WP/16/196

IMF Working Paper

Is Capping Executive Bonuses Useful?

by Kentaro Asai

INTERNATIONAL MONETARY FUND

 WP/16/196

IMF Working Paper

Monetary and Capital Markets

Is Capping Executive Bonuses Useful?

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September 2016

Abstract

This paper develops a theoretical framework to study the impact of bonus caps on banks' risk taking. In the model, labor market price adjustments can offset the direct effects of bonus caps. The calibrated model suggests that bonus caps are only effective when bank executives' mobility is restricted. It also suggests, irrespective of the degree of labor market mobility, bonus caps simultaneously reduce risk shifting by bank executives (too much risk taking because of limited liability), but aggravate underinvestment (bank executives foregoing risky but productive projects). Hence, the welfare effects of bonus caps critically depend on initial conditions, including the relative importance of risk shifting versus underinvestment.

JEL Classification Numbers: G32, G38, J33, M52, N20

Keywords: executive compensation; risk taking; risk shifting; underinvestment

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[1] Kentaro Asai was with the Global Stability Division of the IMF's Monetary and Capital Markets Department in 2014. The author would like to thank Gaston Gelos, Luis Brandão-Marques and all the participants at MCM Policy Forum for insightful suggestions, as well as Selim Elekdag, Pragyan Deb, Lev Ratnovski and Miguel Savastano for their additional comments. A condensed and simplified version of some of the analysis in this paper was included in Box 3.3 of International Monetary Fund (2014). All errors and omissions are my own.

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I. Introduction

Shareholders have limited liability, which means that they have a limited downside to their investment, but receive all the gains from an increase in the company's value. Therefore, they have an incentive to transfer wealth from creditors to themselves by choosing risky projects that do not create value for the firm. In practice, they outsource investment decisions to executive managers while aligning the incentives of these managers with their own interests using incentive contracts. As a result, these managers, on behalf of shareholders, can engage in risk shifting, that is, investing in risky projects with negative net present values. Although the debt market partly corrects risk shifting by adjusting credit spreads, this adjustment is not perfect because insured creditors are not incentivised to monitor credit risks (Demirgüç-Kunt and Kane, 2002).

Based upon this premise, it has been argued that bank executives' risk shifting played an important role in the global financial crisis (Boyd and Hakenes, 2014). In the aftermath of the crisis, regulators, particularly in the European Union (EU), have proposed various measures to restrict risk shifting by bank executives, including a bonus cap. For example, EU regulators have capped bonuses at 100 percent of salary in general, with the provision to increase it to 200 percent of salary with the approval of at least 65 percent of the firm's shareholders (or 75 percent in the absence of a quorum).

However, bonus caps remain controversial. In particular, there have been legal disputes among regulators (the United Kingdom (UK) sued the EU in September 2013), while academics have raised concerns. First, if the restrictions on variable pay, such as the ratio cap on fixed to variable remuneration, make bank managers move abroad to avoid the regulation, banks may respond to the ensuing shortage of qualified managers by increasing their base pay (International Monetary Fund (IMF), 2014; Murphy, 2013). This increase in base pay can raise the manager's expected payoff from a risky project, because it raises the compensation floor for the manager (that is the compensation received when a risky project yields a low return). Therefore, it can undo the effect of the cap because it can increase the attractiveness of undertaking a risky project. Thus, labor market adjustments, i.e. the increase in base pay for keeping bank executives from escaping to unregulated jurisdictions, can offset the impact of the policy.

Second, a bonus cap can potentially reduce good risk taking, excessively discouraging investment into risky projects with positive net present values. Since the bonus cap only matters for payoffs associated with high returns, it reduces the expected payoff from a risky investment with a high expected return more than that with a low expected return. Therefore, the policy can yield underinvestment, i.e. not investing in a risky project with a positive net present value, and cause efficiency losses.

Thus, the effect of a bonus cap on risk shifting is mixed if the labor market adjusts, while its impact on efficiency is ambiguous since it leads to underinvestment. These concerns motivate us to consider the following two questions: (i) to what extent can a bonus cap affect risk shifting and underinvestment and (ii) how much of the impact of a bonus cap is offset by labor market adjustments? To address these questions, we first model the investment decisions of bank executives; next, we calibrate the model by matching the theoretical predictions with observed data; and finally, we use the estimated model to simulate the impact of bonus caps while allowing for labor market adjustments.

Our model predicts that bonus capping reduces risk taking for all levels of profitability, although it is less effective for unprofitable projects. This suggests that the policy can aggravate underinvestment while having only a limited impact on the prevention of risk shifting. In line with this hypothesis, a numerical simulation suggests that bonus caps substantially foster underinvestment while they are only useful in the absence of labor market adjustments. Our analysis suggests that regulatory efforts to eliminate labor market adjustments (such as setting caps in all the sectors bank executives may move to, possibly at the international level) strengthen the effect of bonus capping on risk shifting to some extent, but they never fully prevent the problem of underinvestment from arising.

The rest of this paper is structured as follows. Section 2 briefly reviews the related literature. Section 3 describes the model of investment decisions by bankers. Section 4 characterizes the behavior of a regional representative bank. Section 5 calibrates the model. Section 6 simulates the impact of a bonus cap on risk shifting and underinvestment. Section 7 discusses policy implications.

II. LITERATURE REVIEW

To the best of our knowledge, no empirical studies have assessed the impact of bonus caps, largely because the regulatory reforms that followed the Global Financial Crisis are very recent. Moreover, although the existing empirical compensation literature, such as International Monetary Fund (IMF) (2014), suggests that performance-linked compensation in the form of options tends to be associated with more risk, their implications for other forms of bonus instruments are mixed (Table 1).[1] Therefore, the findings in these studies do not allow to derive straightforward predictions on the impact of bonus capping. Furthermore, the data do not distinguish the effect on risk shifting from the effect on risk taking, nor do they reveal the effect on underinvestment. Reduction in the observed risk measure may or may not correspond to a decrease in risk shifting or an increase in underinvestment. Without knowing the changes in these metrics, it is difficult to measure the welfare impact of reform. All of this motivates us to estimate the impact of bonus capping structurally.

Structural studies most relevant to this paper focus on the implication of bonus caps in individual countries. They include Dittmann, Maug, and Zhang (2011) and Llense (2010), who calibrate how firms in US and France, respectively, would react to different types of pay restrictions. Both studies find that bonus caps only have a moderate impact on shareholder value due to adjustments in labor markets. Our work complements these papers by assessing the implications of bonus caps in other regions.

Our approach is parsimonious relative to these papers, because we only need easily observable data at the region, country, and bank levels in order to simulate policies for a variety of objectives. This also enables us to conduct international analyses, which have seldom been done before. On the other hand, the downside of this approach is over-simplification. Our approach only focuses on the sensitivity of variable pay with respect to performance in the spirit of Gollier, Koehl, and Rochet (1997), so we do not evaluate the regulations of different bonus instruments (cash, equity, options, etc.).

III. MODEL

Shareholders with limited liability align the interests of bank executives with their incentives through incentive contracts. Therefore, incentive contracts have to offer a compensation schedule that resembles the payoff schedule of shareholders with limited liability, which is flat up to a certain performance threshold and positively associated with the performance of the bank thereafter. As a result, executive compensation is a convex function of a bank's performance. In this section, we examine the incentives for risk taking by bank executives under convex compensation schedules and how they are altered by a bonus cap.

[1] See International Monetary Fund (IMF) (2014) for a comprehensive cross-country assessment of the effect of different types of executive compensation on bank risk taking.

A. Investment decision

First, we characterize the investment decision by bank executives. The performance threshold is the benchmark against which the banker's performance is measured. It may be zero profit, the risk free rate, the previous year's performance, the performance of rivals, etc. We denote it by θ. Let β be the incentive parameter that specifies the amount by which his/her compensation increases based on his/her performance above the performance threshold.

There are two periods ($t = 0, 1$). At $t = 0$, the banker receives the fixed salary w_0 and the opportunity of investing in a risky project. At $t = 1$, he/she receives the bonus that is linked to performance. The banker's performance is measured by the realized return of his/her portfolio. The risky project yields a return of x at $t = 1$. But, the banker does not know this at $t = 0$. Instead, he/she has a belief about the risky project's return denoted by $\tilde{x}$, which follows the distribution characterized by the cumulative distribution function G_x. The return of the safe asset x_0 is known.

The banker has to decide on exposure to the risky project $s \in \{0, 1\}$ at $t = 0$, which maximizes the expected compensation at $t = 1$. Thus, his/her belief about the return of the portfolio is expressed by $s\tilde{x} + (1 - s)x_0$. Accordingly, the belief about the compensation is:

$$w(s, \tilde{x}) \equiv \max\{w_0 + \beta(s\tilde{x} + (1 - s)x_0 - \theta), w_0\}.$$

Moreover, we assume that there is a transaction cost λs ($\lambda > 0$) for having exposure to the risky asset. [2] Since the banker chooses the exposure that maximizes the expected compensation, his/her investment decision is characterized by:

$$s^*(x) = \arg\max_{s \in \{0,1\}} E_x[w(s, \tilde{x})] - \lambda s,$$

where he/she expects to receive:

[2] We observe that compensation tends to be higher in a region with higher risk exposure. Assuming that a banker is indifferent across regions, there has to be some cost associated with risk taking. For example, a banker may be accountable to both regulators and clients when he/she has greater exposure to risky asset or, simply, may be risk-averse.

$$w^*(x) \equiv E_x[w(s^*(x), \tilde{x})].$$

Then, we obtain the following solution:

$$s^*(x) = \begin{cases} 1 & if E_x[w(1,\tilde{x})] - \lambda > E_x[w(0,\tilde{x})] \\ 0 & if E_x[w(1,\tilde{x})] - \lambda \leq E_x[w(0,\tilde{x})] \end{cases}.$$

B. Comparative statics

Next, we analyze how the incentive of taking risk is altered by parameters in our model.[3] Let the value of fully investing in the risky asset relative to fully investing in the safe asset be $\Delta(x)$. It is characterized by:

$$\Delta(x) \equiv \begin{cases} \beta \int_{\theta}^{\infty} (\tilde{x} - \theta) dG_x(\tilde{x}) - \lambda & if \theta > x_0 \\ \beta \int_{\theta}^{\infty} (\tilde{x} - \theta) dG_x(\tilde{x}) - \beta (x_0 - \theta) - \lambda & if \theta \leq x_0 \end{cases}.$$

First, we find that the value of risk taking decreases with the distance between the benchmark return θ and the risk free return x_0:

$$\frac{\partial \Delta(x)}{\partial \theta} = \begin{cases} -\beta[1 - G_x(\theta)] & if \theta > x_0 \\ \beta G_x(\theta) & if \theta < x_0 \end{cases}.$$

To provide the intuition for this result, consider the case in which a bank executive has a risky investment project, with the performance of a bank above the performance threshold in the good state and below the performance threshold in the bad state. When the performance threshold is lower than the risk free rate, the increase in the performance threshold lowers the payoff that the banker receives at the risk free rate and the payoff that the banker receives from the risky investment in the high state. However, it does not affect the payoff

[3] See also Box 3.3 of International Monetary Fund (IMF) (2014) for a simplified discussion of this setup.

that the banker receives from the risky investment in the low state. As a result, on average the decrease in payoff is milder for the risky investment.

When the performance threshold is higher than the risk free rate, the decline in the performance threshold does not affect the payoff that the banker receives at the risk free rate or the payoff that the banker receives from the risky investment in the bad state. However, it increases the payoff that the banker receives from the risky investment in the good state. As a result, on average the increase in the payoff is greater for the risky investment.

Thus, in both cases, the incentive for risk taking rises when the performance threshold is closer to the risk free rate.

Second, we can show that an increase in the risk free rate discourages risk taking by increasing the payoff associated with investing in the safe asset:

$$\frac{\partial \Delta(x)}{\partial x_0} = \begin{cases} 0 & if \theta > x_0 \\ -\beta & if \theta < x_0 \end{cases}.$$

Third, we can show the relation between the incentive parameter β and the incentive for risk taking:

$$\frac{\partial \Delta(x)}{\partial \beta} = \begin{cases} \int_{\theta}^{\infty} (\tilde{x} - \theta) dG_x(\tilde{x}) & if \theta > x_0 \\ \int_{\theta}^{\infty} (\tilde{x} - \theta) dG_x(\tilde{x}) - (x_0 - \theta) & if \theta \leq x_0 \end{cases}.$$

We note that an increase in the incentive parameter can both encourage and discourage risk taking. It unambiguously raises the compensation associated with the return above the risk free rate. If the risk free rate is below the performance threshold, the compensation associated with the return below the risk free rate remains unchanged relative to the compensation at the risk free rate, after the increase in the incentive parameter. Therefore, it necessarily raises the incentive for taking risk. However, if the risk free rate is above the performance threshold, the compensation associated with the return below the risk free rate decreases relative to the compensation at the risk free rate. As a result, performance-based compensation does not necessarily increase risk-taking incentives.

C. Bonus capping

Lastly, we investigate how a bonus cap affects the incentive to take risk. A bonus cap makes the compensation schedule less convex by setting the maximum amount of bonus payable. It is usually expressed as a multiple of a fixed salary. We denote the multiple by ρ ($\rho > 0$). Then the regulated compensation schedule is described as:

$$w(s,\tilde{x}) \equiv \max\{w_0 + \min\{\beta(s\tilde{x} + (1-s)x_0 - \theta), \rho w_0\}, w_0\}.$$

When a bank executive does not earn the maximum bonus at the risk free rate, ρ satisfies $\frac{\rho w_0}{\beta} + \theta \geq x_0$. Unless otherwise noted, we assume this condition holds. If $\frac{\rho w_0}{\beta} + \theta < x_0$, the banker earns the highest compensation when he/she fully invests in the safe asset as long as λ is positive. Thus, he/she does not have any exposure to the risky asset.

Since the upside of the risky return is not as large as without a bonus cap, the marginal value of increasing exposure to the risky asset is lower than before:

$$\begin{aligned}
\frac{\partial(E_x[w(s,\tilde{x})] - \lambda s)}{\partial s} &= \beta \int_{\frac{\theta-(1-s)x_0}{s}}^{\frac{\rho w_0}{\beta s} + \frac{\theta-(1-s)x_0}{s}} (\tilde{x} - x_0) dG_x(\tilde{x}) - \lambda \\
&\leq \beta \int_{\frac{\theta-(1-s)x_0}{s}}^{\infty} (\tilde{x} - x_0) dG_x(\tilde{x}) - \lambda.
\end{aligned}$$

This implies that a bonus cap reduces the incentive for risk taking.

For analyzing the impact of a bonus cap on risk taking, we characterize the value of risk taking as follows:

$$\Delta(x;\rho) \equiv \begin{cases} \beta \int_{\theta}^{\frac{\rho w_0}{\beta}+\theta} (\tilde{x} - \theta) dG_x(\tilde{x}) + \rho w_0 (1 - G_x(\frac{\rho w_0}{\beta} + \theta)) - \lambda & if \theta > x_0 \\ \beta \int_{\theta}^{\frac{\rho w_0}{\beta}+\theta} (\tilde{x} - \theta) dG_x(\tilde{x}) + \rho w_0 (1 - G_x(\frac{\rho w_0}{\beta} + \theta)) - \beta(x_0 - \theta) - \lambda & if \theta \leq x_0 \end{cases}.$$

First, we find that $\Delta(x;\rho)$ is increasing in ρ for any return x:

$$\frac{\partial\Delta(x;\rho)}{\partial\rho} = w_0(1-G_x(\frac{\rho w_0}{\beta}+\theta)).$$

Second, we note that fixed salary w_0 affects $\Delta(x;\rho)$ in the same way as does ρ:

$$\frac{\partial\Delta(x;\rho)}{\partial w_0} = \rho(1-G_x(\frac{\rho w_0}{\beta}+\theta)).$$

Third, we claim that θ affects $\Delta(x;\rho)$ in the same way it does without a bonus cap:

$$\frac{\partial\Delta(x;\rho)}{\partial\theta} = \begin{cases} -\beta[G_x(\frac{\rho w_0}{\beta}+\theta)-G_x(\theta)] & if \theta > x_0 \\ \beta G_x(\theta)+\beta[1-G_x(\frac{\rho w_0}{\beta}+\theta)] & if \theta < x_0 \end{cases}.$$

Fourth, we show that the regulatory impact of a bonus cap is positively associated with the return of a risky asset, if a project with higher return has first-order stochastic dominance (with respect to a banker's belief about the risky return) over a project with lower return:

$$\frac{\partial^2\Delta(x;\rho)}{\partial\rho\partial x} = -w_0\frac{\partial G_x(\frac{\rho w_0}{\beta}+\theta)}{\partial x}.$$

For example, suppose that there are two risky investments, one with a lower and one with a higher expected return. Both projects yield the identical return in the bad state, while one yields a higher return in the good state. Then, the payoff that the banker receives from the risky investment with higher expected return in the good state is more likely to hit the bonus cap because the bonus cap only matters for the payoffs associated with high returns. Therefore, the expected payoff from the risky investment with higher expected return is more likely to decrease by a bonus cap than that from the risky investment with lower expected return.

Our results so far can be summarized as follows:

Proposition 1. *A bonus cap reduces the banker's incentive to invest in a risky asset. Suppose that a project with higher return has first-order stochastic dominance (with respect to a banker's belief about the risky return) over a project with a lower return, then the impact of a bonus cap becomes larger if the return to a risky asset is larger.*

Proof. See the Appendix. □

Proposition 1 suggests that a bonus cap suppresses risk taking for any type of project, but it is more effective for high-return projects. This implies that a bonus cap may not be effective in preventing risk shifting. Moreover, the bonus cap may result in underinvestment because it suppresses investment in risky projects with relatively high returns.

IV. REGIONAL MODEL

So far, we have focused on the investment decision of an individual banker. Now, we characterize the behavior of a representative regional bank that hires many bankers and how this behavior is affected by bonus capping while taking into account labor market adjustments.

A. Representative regional bank

Let us consider a representative regional bank of a generic region j. Let the distribution of return to the risky project for region j be characterized by the cumulative distribution function F_j. Then, the average exposure to risky projects is:

$$s_j^* \equiv \int_{-\infty}^{\infty} s_j^*(x) dF_j(x). \quad (1)$$

Let $w_j(s_j^*(x), x)$ be the compensation from investing in the risky project that yields a return of x, which is received by the banker ex-post. This is distinct from the compensation from investing in the same project ($w_j^*(x) = E_x[w_j^*(s_j^*(x), \tilde{x})]$), which is expected ex-ante by the banker in the presence of uncertainty. Then, the average compensation from investing in the risky projects, received by the banker ex-post, can be expressed as:

$$w_j^* \equiv \int_{-\infty}^{\infty} w_j(s_j^*(x), x) dF_j(x). \quad (2)$$

Let us define risk shifting as the average incidence of investing in risky projects that yield returns below the risk free rate:

$$rs_j^* \equiv \int_{-\infty}^{x_0} s_j^*(x)dF_j(x). \quad (3)$$

Similarly, let us define underinvestment as the average incidence of not investing in risky projects that yield returns above the risk free rate:

$$ui_j^* \equiv \int_{x_0}^{\infty}(1-s_j^*(x))dF_j(x). \quad (4)$$

Thus, risk shifting can be interpreted as the probability of taking on a bad risk, while underinvestment as the probability of refraining to take good risk.

B. Labor market equilibrium

Then, we characterize the labor market equilibrium of bankers. We assume that there are J regions where bankers can travel across. At equilibrium, each banker is indifferent to every region. Therefore, we characterize the labor market equilibrium of bankers by:

$$u^* \equiv w_j^* - \lambda s_j^* - c_j \quad \forall 1 \leq j \leq J, \quad (5)$$

where c_j is the entry cost to participate in the market j.

C. Regulation with a restriction on the labor mobility of bankers

Next, we analyze the impact of bonus capping on a bank's risk taking while preventing labor market adjustments. Immediately after bonus capping is introduced, a banker does not know the average compensation that he/she will actually receive under the new compensation schedule. This is because he/she does not yet know the return from his/her investment. Therefore, the banker remains in the region if the average compensation that he/she expects to receive ex-ante is at least as large as the original one. Then the reservation value for the banker to stay in the regulated region is expressed by:

$$v_j^* \equiv \int_{-\infty}^{\infty} w_j^*(x) dF_j(x) - \lambda s_j^* - c_j. \quad (6)$$

Let $u_j^C(\hat{\rho}_j)$ be the average value that the banker expects to receive ex-ante following the introduction of the bonus cap $\hat{\rho}_j$. Then it is characterized by:

$$u_j^C(\hat{\rho}_j) \equiv w_j(0;\hat{\rho}_j) + \int_{-\infty}^{\infty} 1[\Delta_j(x_j;\hat{\rho}_j) > 0]\Delta_j(x_j;\hat{\rho}_j) dF_j(x_j) - c_j.$$

where $\Delta_j(x_j;\hat{\rho}_j)$ is the value of risk taking after regulation and $w_j(0;\hat{\rho}_j)$ is the compensation the banker earns at the risk free rate under the regulation.

To keep the banker within region j, we need to make the banker who leaves for the new job pay $v_j^* - u_j^C(\hat{\rho}_j)$.

D. Regulation without any restriction on the labor mobility of bankers

Lastly, we consider the case where a regulator does not control labor market adjustments. First, we notice:

$$u_j^C(\hat{\rho}_j) < v_j^*.$$

Since it does not satisfy the participation condition of a banker, the compensation of a banker has to be adjusted upwards. Then the modified aggregate ex-ante expected utility $u_j^L(\hat{\rho}_j, \hat{w_0}_j, \hat{\theta}_j)$ satisfies:

$$u_j^L(\hat{\rho}_j, \hat{w_0}_j, \hat{\theta}_j) = v_j^*.$$

Keeping the incentive parameter unaffected, there may be two types of adjustment: (i) an increase in w_{0j} and (ii) simultaneous increases in w_{0j} and θ_j. For (i), the adjusted fixed salary

$\hat{w_{0j}}$ satisfies:

$$v_j^* \;= w_j(0;\hat{\rho}_j;\hat{w_{0j}},\theta_j) + \int 1[\Delta_j(x_j;\hat{\rho}_j;\hat{w_{0j}},\theta_j) > 0]\Delta_j(x_j;\hat{\rho}_j;\hat{w_{0j}},\theta_j)dF_j(x_j) - c_j. \quad (7)$$

where $\Delta_j(x_j;\hat{\rho}_j;\hat{w_{0j}},\theta_j)$ is the value of risk taking and $w_j(0;\hat{\rho}_j;\hat{w_{0j}},\theta_j)$ is the compensation the banker earns at the risk free rate under the regulation. Since the right hand side of Equation (7) is continuous and strictly increasing in $\hat{w_{0j}}$, it diverges to infinity as $\hat{w_{0j}}$ goes to infinity. Moreover, it converges to $u_j^C(\hat{\rho}_j)$ as $\hat{w_{0j}}$ goes to w_{0j}. Therefore, there exists a unique $\hat{w_{0j}}$ satisfying Equation (7).

Alternatively, the labor market may adjust both the fixed salary and the performance threshold, as suggested by Murphy (2013).[4] In this case, the new performance threshold satisfies: $\hat{\theta}_j(\hat{w_{0j}}) = \theta_j + \frac{\hat{w_{0j}} - w_{0j}}{\beta}$. Then the new fixed salary is the solution of:

$$v_j^* \;= w_j(0;\hat{\rho}_j;\hat{w_{0j}},\hat{\theta}_j(\hat{w_{0j}})) + \int 1[\Delta_j(x_j;\hat{\rho}_j;\hat{w_{0j}},\hat{\theta}_j(\hat{w_{0j}})) > 0]\Delta_j(x_j;\hat{\rho}_j;\hat{w_{0j}},\hat{\theta}_j(\hat{w_{0j}}))dF_j(x_j) - c_j. \quad (8)$$

It is not clear if there is a unique $\hat{w_{0j}}$ satisfying Equation (8), analytically. This is because the right hand side of Equation (8) may not be monotone in $\hat{w_{0j}}$; an increase in the performance threshold can increase the distance between the performance threshold and the risk free rate and discourage risk taking, whereas an increase in $\hat{w_{0j}}$ encourages risk taking. Therefore, we numerically search $\hat{w_{0j}}$ that satisfies Equation (8) with various initial values, but we only find a single fixed salary that satisfies Equation (8) in our numerical search.

For both (i) and (ii), we anticipate that the regulatory impact will be offset by an increase in a fixed salary. However, it is unclear how much a bonus cap can reduce risk shifting ceteris paribus, and how much labor market adjustments offset (or overwhelm) the regulatory impact. To answer these questions, we calibrate the model and simulate the impact of regulation in the next few sections.

V. Calibration

In this section, we describe the strategy for calibrating the model and present the estimated parameters.

[4] See Figure 3 of Murphy (2013).

A. Data

First, we take the estimates for the aggregate ex-post compensation and the average fixed salary of bank CEOs in five large geographic regions from 2005 to 2013 ($\{w_{0j}, w_j^*\}_{1\leq j\leq J}$) from S&P Capital IQ (Tables 2 and 8).

Second, we observe the aggregate exposure to risky assets of each region for the same period ($\{s_j^*\}_{1\leq j\leq J}$) from the market beta of the banking sector in each region (Table 8).[5] In order to recover the aggregate exposure to risky assets from the market beta, we assume that the banking sector in each region has the safe asset and the market portfolio of risky assets, following the two-fund separation theorem.[6]

Since leverage in banking is higher than in other sectors, we account for the leverage gap when we recover s_j^* from the market beta. Let L_j^B be the leverage ratio of the banking sector and L_j^M be that of the constituents of a local market portfolio. Let the ROA (relative to the risk free rate) of banks be B_j and that of the local market portfolio be M_j. Then, $B_j = s_j^* M_j$. Therefore, the ROE (relative to the risk free rate) of the banking sector will be $L_j^B B_j$ and that of the local market portfolio will be $L_j^M M_j$. Finally, we can express the local market beta, $beta_j$, as:

$$beta_j = \frac{COV(L_j^B B_j, L_j^M M_j)}{VAR(L_j^M M_j)} = \frac{L_j^B L_j^M COV(s_j^* M_j, M_j)}{L_j^{M2} VAR(M_j)} = \frac{s_j^* L_j^B VAR(M_j)}{L_j^M VAR(M_j)} = \frac{s_j^* L_j^B}{L_j^M}.$$

Therefore, the aggregate exposure to risky assets is given by: $s_j^* = beta_j \frac{L_j^M}{L_j^B}$. The aggregate exposure to risky assets is inversely proportional to the leverage ratio of the banking sector relative to that of the constituents of a local market portfolio.

Third, we calculate the average three-month U.S. Treasury bill rate between 2005 and 2013 and take it as a proxy for the return on safe assets of every region (x_0). This is equal to 1.5 percent.

Fourth, we observe the distribution of return to the risky project for each region ($\{F_j\}_{1\leq j\leq J}$) from the BIS consolidated banking statistics and accounting data. Since banks in each region have exposure to the global market, we start with observing the geographical breakdown of their assets in order to account for international asset allocation (Table 3). To complete

[5]We take the average of the market beta of banks by region from 2005 to 2013 based on the data we used to report Table 3.6 in International Monetary Fund (IMF) (2014).

[6]According to the theorem, all investors will hold a combination of the safe asset and the market portfolio.

this, we use the BIS consolidated banking statistics. The BIS data allows us to compute total foreign claims as well as claims on the individual countries of banks headquartered in the BIS reporting countries. We follow the definition of regions used in International Monetary Fund (IMF) (2014), which is explicitly described in Table 3. The definition is based on Macey and O'Hara (2003) classification of regional corporate governance models: Anglo- American, Franco-German or Advanced European, and Other. Therefore, we separate Anglo-Saxon countries like UK and Ireland from continental Europe even if they all belong to Western Europe, because the corporate governance models are different.

We note that many of the countries listed in Table 3 do not report data to the BIS. In the BIS data, non-reporting countries are captured in their role as borrowers, but not in their role as lenders. Because of this, our geographical breakdown data over-represent banks headquartered in the BIS reporting countries. However, we also note that banks headquartered in the BIS reporting countries tend to dominate a large part of total assets in each region. For each region, we obtain the aggregated claims on the other regions and obtain the aggregated total assets of banks from SNL financial and FDIC. By dividing the former by the latter, we obtain the geographical breakdown of asset exposure of banks in each region. We use the average geographical breakdown of each region from 2005 to 2013 for our estimates.

Next, we observe the ROA of all constituents in the local equity index for each region by year from Datastream.[7] We draw samples for the simulation by year because this enables us to estimate risk shifting and underinvestment by year. Many regulators are interested in the prevalence of risk shifting during economic crises, so it is valuable to provide estimates for the year 2008 in addition to overall estimates. We construct the empirical distribution of ROA for each invested region by year (Table 4). The mixture distribution generated from the convex combination of the geographical breakdown of bank assets and the ROA distribution of each invested region replicates the distribution of the risky return of each region ($\{F_j\}_{1 \leq j \leq J}$).

[7]For Asia, we use the TOPIX, the SSE Composite Index, and the CNX 500. For Anglo-Saxon countries, excluding the U.S., we use the FTSE All-Share, the S&P/ASX 300, and the S&P TSE Composite Index. For the U.S., we use the S&P 500. For Continental Europe, we use the DAX 100, the CAC All-Share, Milan Comit General, IBEX 35, IBEX Medium & Small Caps, and the AEX All-Share. For EMEA, we use the ISE National All-Share, the Russian RTS, and the DJ TA 100 Index. We drop any constituents without full observation of the ROA between 2005 and 2013.

Lastly, we take the historical coefficient of variation of each constituent[8] in the local equity index to estimate the degree of uncertainty for risky investment.[9] We assume that a banker's belief about a risky return is normally distributed around the true return with a standard deviation based on the historical coefficient of variation. In this way, we can recover a belief about the risky project's return (G_x) if we know that the constituent's ROA is x.

B. Estimation

Our goal is to estimate structural parameters by fitting model prediction to data.[10] First, we estimate the cost of investing in a risky project as well as the entry cost in each region (λ,$\{c_j\}_{1\leq j\leq J}$) using Equation (5). Notice that we obtain the following linear relationship:

$$(w_j^* - w_1^*) = \lambda(s_j^* - s_1^*) + (c_j - c_1) \quad \forall 2 \leq j \leq J. \quad (9)$$

After arbitrarily determining region 1, we can regress the aggregate ex-post compensations (relative to region 1) on the aggregate exposures to risky assets (relative to region 1).[11] The coefficient is the cost of investing in risky projects, while the entry cost of each region (relative to region 1) is calculated by adding the constant and the residual. Without loss of generality, we set $c_1 = 0$.

Next, we estimate the remaining parameters ($\{\theta_j, \beta_j\}_{1\leq j\leq J}$) using Equations (1) and (2). Note that we have already obtained the estimator for the cost of investing in risky projects ($\hat{\lambda}$). Since Equations (1) and (2) provide us with $2J$ equations, we can estimate at most $2J$ parameters if we know all the rest of the parameters and the distributions.

Utilizing the data, we are able to predict the investment decision of an individual banker for each region if we are given $\{\theta_j, \beta_j\}_{1\leq j\leq J}$. After a sufficient number of iterations, we can predict the aggregate ex-post compensation and exposure to risky assets for each region. We try to match the simulation result with the observed data by choosing appropriate$\{\theta_j, \beta_j\}_{1\leq j\leq J}$.

[8] Standard deviation of the ROA between 2005 and 2013/absolute mean of the ROA between 2005 and 2013.

[9] The standard deviation of forecast errors is recovered by multiplying the absolute value of the ROA with the coefficient of variation.

[10] Jokivuolle, Keppo, and Yuan (2015) take a similar approach to ours in order to simulate the impact of a bonus cap. While our primary goal is to estimate compensation structure, their aim is to estimate the cost of risk taking.

[11] The identifying assumption is the independence of $\{s_j^*\}_{1\leq j\leq J}$ from $\{c_j\}_{1\leq j\leq J}$.

Formally, for each region j by year from 2005 to 2013, we start by drawing a region in which to invest using the geographical breakdown we observed. Then, we draw a constituent and its ROA from the set of constituents of the local equity index associated with the location we drew in the first step. We repeat this procedure K times to get $\{x_j^k\}_{k=1}^K$. Lastly, we draw forecast errors from the normal distribution associated with that constituent R times to get $\{\tilde{x_j}^{k_r}\}_{r=1}^R$. In our estimation, we set $K = 1000$ and $R = 100$. Then, we approximate the integrals represented by the right hand side of Equations (1) and (2) by Monte Carlo simulation as follows:

$$\begin{aligned}
\hat{s_j}^*(x_j^k) &= 1[\beta_j \frac{1}{R}\sum_{r=1}^{R}[1[\tilde{x}^{k_r} > \theta_j](\tilde{x}^{k_r} - \theta_j) - 1[x_0 > \theta_j](x_0 - \theta_j)] - \hat{\lambda} > 0] \\
\hat{w_j}^*(\hat{s_j}^*(x_j^k), x_j^k) &= w_{0j} + \beta_j 1[\hat{s_j}^*(x_j^k)x^k + (1 - \hat{s_j}^*(x_j^k))x_0 \geq \theta_j][\hat{s_j}^*(x_j^k)x^k + (1 - \hat{s_j}^*(x_j^k))x_0 - \theta_j].
\end{aligned}$$

Then, we minimize the approximated objective function with constraints as below:

$$\hat{g} = \left\{ \begin{bmatrix} \frac{\sum_{k=1}^{K}\hat{s_j}^*(x_j^k)}{K} - s_j^* \\ \frac{\sum_{k=1}^{K}\hat{w_j}^*(\hat{s_j}^*(x_j^k), x_j^k)}{K} - w_j^* \end{bmatrix} \right\}_{j=1}^{J}$$

$$\min_{\{\theta_j, \beta_j\}_{1 \leq j \leq J}} \hat{g}'\hat{g} \quad s.t. \beta_j \geq 0. \quad (10)$$

C. Estimated parameters

We report our estimated parameters in Tables 6 and 7. We also present the fit of our model in Table 8. We find that our estimation is sufficiently close to the observed data. From the first step, we find that the cost of risky investment is positive, implying that the CEO of a financial institution is burdened with some cost when investing in a risky asset. Alternatively, this may be interpreted as risk aversion. The entry costs in the U.S. and the other Anglo-Saxon countries are larger than those in Asia. This may be because it may require a larger investment of human capital to become a CEO in these countries. From the second step, we find that the incentive parameter is larger in emerging regions and smaller in advanced regions. The estimated performance threshold of each region is close to the risk free rate.

Next, we estimate the status-quo of risk shifting and underinvestment using Equations (3) and (4) via Monte Carlo simulation (Figures 1 and 2). First, we find that risk shifting is not proportional to the exposure to risky assets. For example, the exposure to risky assets is higher in the U.S. than in continental Europe but risk shifting is much lower in the U.S. Moreover, we observe that risk shifting peaks around 2008, confirming the tendency of gambling for resurrection during financial crises in all regions. Second, our estimates indicate that there is substantial underinvestment.[12]

VI. COUNTERFACTUAL ANALYSIS

In this section, we simulate the impact of a bonus cap on risk shifting and underinvestment with the calibrated model.

A. Main results

First, we simulate the average impact of a bonus cap on average risk shifting and underinvestment over the period 2005 to 2013 for each region. The bonus cap is represented as a multiple of a fixed salary. We report our estimation results in Figures 3 and 4.

Initially, we consider the case where the labor mobility of bank executives is restricted. Using the parameters estimated in Section 5, coupled with each proposed cap (a cap is more severe if it is lower), we simulate the investment decisions of bank executives with the compensation scheme redefined in Section 4. As we have done in Section 5, we predict risk shifting and underinvestment for each proposed cap. We find that risk shifting is substantially reduced in all regions with a moderate cap size. However, there is a trade-off between a reduction of risk shifting and an increase in underinvestment for all the regions. The regulatory impact is largest in emerging regions because the fixed salary is so low that a bonus cap is very powerful.

Next, we assume that labor mobility of bank executives is not restricted. Using the parameters estimated in Section 5, combined with each proposed cap, we compute the equilibrium

[12]While these results may be subject to the choice of the return on safe assets, Figures 6 and 7 suggest we have similar results when we consider the average five-year U.S. Treasury bill rate between 2005 and 2013 (2.5 percent) as the return on safe assets.

base salary of each region, maintaining the ex-ante expected utility of the banker at its original level. We do this for each type of labor market adjustment. In our simulation, we find only one equilibrium fixed salary for each proposed cap when the labor market adjustment involves the shift in the performance threshold. After obtaining a new base salary, we again simulate the investment decisions of bank executives and estimate risk shifting and underinvestment after labor market adjustments. We find that labor market adjustments substantially offset the regulatory impact on risk shifting and underinvestment for most regions. For Asia, Anglo-Saxon ex U.S., U.S., and Continental Europe, only very tight caps (5 x fixed wage or less) reduce risk shiting. As an exception, for case (ii), moderate caps eliminate risk shifting for EMEA due to a shift in the performance threshold.

B. Is a bonus cap useful in times of financial crisis?

Second, we simulate the impact of a bonus cap on risk shifting in 2008 (Figure 5), since reducing risk shifting around economic crises is of particular interest. Our simulation suggests that the impact of a bonus cap on risk shifting is largely offset by labor market adjustments in 2008 for most regions, regardless of case (i) or (ii), although the labor market during economic crises may be rigid compared to normal times so that labor market may not adjust as much as we estimate.

VII. Discussion

Our analysis implies that there is substantial variation in the level of risk shifting across regions under the existing system, meaning that it is important for regulators to know the level of risk shifting in advance, in order to find the right targets to regulate. For example, we find that risk shifting is lower in the U.S. than in other regions.

A bonus may be an effective policy tool for eliminating risk shifting only in the absence of labor market adjustments. To substantially reduce risk shifting by the bonus cap, regulators would have to eliminate labor market adjustments. In principle, they can set bonus caps on all the sectors bank executives may move to. In line with this, the European Banking Authority (EBA) has recently decided that national regulators would no longer be allowed to exempt small banks and some large asset managers from rules that cap bonuses as a proportion of fixed pay (European Banking Authority, 2015).

Our analysis also implies that the bonus cap aggravates the underinvestment problem. Eliminating labor market adjustments does not resolve this issue.

Lastly, I discuss a potential extension of this research. First, building a dynamic model may improve the understanding of a banker's risk taking behavior. If a threat of losing future earnings increased a penalty on risk shifting, the banker's risk shifting would be less common than that predicted by our model.

Other opportunities for further research include the consideration of a banker's efforts for monitoring risky projects' returns. If a banker's monitoring efforts were negatively correlated with the profitability of a risky project, she might be more (less) uncertain about returns on profitable (unprofitable) risky projects, reducing her ex-ante anticipated gain on risky investment. Consequently, our model could underestimate the degree of underinvestment and overestimate risk shifting. On the other hand, if her monitoring efforts were positively associated with the profitability of a risky project, our model's prediction could be biased in the opposite direction.

Allowing heterogeneous costs for different types of risky projects may also improve our understanding of bank risk taking behavior. If regulatory costs incurred by a banker were negatively correlated with the profitability of a risky project, the banker's ex-ante anticipated gain on profitable risky investment would increase while that on unprofitable risky investment would decrease. As a result, our model could overestimate both unverinvestment and risk shifting.

APPENDIX

The first claim is verified by the following:

$$
\begin{aligned}
& \Delta(x;\rho') - \Delta(x;\infty) \\
= & -\int_{\rho'}^{\infty} \frac{\partial \Delta(x;y)}{\partial \rho} dy \\
= & -\int_{\rho'}^{\infty} w_0 (1 - G_x(\frac{y w_0}{\beta} + \theta)) dy \\
< & \ 0,
\end{aligned}
$$

where ρ' is an arbitrary finite positive cap. This result implies that any bonus cap reduces the option value of risk-taking.

Assuming first-order stochastic dominance, that is $G_{x'}(.) < G_{x''}(.)$ if $x' > x''$, the second claim is verified by the following:

$$
\begin{aligned}
& (\Delta(x';\rho') - \Delta(x';\infty)) - (\Delta(x'';\rho') - \Delta(x'';\infty)) \\
= & \int_{\rho'}^{\infty} (\frac{\partial \Delta(x'';y)}{\partial \rho} - \frac{\partial \Delta(x';y)}{\partial \rho}) dy \\
= & \int_{\rho'}^{\infty} \int_{x''}^{x'} w_0 \frac{\partial G_z(\frac{y w_0}{\beta} + \theta)}{\partial x} dz dy \\
< & \ 0.
\end{aligned}
$$

This result implies that the reduction in the option value of risk-taking is larger when the return on investment is higher.

Table 1. Summary of the empirical literature

Authors/Title	Independent Variable	Risk Measure	Sign	Country
International Monetary Fund (IMF) (2014)	Share of salary	Default risk, beta, and ROA volatility	(+)	International
	Equity-based pay		(-)	
	Compensation horizon		(-)	
Acrey, McCumber, and Nguyen (2011)	Compensation elements	SEER risk variables and EDF	Mostly none	US
Bai and Elyasiani (2013)	Sensitivity to asset return volatility	Default risk and ROA volatility	(+)	US
Balachandran, Kogut, and Harnal (2011)	Equity-based pay	Default risk	(+)	US
Chen, Steiner, and Whyte (2006)	More option-based pay	Aggregate risk and beta	(+)	US
Chesney, Stromberg, and Wagner (2012)	Sensitivity to asset return volatility	Write-downs	(+)	US
DeYoung, Peng, and Yan (2013)	Sensitivity to asset return volatility	Idiosyncratic risk and beta	(+)	US
	Sensitivity to asset return		None	
Hagendorff and Vallascas (2011)	Sensitivity to asset return volatility	Merger-related default risk	(+)	US
	Sensitivity to asset return		(-)	
Tung and Wang (2011)	Inside debt holding	Idiosyncratic risk and fall in bond price	(-)	US

Notes: This table surveys the effects of various executive compensation schemes on bank risk taking. SEER (System for Estimating Examination Ratings) risk variables appear in the Federal Reserve's early warning model, which have been proven to be effective determinants of the probability that a bank will fail within two years (Cole, Cornyn, and Gunther, 1995). EDF (Expected Default Frequency) is a forward-looking measure of actual probability of default.

Table 2. Fixed salary by region

Region	Fixed salary (USD)
Asia	479,338
Anglo-Saxon ex U.S.	1,276,595
U.S.	2,472,828
Continental Europe	1,337,889
EMEA	245,443

Notes: This table shows the average fixed salary of bank CEOs by region (Sources: S&P Capital IQ and IMF staff calculations).

Table 3. Asset exposure by vis–a–vis region

Exposed to	Asset exposure (percent)				
	Asia	Anglo-Saxon ex US	US	Continental Europe	EMEA
Asia	76.84	3.43	3.68	2.74	0.05
Anglo-Saxon ex U.S.	4.80	69.02	8.12	12.21	2.01
U.S.	13.94	18.46	82.85	15.70	0.99
Continental Europe	4.15	8.69	4.79	68.34	1.56
EMEA	0.26	0.41	0.56	1.00	95.39

Notes: This table shows the average geographical breakdown of asset exposure of banks by region from 2005 to 2013 (Sources: BIS Consolidated Banking Statistics, SNL Financial, FDIC, and IMF staff calculations). The asset exposure of region A to region B is defined as the ratio of region A's aggregated claims on region B to region A's total bank assets. For example, this table suggests that 13.9 percent of bank assets in Asia is exposed to the U.S. Asia includes China, Hong Kong SAR, India, Japan, Korea, Malaysia, Pakistan, Philippines, Singapore, Sri Lanka, Taiwan, and Thailand. Anglo-Saxon ex U.S. includes Australia, Canada, Ireland, South Africa, and United Kingdom. Continental Europe includes Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Italy, Liechtenstein, Netherlands, Norway, Portugal, Spain, Sweden, and Switzerland. EMEA includes Hungary, Israel, Jordan, Lithuania, Poland, Russia, Saudi Arabia, Slovenia, Tunisia, Turky, and Zimbabwe.

Table 4. Mean ROA and coefficient of variation by region

Region	ROA (percent)									Coefficient of variation
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Asia	4.21	4.72	5.58	4.50	2.47	3.97	4.38	4.21	3.97	3.85
	(8.53)	(7.65)	(10.75)	(9.10)	(10.61)	(8.08)	(8.40)	(10.20)	(6.59)	(32.37)
Anglo-Saxon ex U.S.	6.76	14.33	8.32	3.62	2.68	8.26	7.39	6.44	7.40	4.46
	(18.41)	(201.71)	(14.75)	(14.82)	(16.11)	(12.24)	(11.17)	(11.50)	(13.59)	(57.61)
U.S.	9.00	8.73	9.03	6.83	6.56	8.18	8.60	7.87	7.97	1.93
	(9.52)	(8.26)	(7.86)	(10.07)	(8.29)	(6.68)	(6.30)	(7.07)	(5.85)	(17.65)
Continental Europe	6.55	6.08	6.29	3.05	2.11	3.66	4.41	2.23	1.90	2.69
	(18.26)	(9.95)	(9.42)	(10.85)	(9.17)	(11.62)	(28.37)	(11.90)	(14.01)	(8.77)
EMEA	5.69	8.18	3.66	2.47	4.88	5.84	6.46	5.75	7.21	32.45
	(15.23)	(13.51)	(73.45)	(21.72)	(17.30)	(13.38)	(12.46)	(8.12)	(43.34)	(478.61)

Notes: This table shows the summary statistics of ROA by year and region (Sources: Datastream and IMF staff calculations). For each year and region, we take the ROA distribution of constituents in the local equity index. For Asia, we use the TOPIX, the SSE Composite Index, and the CNX 500. For Anglo-Saxon countries, excluding the U.S., we use the FTSE All-Share, the S&P/ASX 300, and the S&P TSE Composite Index. For the U.S., we use the S&P 500. For Continental Europe, we use the DAX 100, the CAC All-Share, Milan Comit General, IBEX 35, IBEX Medium & Small Caps, and the AEX All-Share. For EMEA, we use the ISE National All-Share, the Russian RTS, and the DJ TA 100 Index. We drop any constituents without full observation of the ROA between 2005 and 2013. Standard deviation in parentheses.

Table 5. List of parameters

Symbol	Parameter
λ	Cost of risky investment
c_x	Entry cost of region x
β_x	Incentive parameter of region x
θ_x	Benchmark of region x (percent)

Notes: This table lists the set of parameters to be estimated.

Table 6. Estimated parameters (first step)

Parameter	Estimator
λ	3,593,384
$c_{AS\ ex\ U.S.}$	1,962,863
$c_{U.S.}$	3,746,119
c_{CE}	623,313
c_{EMEA}	821,428

Notes: This table reports estimation results for the cost of investing in a risky project as well as the entry cost in each region (Equation 9). Entry costs are relative to the entry cost in Asia.

Table 7. Estimated parameters (second step)

Parameter	Estimator
β_{ASIA}	5.25×10^7
$\beta_{AS\ ex\ U.S.}$	3.04×10^7
$\beta_{U.S.}$	3.91×10^7
β_{CE}	3.93×10^7
β_{EMEA}	4.76×10^7
θ_{ASIA}	1.80
$\theta_{AS\ ex\ U.S.}$	-3.18
$\theta_{U.S.}$	-3.09
θ_{CE}	2.20
θ_{EMEA}	0.60

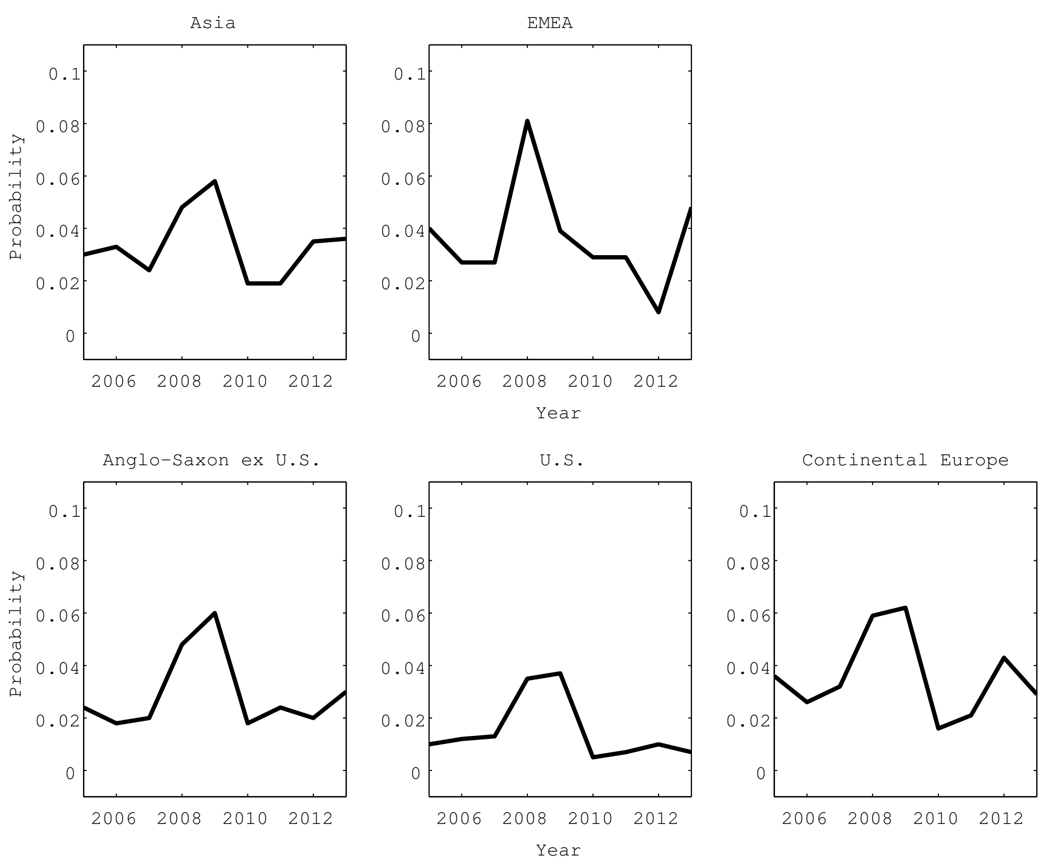
Notes: This table reports estimation results for the parameters that characterize compensation schemes in each region (Equation 10).

Table 8. Fitness of our model

Region	Exposure to risky assets (percent)		Compensation (USD)	
	Actual	Estimated	Actual	Estimated
Asia	26.5	28.0	1,930,123	1,920,500
Anglo-Saxon ex U.S.	24.3	24.2	3,812,937	3,847,000
U.S.	30.8	30.8	5,829,346	5,867,600
Continental Europe	23.1	23.1	2,429,083	2,397,800
EMEA	38.9	41.0	3,196,900	3,185,400

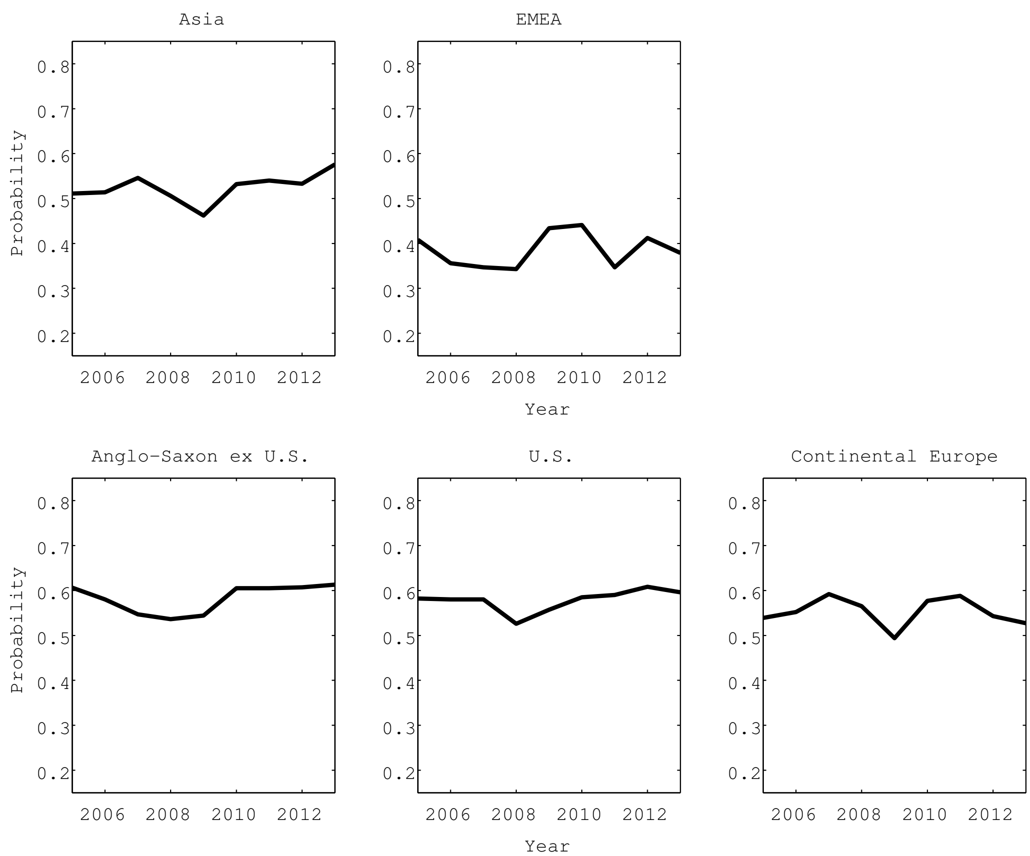
Notes: This table reports the fitness of our calibrated model (Sources: S&P Capital IQ, International Monetary Fund (IMF) (2014), and IMF staff calculations).

Figure 1. Risk shifting under the existing system



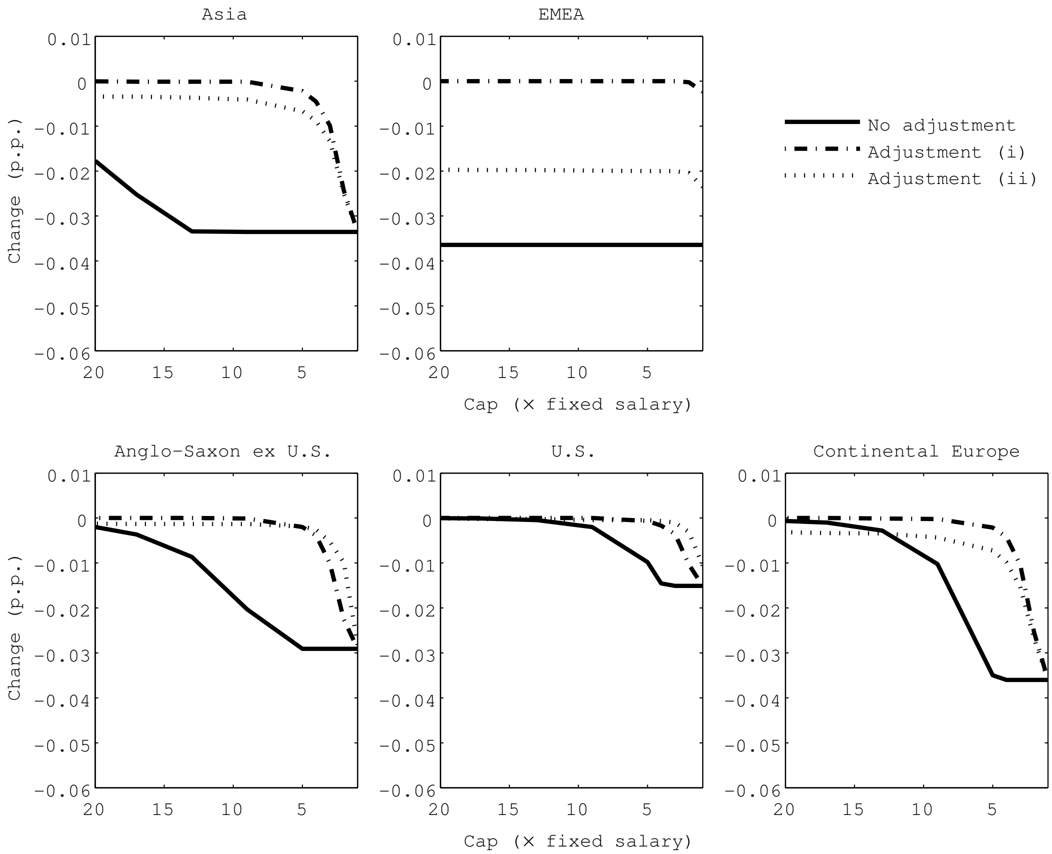
Notes: This figure reports the estimated level of risk shifting, which can be interpreted as the probability of investing in risky projects that yield lower returns than safe assets.

Figure 2. Underinvestment under the existing system



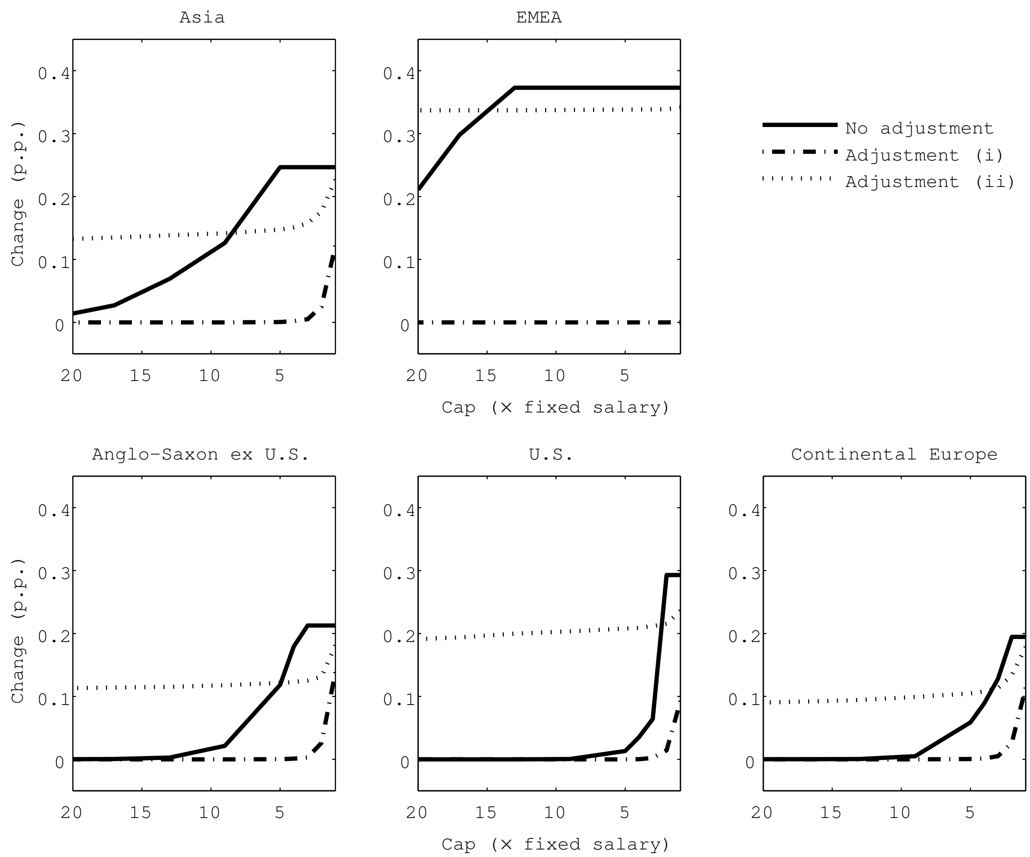
Notes: This figure reports the estimated level of underinvestment, which can be interpreted as the probability of not investing in risky projects that yield higher returns than safe assets.

Figure 3. Regulatory impact on risk shifting



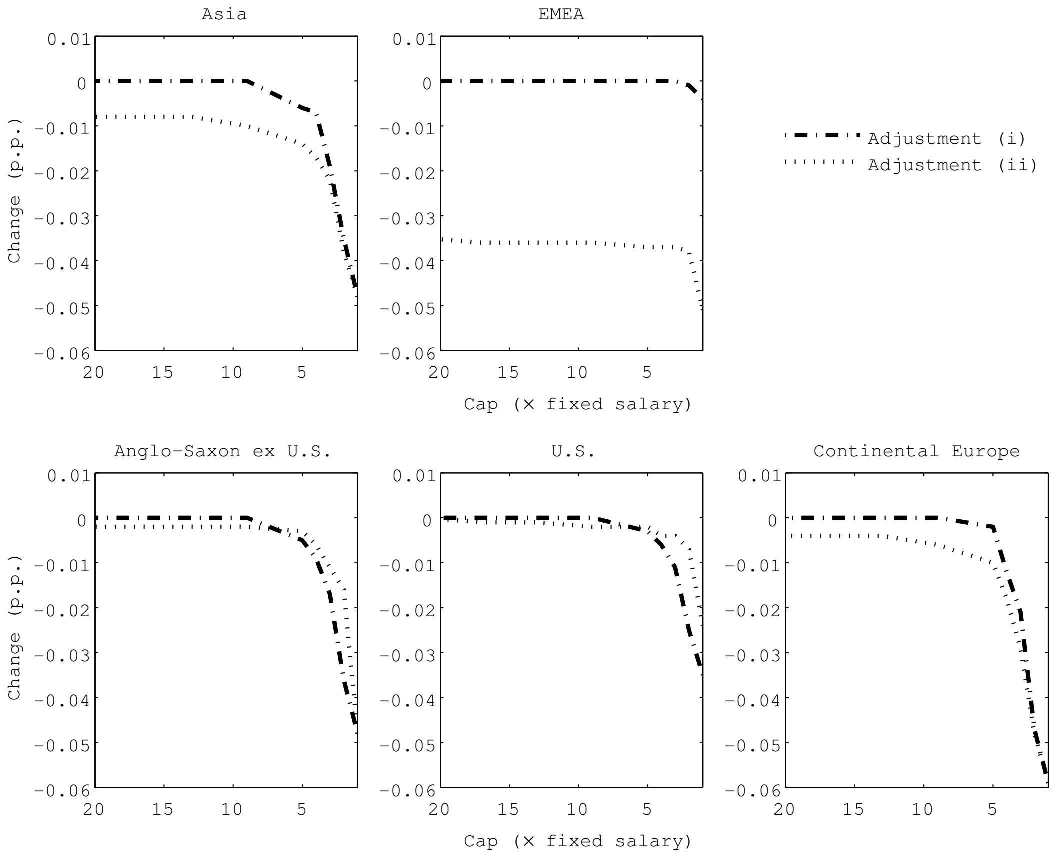
Notes: This figure shows the regulatory impact of a bonus cap on risk shifting. We simulate the regulation with a restriction on the labor mobility of bankers that precludes labor market adjustments and the one that does not restrict labor mobility. When we simulate the latter, we analyze the case in which only fixed salaries are adjustable (i) and the case in which both fixed salaries and performance benchmarks are adjustable (ii). Policy impact is measured against the level of risk shifting without regulation. A lower cap means severer regulation.

Figure 4. Regulatory impact on underinvestment



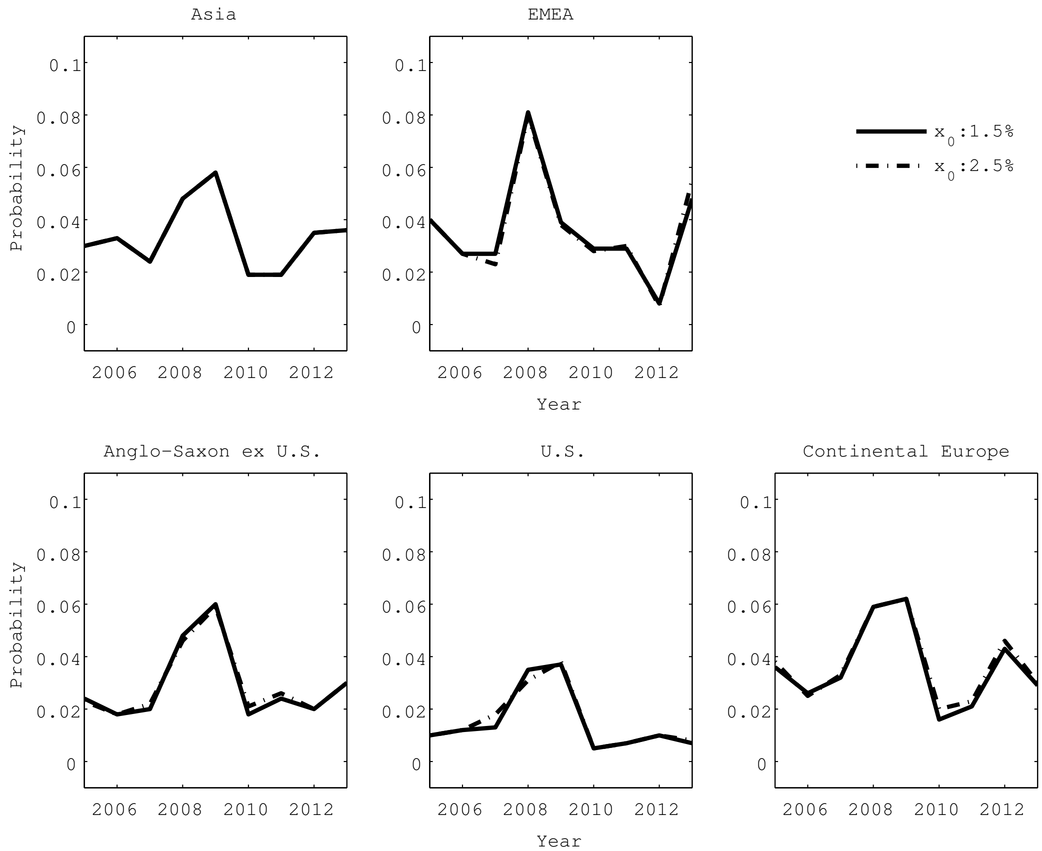
Notes: This figure shows the regulatory impact of a bonus cap on underinvestment. We simulate the regulation with a restriction on the labor mobility of bankers that precludes labor market adjustments and the one that does not restrict labor mobility. When we simulate the latter, we analyze the case in which only fixed salaries are adjustable (i) and the case in which both fixed salaries and performance benchmarks are adjustable (ii). Policy impact is measured against the level of underinvestment without regulation. A lower cap means severer regulation.

Figure 5. Regulatory impact on risk shifting in 2008



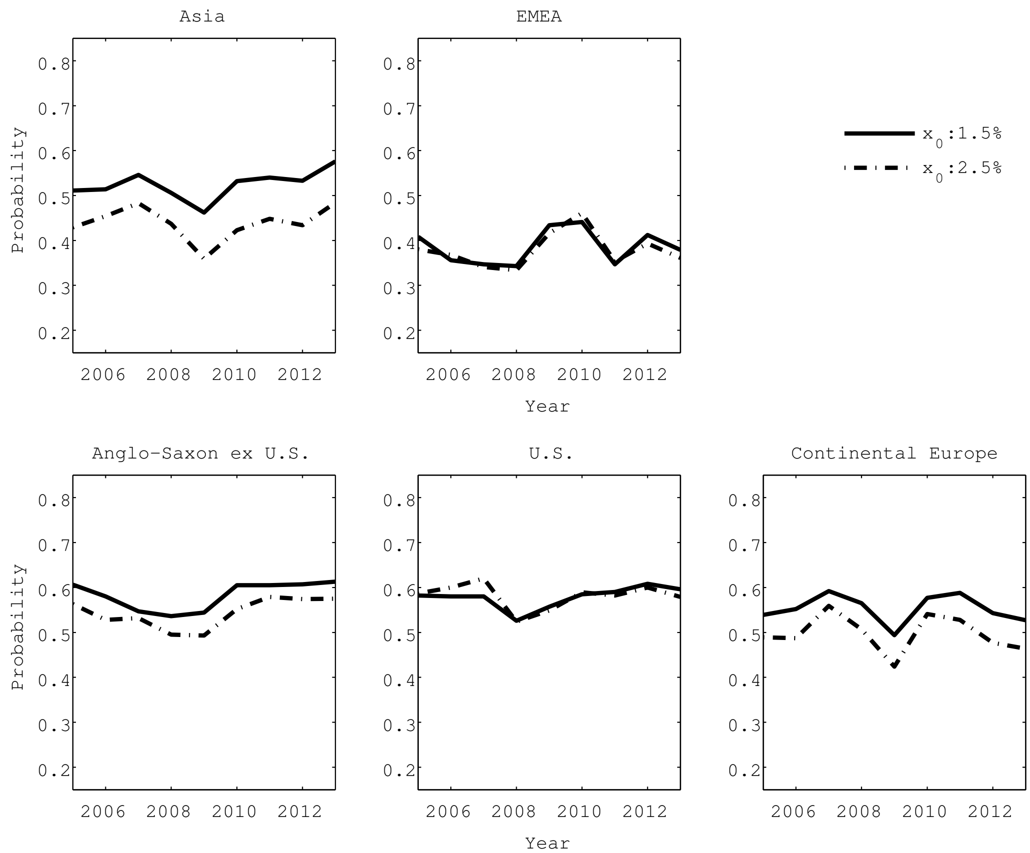
Notes: This figure shows the regulatory impact of a bonus cap on risk shifting in 2008. We simulate the regulation that does not restrict labor mobility. We analyze the case in which only fixed salaries are adjustable (i) and the case in which both fixed salaries and performance benchmarks are adjustable (ii). Policy impact is measured against the level of risk shifting without regulation in 2008. A lower cap means severer regulation.

Figure 6. Robustness to the return on safe assets (risk shifting)



Notes: This figure reports the estimated level of risk shifting. x_0 represents the return on safe assets.

Figure 7. Robustness to the return on safe assets (underinvestment)



Notes: This figure reports the estimated level of underinvestment. x_0 represents the return on safe assets.

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