than for the rest of the world? I find that IPRs have an insignificant effect on economic growth across the countries of East Asia, and these effects are not statistically different than those for the world. The positive effects of IPRs on economic growth appear to cancel out the negative effects, such that the net effect is ambiguous.

Third, did the 1995 TRIPs Agreement alter the growth effects of IPRs for the world and for East Asia? The results show that countries with relatively weak IPRs had higher economic growth, particularly in East Asia, during the pre-TRIPs period. In the *post*-TRIPs period, this pattern reversed such that countries with relatively strong IPRs had higher economic growth, globally and in East Asia.

The results showed evidence that growth in the post-TRIPs period deviates from that of the entire period in a positive way; yet these positive effects are more modest for East Asia.

Fourth, is there a tipping point in the relationship between IPRs and growth that is related to the development level of countries? The results for the world show that IPRs have a negative effect on growth for countries above a threshold development level during the pre-TRIPs period, and have a positive effect for this same group during the post-TRIPs period. In contrast, countries below the threshold are insensitive to the strength of IPRs. These results suggest that there is a tipping point, and that highly developed countries do experience growth benefits from strong IPRs, particularly in the post-TRIP era. For East Asia, the results show that countries at lower development levels experience positive growth effects from weak IPRs, while those at higher development levels experience positive growth effects from strong IPRs during the pre-TRIPs period.

Chapter 3 investigates how stronger IPRs affect exports embodying an exchange of intermediate inputs. I consider two questions. First, do stronger IPRs is important determinant of comparative advantage in value added exports? Also, does it have different effect compare to the case in gross export? The results show that stronger patent protection has a positive effect on both value added exports and gross exports in patent intensive industries. The effect is bigger in value added exports. Countries with high levels of patent protection specialize in high-tech industries while countries with low levels of protection specialize in low-tech industries. That is, the effect of stronger patent protection is biased positively towards patent-intensive industries in both value added exports and gross exports. I calculate valued added contents of export, gross exports, and value added ratio to gross exports.

Second, how does strong IPRs effect on production fragmentation estimated by VAX ratio? The results suggest that high levels of patent protection are associated with a high VAX ratio in patent-intensive industries indicating lower production fragmentation, which means stronger IPRs lead less fragmentation in patent-intensive industries. In other words, countries with higher patent protection have less fragmentation of production in patent-intensive industries.

In Chapter 4, I estimate the effect of unionization using Regression-Discontinuity. From the results, I find that there is evidence of positive effects of union certification on establishments rate of OSHA inspection, the share of inspections carried out in the presence of a labor representative, violations cited, and penalties assessed.

Specifically, union certification increases the share of inspections that have a labor representative participating by 27 percentage points conditional on having any OSHA inspection. This provides the strongest evidence in the literature documenting a rights-facilitation effect of unions. These results imply that falling unionization rates nationally are reducing workers exercise of their rights to participate in the occupational safety enforcement process and weakening a private actor that may co-produce law enforcement along with agency staff. Also, union certification appears to increase OSHA activity - inspection rates, violations cited, and penalties assigned - each by about 8 percent of a standard deviation. Despite union effects in increasing OSHA enforcement activity, I do not see evidence of a substantial reduction in occupational injury though we have access only to a flawed measure of injuries.

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Appendix A

A.1 Data Description and Sources

This appendix describes the variable measures and data sources. The descriptions provided are those not provided elsewhere in the text.

Variable Measures and Data Sources

The endogenous variable in all specifications is economic growth. *Economic growth* (ΔY) is measured as the difference in the log value of gross domestic product (GDP) per capita between the beginning and end of the period (i.e., $\ln(Y_{i,t+1}) - \ln(Y_{i,t})$). For a given sub-period, it is measured as the average of annual growth rates. The GDP per capita data are measured in 2000 constant dollars.

Baseline determinants of growth include the initial growth level, and growth in capital, labor, and human capital. The *initial growth level* (Y_0) is measured as the log value of GDP per capita at the beginning of the period (i.e., $\ln(Y_{i,t})$). Capital growth, labor growth, and human capital growth are measured as the period average of annual growth rates. Specifically, *capital growth* (ΔK) is measured as gross domestic investment. *Labor growth* (ΔL) is measured as population growth. *Human capital growth* (ΔH) is measured as the secondary school enrollment rate as a percentage of the population.

Additional baseline determinants of growth include openness to trade and economic instability (or inflation). Consistent with the measures above, these variables are constructed as period averages. *Openness to trade* (O) is measured as the sum of merchandise exports plus imports as a percentage of GDP. *Economic instability or inflation* (π) is measured as inflation rates.

Interaction terms include dummy variables for East Asia and the time period following the TRIPs agreement. The *East Asia dummy* (DUMA) takes a value of one for countries in East Asia and zero otherwise. East Asia is defined based on the World Banks regional definitions and the availability of comparable data. Countries include China, Hong Kong, Indonesia, Japan, Korea, Malaysia, Myanmar, Papua New Guinea, Philippines, Thailand, and Vietnam. Finally, the *TRIPs dummy* (DUMT) takes a value of one for the periods following the TRIPs agreement (e.g, 1995-2010) and zero otherwise (e.g., 1980-1994).

All data described above are from the World Bank and are published in the *World Development Indicators*. The exceptions are the few cases where comparable data are not available. The exceptions include the data on GDP per capita of Myanmar which is collected from the United Nations; data on openness to trade for Myanmar which is collected from the Asia Development Bank; and data on inflation in Vietnam for 1980-95 which is collected from the International Monetary Fund.

A.2 IPRs measure for all countries

Table A.1: Index Measure of Strength of Intellectual Property Rights, by Country

Country	1980	1985	1990	1995	2000	2005
Algeria	2.58	2.58	2.58	2.58	2.78	2.78
Angola	0.00	0.00	0.00	0.88	1.08	1.20
Argentina	1.54	1.54	1.54	2.31	3.56	3.56
Australia	2.49	2.49	3.28	4.33	4.33	4.33
Austria	3.01	3.43	3.68	4.21	4.33	4.33
Bangladesh	1.30	1.30	1.30	1.70	1.70	1.70
Belgium	3.23	4.09	4.34	4.54	4.67	4.67
Benin	1.70	1.70	1.90	1.78	2.10	2.77
Bolivia	1.22	1.22	1.22	2.20	2.98	2.98
Botswana	1.71	1.71	1.71	1.91	3.15	3.35
Brazil	1.28	1.28	1.28	1.48	3.43	3.43
Bulgaria			1.74	2.89	3.75	3.88
Burkina Faso	1.58	1.70	1.70	1.98	2.10	2.77
Burundi	1.91	1.91	1.91	1.98	1.98	1.98
Cameroon	1.90	1.90	1.90	2.10	2.23	2.89
Canada	2.91	3.16	3.28	4.34	4.54	4.54
Central African Republic	1.90	1.90	1.90	1.98	2.10	2.77
Chad	1.78	1.78	1.78	1.78	2.10	2.77
Chile	2.01	2.01	2.26	3.91	4.48	4.48
China		1.33	1.33	2.12	3.09	4.08
Colombia	0.96	0.96	0.96	2.58	3.30	3.43
Congo, Dem. Rep.	1.58	1.58	1.58	1.58	1.78	2.11
Congo, Rep.	1.90	1.90	1.90	1.90	2.23	2.89
Costa Rica	1.04	1.16	1.16	1.56	2.89	2.89
Cote d'Ivoire	1.70	1.70	1.70	1.90	2.36	2.89
Cyprus	2.58	2.58	2.58	2.78	3.48	3.48
Czech Republic				2.96	3.21	4.33
Denmark	3.18	3.63	3.88	4.54	4.67	4.67
Dominican Republic	2.12	2.12	2.12	2.32	2.11	2.48
Ecuador	1.16	1.16	1.16	2.04	3.56	3.56
Egypt, Arab Rep.	1.41	1.41	1.41	1.73	1.86	2.89
El Salvador	1.71	1.71	1.71	3.23	3.23	3.36
Ethiopia	0.00	0.00	0.00	0.00	2.00	2.13
Fiji	2.20	2.20	2.20	2.20	2.40	2.40
Finland	2.98	3.31	3.31	4.42	4.54	4.67
France	3.63	3.76	3.88	4.54	4.67	4.67
Gabon	1.90	1.90	1.90	2.10	2.23	2.89
Germany	3.81	4.01	4.13	4.33	4.67	4.67
Ghana	1.58	1.58	1.58	2.83	3.15	3.35
Greece	2.33	2.33	3.03	3.63	4.13	4.47
Grenada	1.63	1.76	1.76	1.76	2.36	2.69
Guatemala	0.75	0.75	0.88	1.08	1.28	3.15
Guyana	0.80	0.80	0.93	1.13	1.33	1.66
Haiti	2.58	2.58	2.58	2.58	2.90	2.90
Honduras	1.25	1.25	1.25	1.90	2.69	2.82
Hong Kong SAR, China	2.50	2.70	2.70	2.90	3.81	3.81
Hungary			2.12	3.88	3.88	4.33
Iceland	1.67	1.67	1.67	2.84	3.55	3.68
India	1.03	1.03	1.03	1.23	2.27	3.76
Indonesia	0.20	0.20	0.20	1.56	2.47	2.77

Iran, Islamic Rep.	1.91	1.91	1.91	1.91	1.91	1.91
Iraq	2.12	2.12	2.12	2.12	2.12	1.78
Ireland	2.03	2.03	2.16	4.14	4.67	4.67
Israel	2.78	2.78	2.78	2.98	3.96	3.96
Italy	3.36	3.68	4.01	4.33	4.67	4.67
Jamaica	2.66	2.66	2.66	2.86	3.06	3.36
Japan	3.43	3.43	3.88	4.42	4.67	4.67
Jordan	0.58	0.58	0.58	0.91	2.70	3.10
Kenya	1.58	1.58	2.03	2.43	2.88	3.22
Korea, Rep.	2.28	2.49	3.69	3.89	4.13	4.33
Liberia	1.83	1.83	1.83	2.11	2.11	2.44
Lithuania			1.00	2.57	3.35	3.88
Luxembourg	2.57	2.57	2.69	3.89	4.14	4.14
Madagascar	1.15	1.15	1.15	1.85	2.18	2.18
Malawi	1.33	1.33	1.33	1.86	1.98	1.98
Malaysia	1.59	1.92	2.05	2.70	3.03	3.48
Mali	0.13	1.78	1.78	1.98	2.10	2.77
Malta	1.40	1.40	1.40	1.60	3.18	3.48
Mauritania	1.70	1.90	1.90	1.98	2.43	3.10
Mauritius	1.73	1.73	1.73	1.93	1.93	2.57
Mexico	0.79	1.02	1.02	2.68	3.22	3.42
Morocco	1.58	1.58	1.58	1.78	2.89	3.35
Mozambique	0.00	0.00	0.00	0.20	1.06	2.52
Myanmar	0.00	0.00	0.00	0.20	0.20	0.20
Nepal	1.79	1.79	1.79	1.79	1.79	2.19
Netherlands	3.77	3.77	4.22	4.54	4.67	4.67
New Zealand	2.37	2.37	2.37	3.68	3.68	3.68
Nicaragua	0.59	0.59	0.59	0.79	1.91	2.72
Niger	1.70	1.70	1.70	1.78	2.10	2.77
Nigeria	2.37	2.37	2.37	2.69	2.69	2.89
Norway	2.98	2.98	3.18	3.83	3.96	4.29
Pakistan	1.05	1.18	1.18	1.38	1.83	2.03
Panama	1.34	1.34	1.34	1.46	3.35	3.35
Papua New Guinea	0.00	0.00	0.00	0.00	2.57	2.77
Paraguay	1.13	1.13	1.13	1.53	2.39	2.89
Peru	0.59	0.59	0.59	2.57	3.03	3.03
Philippines	2.16	2.36	2.36	2.56	3.68	3.88
Poland			1.21	3.29	3.75	3.88
Portugal	1.67	1.67	1.67	3.31	3.96	4.33
Romania			1.33	3.35	3.55	4.00
Russian Federation	1.21	1.41	1.41	3.48	3.68	3.68
Rwanda	1.71	1.91	1.91	1.78	2.11	2.11
Saudi Arabia	1.33	1.33	1.71	1.71	1.71	2.57
Senegal	1.70	1.90	1.90	1.98	2.10	2.77
Sierra Leone	2.38	2.38	2.38	2.45	2.98	2.98
Singapore	1.71	1.71	2.04	3.88	4.01	4.21
Slovak Republic		1.21	1.21	2.96	2.96	4.21
Somalia	1.33	1.33	1.33	1.33	1.46	1.46
South Africa	2.90	2.90	3.03	3.23	3.75	3.75
Spain	2.44	2.64	3.23	3.88	4.33	4.33
Sri Lanka	2.58	2.78	2.78	2.98	3.11	3.11
Sudan	0.00	2.32	2.32	2.32	2.32	2.32
Swaziland	1.38	1.38	1.38	1.98	2.43	2.43
Sweden	3.28	3.48	3.88	4.42	4.54	4.54
Switzerland	3.46	3.66	3.91	4.21	4.21	4.21

Syrian Arab Republic	1.87	1.87	1.87	1.87	1.87	2.07
Taiwan	1.26	1.26	1.26	3.17	3.29	3.74
Tanzania	1.91	1.91	2.24	2.32	2.64	2.64
Thailand	1.21	1.21	1.21	2.24	2.37	2.49
Togo	1.70	1.70	1.70	1.98	2.10	2.77
Trinidad and Tobago	1.73	1.73	1.73	2.33	3.63	3.75
Tunisia	1.45	1.45	1.45	1.65	2.32	3.25
Turkey	1.20	1.20	1.20	2.65	4.01	4.01
Uganda	1.91	1.91	1.91	2.85	3.10	3.10
Ukraine	0.00	0.00	1.33	3.68	3.68	3.68
United Kingdom	3.76	3.88	4.34	4.54	4.54	4.54
United States	4.35	4.68	4.68	4.88	4.88	4.88
Uruguay	1.67	1.67	1.67	2.07	2.98	3.23
Venezuela, RB	0.92	0.92	0.92	2.65	3.15	3.15
Vietnam	0.88	0.88	1.13	2.65	2.65	2.78
Zambia	1.38	1.38	1.38	1.45	1.70	1.90
Zimbabwe	1.58	1.91	1.91	2.11	2.56	2.56
Descriptive Statistics						
Mean (East Asia)	1.42	1.50	1.69	2.29	2.97	3.21
Standard deviation (East Asia)	1.17	1.17	1.38	1.34	1.18	1.23
Mean (World)	1.77	1.86	1.94	2.53	2.98	3.25
Standard deviation (World)	0.92	0.95	1.01	1.09	1.00	0.90

Note: Original data are from Walter Park at American University.

Appendix B

Table B.1: VAX Ratio by Country for the Manufacturing Sector

Variable	**Mean**	**Std. Dev.**
Australia	0.56	0.35
Austria	0.66	0.37
Belgium	0.63	0.37
Brazil	0.67	0.33
Bulgaria	0.61	0.42
Canada	0.74	0.44
China	0.66	0.40
Cyprus	0.57	0.42
Czech Republic	0.65	0.38
Denmark	0.65	0.42
Estonia	0.64	0.38
Finland	0.56	0.41
France	0.65	0.38
Germany	0.62	0.42
Greece	0.55	0.39
Hungary	0.60	0.39
India	0.72	0.37
Indonesia	0.83	0.49
Ireland	0.43	0.41
Italy	0.68	0.39
Japan	0.60	0.50
Korea	0.63	0.48
Latvia	0.54	0.45
Lithuania	0.71	0.60
Luxembourg	0.52	0.50
Malta	0.43	0.42
Mexico	0.70	0.73
Netherlands	0.59	0.39
Poland	0.69	0.34
Portugal	0.72	0.35
Romania	0.58	0.39
Russia	0.41	0.47
Slovakia	0.64	0.35
Slovenia	0.66	0.40
Spain	0.67	0.38
Sweden	0.59	0.40
Taiwan	0.62	0.50
Turkey	0.63	0.39
United Kingdom	0.61	0.40
United States	0.66	0.39

Source: Calculated by author using WIOD dataset from 1995-2010.

Table B.2: VAX Ratio by Industry in Manufacturing Sector

WIOD code	Industry Descriptions	Mean	Std. Dev.
3	Food, beverages and tobacco	0.29	0.19
4	Textiles and textile products	0.52	0.23
5	Leather, leather products and footwear	0.16	0.20
6	Wood and products of wood and cork	0.45	0.36
7	Pulp, paper, printing and publishing	0.58	0.27
8	Coke, refined petroleum and nuclear fuel	0.51	0.53
9	Chemicals and chemical products	1.14	0.22
10	Rubber and plastics	0.92	0.38
11	Other non-metallic mineral	0.33	0.19
12	Basic metals and fabricated metal	1.24	0.22
13	Machinery, not elsewhere classified	0.77	0.25
14	Electrical and optical equipment	0.85	0.26
15	Transport equipment	0.56	0.22
16	Manufacturing, not elsewhere classified; recycling	0.40	0.48

Source: Calculated by author using WIOD dataset from 1995-2010.

Table B.3: Park's IPR Index by Country

	1995	**2000**	**2005**	**2010**	**Average**
U.S.	4.88	4.88	4.88	4.88	4.88
Belgium	4.54	4.67	4.67	4.67	4.64
Denmark	4.54	4.67	4.67	4.67	4.64
France	4.54	4.67	4.67	4.67	4.64
Netherlands	4.54	4.67	4.67	4.67	4.64
Japan	4.42	4.67	4.67	4.67	4.60
Germany	4.33	4.67	4.67	4.67	4.58
Italy	4.33	4.67	4.67	4.67	4.58
Finland	4.42	4.54	4.67	4.67	4.57
U.K.	4.54	4.54	4.54	4.54	4.54
Ireland	4.14	4.67	4.67	4.67	4.54
Sweden	4.42	4.54	4.54	4.54	4.51
Canada	4.34	4.54	4.54	4.54	4.49
Australia	4.33	4.33	4.33	4.33	4.33
Austria	4.21	4.33	4.33	4.33	4.30
Spain	3.88	4.33	4.33	4.33	4.22
Greece	3.63	4.13	4.47	4.47	4.18
Korea	3.89	4.13	4.33	4.33	4.17
Hungary	3.88	3.88	4.33	4.33	4.10
Luxembourg	3.89	4.14	4.14	4.14	4.08
Portugal	3.31	3.96	4.33	4.33	3.98
Poland	3.29	3.75	3.88	4.00	3.73
Romania	3.35	3.55	4.00	4.00	3.73
Czech Republic	2.96	3.21	4.33	4.33	3.71
Turkey	2.65	4.01	4.01	3.88	3.64
Russia	3.48	3.68	3.68	3.68	3.63
Slovak Republic	2.96	2.96	4.21	4.33	3.61
Bulgaria	2.89	3.75	3.88	3.88	3.60
Taiwan	3.17	3.29	3.74	3.74	3.49
Lithuania	2.57	3.35	3.88	3.88	3.42
China	2.12	3.09	4.08	4.21	3.38
Mexico	2.68	3.22	3.42	3.75	3.27
Cyprus	2.78	3.48	3.48	3.14	3.22
Malta	1.60	3.18	3.48	3.68	2.99
Brazil	1.48	3.43	3.43	3.43	2.94

Source: [Ginarte and Park, 1997]'s IPRs index updated version in 2012.

Table B.4: Alternative Measure of Patent Intensity

ISIC rev. 3	Industry descriptions	Patent intensity
15	Food and beverages	0.0012
16	Tobacco	0.0045
17	Textiles	0.0058
18	Apparel	0.0058
19	Leather	0.0105
20	Wood products	0.025
21	Paper products	0.0072
22	Publishing, printing	0.0063
23	Coke and petroleum products	0.0108
241	Basic chemicals	0.0272
242	Other chemicals (incl. pharmaceuticals)	0.024
25	Rubber and plastics	0.011
26	Other non-metal	0.0106
27	Basic metals	0.0107
28	Fabricated metals	0.0114
29	Machinery and equipment	0.0122
30	Office, accounting, and computing machinery	0.0513
311	Electric motors, generators and transformers	0.029
312	Electricity distribution and control apparatus	0.0463
313	Insulated wire and cable	0.0095
314	Accumulators, primary cells and primary batteries	0.142
315	Electric lamps and lighting equipment	0.0695
321	Electronic valves, tubes and other electronic components	0.0425
322	TV and radio transmitters	0.0423
323	TV and radio receivers	0.0163
331	Medical appliances and instruments	0.0323
34	Motor vehicles, trailers and semi-trailers	0.0105
35	Other transport equipment	0.0123
36	Furniture and other manufactures	0.013

Source: [Hu and Png, 2013]

Table B.5: WIOD Industry Categorization

ISIC rev. 3	Industry Name
A to B	Agriculture, hunting, forestry and fishing
C	Mining and quarrying
15 to 16	Food, beverages and tobacco
17 to 18	Textiles and textile products
19	Leather, leather products and footwear
20	Wood and products of wood and cork
21 to 22	Pulp, paper, printing and publishing
23	Coke, refined petroleum and nuclear fuel
24	Chemicals and chemical products
25	Rubber and plastics
26	Other non-metallic mineral
27 to 28	Basic metals and fabricated metal
29	Machinery, not elsewhere classified
30 to 33	Electrical and optical equipment
34 to 35	Transport equipment
36 to 37	Manufacturing, not elsewhere classified; recycling
E	Electricity, gas and water supply
F	Construction
50	Sale and repair of motor vehicles and motorcycles; retail sale of fuel
51	Wholesale trade, except of motor vehicles and motorcycles
52	Retail trade and repair, except of motor vehicles and motorcycles;
H	Hotels and restaurants
60	Inland transport
61	Water transport
62	Air transport
63	Other supporting transport activities
64	Post and telecommunications
J	Financial intermediation
70	Real estate activities
71 to 74	Renting of machinery & equipment and other business activities
L	Public administration and defense; compulsory social security
M	Education
N	Health and social work
O	Other community, social and personal services
P	Private households with employed persons

Source: [Timmer et al., 2015]

Table B.6: Concordance between WIOD and ISIC Rev3

WIOD code	**ISIC rev. 3**
3	15
3	16
4	17
4	18
5	19
6	20
7	21
7	22
8	23
9	24
10	25
11	26
12	27
12	28
13	29
14	30
14	31
14	32
14	33
14	34
15	35
16	36
16	37

Source: [Timmer et al., 2015]

Appendix C

C.1 Additional Detail on Variable Construction

To construct the merged NLRB election and OSHA inspection panel, we use a series of data cleaning and matching steps aimed at creating reliable linkages to records on the same establishment across time and source.

1. Preprocess each record to create standardized format:

   (a) standardize state names to postal abbreviations,

   (b) all street/avenues/road abbreviations to st/ave/rd

   (c) establishment names in a uniform case and standardize abbreviations (corp/corporation/co to corp, inc/incorporated/Inc to inc)

2. Crosswalk later NLRB election industry codes back to SIC87.

   (a) NLRB switched from SIC-1978 to SIC-1987 to NAICS-2002 industry codes. In each The SIC-78 to SIC-87 has negligible impact on the first and second digits of the industry code, which is all we use. The switch to NAICS-02 is more consequential. OSHA never switched to NAICS so we convert NLRB industry codes that appear to be NAICS-02 back to SIC-87. Heres how.

(b) We judge whether each NLRB election's industry is coded under SIC or NAICS by merging its 2-digit industry code to both the SIC industry and the NAICS industry with that number.

  i. In some cases, the 2-digit number matches to only an SIC code and not a NAICS code. That is SIC.

  ii. In other cases, the 2-digit number matches to only a NAICS code and not an SIC code. That is NAICS.

  iii. In the rest of the cases, the 2-digit number matches to both an SIC code and a NAICS code. We inspect these by hand sorting by election date and paying attention to establishment name. We know that earlier elections are generally SIC coded as NAICS did not exist in early years of the study, although there appears to be some back-coding of pre-2002 elections under NAICS. Within each 2-digit industry code, there is usually a year where establishment names switch from being that of the SIC code to that of the NAICS code. We use that break point to assign each NLRB elections industry code as either SIC or NAICS.

(c) For election with NAICS codes, we use the NAICS-02 to SIC-87 crosswalk provided by the Bureau of Labor Statistics under its Current Employment Statistics (CES) program.[1]

  i. For many NAICS codes, the mapping to SIC is one-to-one. We convert these directly.

  ii. For the other NAICS codes, the mapping is to multiple SIC codes and the crosswalk provides probabilities based on employment shares. In those cases (5,579), we create multiple versions of the NLRB election record, each associated with a different SIC code and share.

3. Create longitudinal links within the NLRB election data to identify multiple elections in the same establishment over time.

(a) Split the NLRB data into subsamples with the same state-SIC2 combination.

(b) Within subsample, use Stata command *strgroup* to find multiple NLRB election records with the same establishment name, street address (where available), and city. This generates a set of potential links with various match qualities. We inspect by hand to judge the best match-quality threshold (0.25). We also present results using alternative thresholds (0.2 and 0.3).

4. Create links between NLRB records and OSHA records to identify the same establishment in both data sets.

   (a) For each OSHA record, search within the NLRB records with the same state-SIC2 combination using the Stata command *reclink* to find NLRB elections that occurred in establishments with the same name, street address (where available), and city. We inspect by hand to judge the best match-quality threshold (0.8853 for matches to NLRB records with street address and 0.8895 for matches to NLRB records without address).

5. In cases where the NLRB election has only one associated SIC code, this process creates a longitudinal establishment identifier across datasets.

6. In cases where the NLRB election has multiple associated SICS codes from the NAICS crosswalk process, further refinement is needed. Here, each election has multiple possible SIC codes. We choose one using information from OSHA records and from the CES cross-walks employment shares.

   (a) Where available, use information from the OSHA code to classify the establishment into the correct SIC industry.

      i. Calculate the number of OSHA records connected to each election-SIC pair for that election.

   ii. Keep the election-SIC record(s) with the highest number of linked OSHA records. Drop the records of the other possible election-SIC pairs for that election.

(b) Use information from CES employment shares to classify the establishment into the correct SIC industry.

   i. If multiple possible SIC matched to the same, highest number of OSHA records for an election (4,418), then use CES employment share to break the tie. Keep the election-SIC record with the highest employment share. Drop the records of the other possible election-SIC pairs for that election.

   ii. If an election had no OSHA matches for any of its possible SICs, then keep the record with the SIC code that has with the highest employment share from the CES crosswalk (11,182). Drop the records of the other possible election-SIC pairs for that election.

(c) For a few elections (89), there is still a tie between two possible SIC codes that have the same highest-number of linked OSHA records and the same employment shares. In those cases, we pick one of its possible SIC codes at random to keep and drop the other(s).

This process produces a set of measured unique establishments each with linked NLRB election record(s), perhaps linked OSHA records, and a single SIC code.

[1] http://www.bls.gov/ces/naicstosic2.htm

C.2 Additional Tables & Figures

Table C.1: Distribution of elections across industry divisions

Div.	Industry	Freq.	Percent
B	Mining	280	0.90
C	Construction	1,627	5.24
D	Manufacturing	10,878	35.03
E	Transportation, Communications, Electric, Gas, And Sanitary	5,456	17.57
F	Wholesale Trade	1,683	5.42
G	Retail Trade	2,067	6.66
H	Finance, Insurance, And Real Estate	245	0.79
I	Services	8,816	28.39
Total		31,052	100

Figure C.1: Number of fatal occupational injuries in OSHA database annually for 1970 to 2014

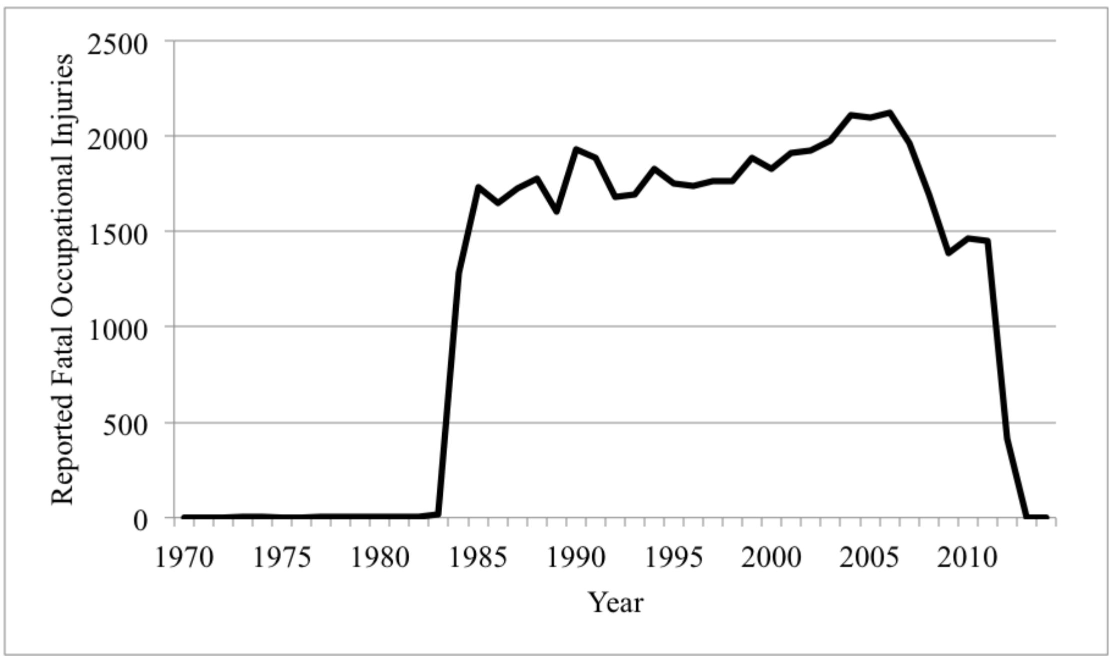

Figure C.2: Comparison of trends in annual number of fatal injuries recorded in the Census of Fatal Occupational Injuries (CFOI) and the Occupational Safety and Health Administration enforcement database (OSHA) over 1992 to 2011

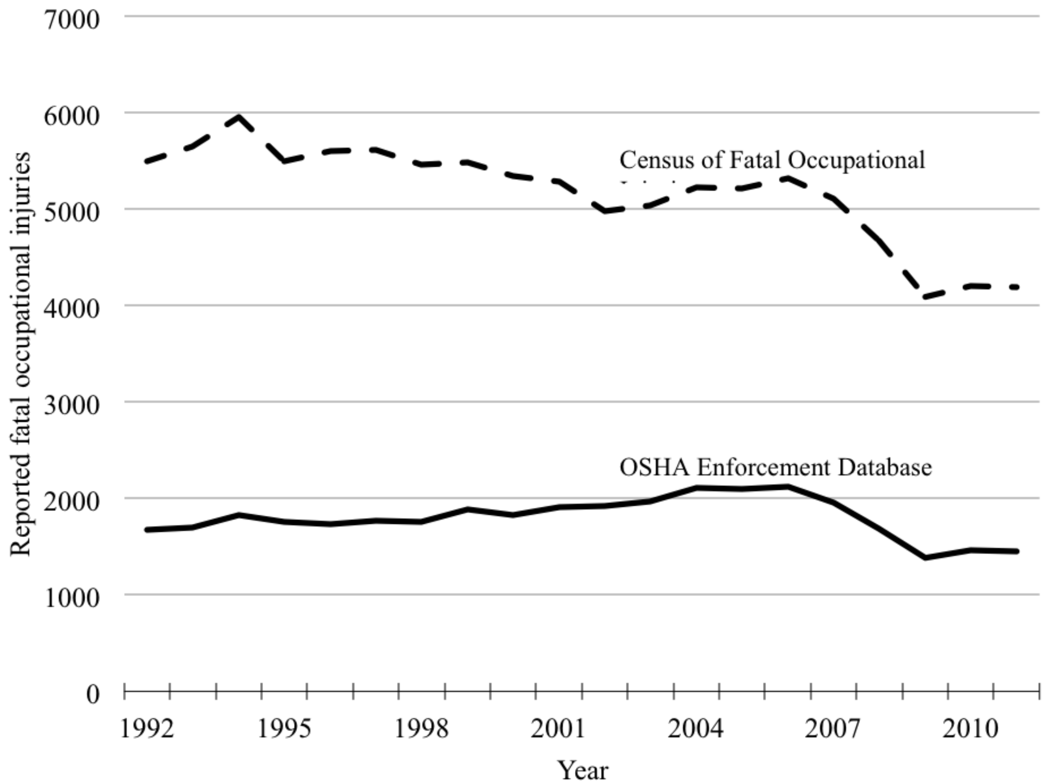

Table C.2: Effects of union certification by inspection type

Specification: Predictors	(1)	(2)	(3)	(4)
Union certified	0.00825** (0.00376)	0.00860** (0.00363)	0.00693** (0.00343)	0.00722** (0.00339)
Vote share	-0.0286 (0.0264)	-0.0201 (0.0257)	-0.0184 (0.0252)	-0.0154 (0.0251)
Vote share*certified	-0.0392 (0.0436)	-0.0514 (0.0420)	-0.0398 (0.0402)	-0.0396 (0.0399)
Pre-election violation index			-0.00589 (0.00408)	-0.00562 (0.00404)
Pre-election penalty index			0.0363*** (0.00878)	0.0339*** (0.00882)
Pre-election labor-representative share			0.0641*** (0.0148)	0.0655*** (0.0147)
Pre-election inspection rate		0.113*** (0.0291)	0.0678*** (0.0216)	0.0631*** (0.0208)
Pre-election injury index			-0.000764*** (0.00163)	-0.000683 (0.00161)
Eligible voters			5.55e-05*** (9.37e-06)	4.79e-05*** (9.29e-06)
Eligible voters squared			-5.45e-09*** (9.50e-10)	-4.65e-09*** (8.93e-10)
Industry Div. C				-0.00657 (0.00913)
Industry Div. D				0.00885 (0.00925)
Industry Div. E				-0.000607 (0.00846)
Industry Div. F				-8.16e-05 (0.00928)
Industry Div. G				-0.00966 (0.00903)
Industry Div. H				-0.000973 (0.00904)
Industry Div. I				0.00404 (0.00903)
Fatal injury rate of SIC2				-0.000185 (0.000126)
Nonfatal illness or injury rate of SIC2				0.00302*** (0.000301)
Constant	0.0289*** (0.00214)	0.0248*** (0.00230)	0.0236*** (0.00255)	-0.00302 (0.00936)
Adj. R^2	0.000195	0.0566	0.115	0.129

Notes: Estimate (Heteroskedasticity-robust SE). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. N=13,830.

Table C.3: Effect of union certification on post-election union-rep share at IK-optimal bandwidth 0.151 with varying sets of conditioning variables

Specification: Predictors	(1)	(2)	(3)	(4)
Union certified	0.0732*** (0.00945)	0.0711*** (0.00930)	0.0705*** (0.00923)	0.0710*** (0.00918)
Vote share	0.122** (0.0491)	0.1219** (0.0480)	0.139*** (0.0483)	0.139*** (0.0483)
Vote share*certified	-0.200* (0.110)	-0.205* (0.108)	-0.207* (0.107)	-0.211** (0.107)
Pre-election violation index			0.000387 (0.00357)	0.000912 (0.00344)
Pre-election penalty index			0.00966 (0.00633)	0.00544 (0.00626)
Pre-election labor-representative share		0.316*** (0.0280)	0.265*** (0.0283)	0.266*** (0.0282)
Pre-election inspection rate			0.0683*** (0.0167)	0.0617*** (0.0157)
Pre-election injury index			0.00238 (0.00147)	0.00246* (0.00143)
Eligible voters			0.000106*** (1.64e-05)	8.88e-05*** (1.62e-05)
Eligible voters squared			-1.03e-08*** (1.74e-09)	-8.47e-09*** (1.60e-09)
Industry Div. C				-0.0165 (0.0102)
Industry Div. D				0.0218* (0.0121)
Industry Div. E				0.0106 (0.00833)
Industry Div. F				-0.00168 (0.0121)
Industry Div. G				-0.0284** (0.0111)
Industry Div. H				-0.0140 (0.0160)
Industry Div. I				0.0187* (0.0110)
Fatal injury rate of SIC2				-0.00101*** (0.000308)
Nonfatal illness or injury rate of SIC2				0.00473*** (0.000861)
Constant	0.0419*** (0.00451)	0.0365*** (0.00439)	0.0250*** (0.00474)	-0.0180 (0.0110)
Adj. R^2	0.0261	0.0589	0.0711	0.0808

Notes: Estimate (Heteroskedasticity-robust SE). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. N=13,830.

Table C.4: Effect of union certification on post-election violation index at IK-optimal bandwidth 0.197 with varying sets of conditioning variables

Specification: Predictors	(1)	(2)	(3)	(4)
Union certified	0.0788** (0.0370)	0.0746** (0.0358)	0.0668* (0.0354)	0.0788** (0.0352)
Vote share	-0.130 (0.180)	-0.146 (0.175)	-0.0603 (0.175)	-0.0315 (0.172)
Vote share*certified	-0.329 (0.304)	-0.252 (0.295)	-0.296 (0.292)	-0.257 (0.288)
Pre-election violation index		0.139*** (0.0287)	0.0247 (0.0397)	0.0264 (0.0384)
Pre-election penalty index			0.216*** (0.0573)	0.183*** (0.0557)
Pre-election labor-representative share			0.288** (0.124)	0.320*** (0.122)
Pre-election inspection rate			0.359*** (0.108)	0.271*** (0.0957)
Pre-election injury index			-0.0103 (0.00693)	-0.00900 (0.00655)
Eligible voters			0.000261*** (6.24e-05)	0.000157** (6.25e-05)
Eligible voters squared			-3.23e-08*** (1.07e-08)	-2.16e-08** (8.97e-09)
Industry Div. C				-0.0385 (0.0294)
Industry Div. D				0.283*** (0.0420)
Industry Div. E				-0.00514 (0.0214)
Industry Div. F				0.103*** (0.0390)
Industry Div. G				0.0119 (0.0367)
Industry Div. H				0.0199*** (0.0347)
Industry Div. I				0.0702* (0.0373)
Fatal injury rate of SIC2				0.000878 (0.00129)
Nonfatal illness or injury rate of SIC2				0.0308*** (0.00366)
Constant	-0.00742 (0.0207)	-0.00736 (0.0202)	-0.0261 (0.0231)	-0.417*** (0.0438)
Adj. R^2	0.000165	0.0352	0.0516	0.0776

Notes: Estimate (Heteroskedasticity-robust SE). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. N=18,053.

Table C.5: Effect of union certification on post-election penalty index at IK-optimal bandwidth 0.153 with varying sets of conditioning variables

Specification: Predictors	(1)	(2)	(3)	(4)
Union certified	0.0731* (0.0410)	0.0681* (0.0396)	0.0657* (0.0393)	0.0735* (0.0388)
Vote share	-0.137 (0.291)	-0.159 (0.284)	-0.102 (0.285)	-0.0499 (0.281)
Vote share*certified	-0.492 (0.469)	-0.417 (0.457)	-0.454 (0.452)	-0.398 (0.446)
Pre-election violation index			0.0286 (0.0450)	0.0318 (0.0440)
Pre-election penalty index		0.297*** (0.0380)	0.187*** (0.0672)	0.151** (0.0651)
Pre-election labor-representative share			0.290** (0.132)	0.321** (0.130)
Pre-election inspection rate			0.434*** (0.147)	0.355*** (0.132)
Pre-election injury index			-0.0167* (0.00939)	-0.0152* (0.00900)
Eligible voters			0.000295*** (6.86e-05)	0.000188*** (6.87e-05)
Eligible voters squared			-2.89e-08*** (6.34e-09)	-1.84e-08*** (6.18e-09)
Industry Div. C				-0.0393 (0.0350)
Industry Div. D				0.226*** (0.0425)
Industry Div. E				-0.0208 (0.0239)
Industry Div. F				0.0745 (0.0473)
Industry Div. G				-0.0437 (0.0379)
Industry Div. H				0.0373 (0.0337)
Industry Div. I				0.0217 (0.0373)
Fatal injury rate of SIC2				-0.00242* (0.00124)
Nonfatal illness or injury rate of SIC2				0.0335*** (0.00396)
Constant	-0.00411 (0.0247)	0.0286 (0.0246)	-0.0354 (0.0270)	-0.379*** (0.0429)
Adj. R^2	8.71e-05	0.0444	0.0544	0.0824

Notes: Estimate (Heteroskedasticity-robust SE). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. N=13,830.

Table C.6: Effect of union certification on post-election injury index at IK-optimal bandwidth 0.146 with varying sets of conditioning variables

Specification: Predictors	(1)	(2)	(3)	(4)
Union certified	0.121 (0.0853)	0.122 (0.0852)	0.117 (0.0832)	0.120 (0.0839)
Vote share	-0.00500 (0.243)	0.0329 (0.247)	0.00305 (0.251)	0.0266 (0.255)
Vote share*certified	-1.252 (0.821)	-1.301 (0.822)	-1.315 (0.828)	-1.324 (0.830)
Pre-election violation index			-0.0329 (0.0291)	-0.0329 (0.0291)
Pre-election penalty index			0.0791 (0.0616)	0.0769 (0.0626)
Pre-election labor-representative share			0.895* (0.541)	0.900* (0.543)
Pre-election inspection rate			-0.0282 (0.103)	-0.0314 (0.101)
Pre-election injury index		0.0628 (0.0654)	0.0586 (0.0648)	0.0585 (0.0646)
Eligible voters			-0.000154** (6.85e-05)	-0.000158** (7.08e-05)
Eligible voters squared			1.47e-08** (7.06e-09)	1.47e-08** (7.15e-09)
Industry Div. C				-0.0259 (0.0344)
Industry Div. D				0.0190 (0.0711)
Industry Div. E				0.0844** (0.0353)
Industry Div. F				-0.00735 (0.0769)
Industry Div. G				-0.0533 (0.0681)
Industry Div. H				-0.0867 (0.0694)
Industry Div. I				-0.0651 (0.0749)
Fatal injury rate of SIC2				-0.00282 (0.00254)
Nonfatal illness or injury rate of SIC2				-0.00101 (0.00262)
Constant	-0.00399 (0.02115)	-0.00243 (0.0218)	0.00828 (0.0256)	0.0388 (0.0810)
Adj. R^2	0.000312	0.00872	0.0153	0.0154

Notes: Estimate (Heteroskedasticity-robust SE). *** Significant at the 1% level, ** Significant at the 5% level, * Significant at the 10% level. N=13,830.

Table C.7: Number of Inspections by year in OSHA (1985-2014)

Year	Inspection	Percent
1985	139,072	3.29
1986	134,640	3.18
1987	130,292	3.08
1988	125,460	2.97
1989	123,194	2.91
1990	135,533	3.2
1991	138,182	3.27
1992	125,339	2.96
1993	112,705	2.67
1994	112,476	2.66
1995	96,848	2.29
1996	92,360	2.18
1997	104,624	2.47
1998	101,230	2.39
1999	102,791	2.43
2000	100,088	2.37
2001	103,553	2.45
2002	111,094	2.63
2003	108,895	2.57
2004	107,194	2.53
2005	104,982	2.48
2006	107,440	2.54
2007	103,737	2.45
2008	106,210	2.51
2009	111,311	2.63
2010	109,337	2.59
2011	103,526	2.45
2012	101,033	2.39
2013	90,647	2.14
2014	2,701	0.06
Total	3,052,113	72

Table C.8: Effects of union certification using donut-RD, with various criteria for excluding based on margin of victory (MOV)

Sample:	Baseline	Excluding MOV≤ 1	Excluding MOV≤ 2	Excluding MOV≤ 3
	Outcome: inspection rate			
Certification effect	0.00722**	0.00507	0.00507	0.00599
	(0.00339)	(0.00506)	(0.00623)	(0.00752)
Adj. R^2	0.129	0.118	0.126	0.138
Obs.	$13,830$	$11,180$	$9,335$	$7,505$
	Outcome: labor-representative share			
Certification effect	0.0710***	0.0894***	0.108***	0.123***
	(0.00918)	(0.0138)	(0.0171)	(0.0204)
Adj. R^2	0.0808	0.0888	0.0918	0.0960
Obs.	$13,830$	$11,180$	$9,335$	$7,505$
	Outcome: violation index			
Certification effect	0.0788**	0.0954*	0.115*	0.140*
	(0.0352)	(0.0522)	(0.0683)	(0.0814)
Adj. R^2	0.0776	0.0758	0.0718	0.0714
Obs.	$18,053$	$15,403$	$13,558$	$11,546$
	Outcome: penalty index			
Certification effect	0.0735*	0.119*	0.134*	0.109
	(0.0388)	(0.0620)	(0.0813)	(0.0888)
Adj. R^2	0.0824	0.0841	0.0814	0.0848
Obs.	$13,830$	$11,180$	$9,335$	$7,505$
	Outcome: injury index			
Certification effect	0.120	-0.0234	-0.0226	0.0213
	(0.0839)	(0.0400)	(0.0455)	(0.0411)
Adj. R^2	0.0154	0.0318	0.00492	0.00656
Obs.	$13,830$	$11,180$	$9,335$	$7,505$

Notes: Estimate (Note: Estimate (Heteroskedasticity-robust SE). Significant at *** 1%, ** 5%, * 10% level. Each cell presents estimated union certification effect as in specification (4) in Table 4.4. The first column displays baseline results for comparison. The second column excludes establishments where the outcome of the focal election could have been changed if 1 vote switched sides. The third and fourth columns exclude elections where a switch of 2 and 3 votes, respectively, could change the outcome. Sample size drops rapidly because we lose many small elections; if they have a large MOV, they must not be close. If they are close, they must have a small MOV. As these more-questionable cases are excluded, you can see how estimates change.