Banco Central de Chile
Documentos de Trabajo

Central Bank of Chile
Working Papers

N° 560

Marzo 2010

AN ASSIGNMENT MODEL WITH MATCH SPECIFIC PRODUCTIVITY

Alberto Naudon

Documentos de Trabajo del Banco Central de Chile
Working Papers of the Central Bank of Chile
Agustinas 1180
Teléfono: (56-2) 6702475; Fax: (56-2) 6702231

Documento de Trabajo
N° 560

Working Paper
N° 560

AN ASSIGNMENT MODEL WITH MATCH SPECIFIC PRODUCTIVITY

Alberto Naudon
Gerencia de Análisis Macroeconómico
Banco Central de Chile

Abstract

In this article I develop a dynamic assignment model where matches are subjected to persistent idiosyncratic shocks. The model nests two independent models commonly used in the matching literature that have highlighted different aspects of the data. On one hand, there is ex ante heterogeneity as in traditional assignment models, so the equilibrium distribution of the match surplus between partners depends on the distributions of both types of agent characteristics in the economy (Roy (1951), Tinbergen (1951) and Koopmans and Beckmann (1957)). On the other hand, the model incorporates the fact that match outcomes are subjected to match–specific shocks, which may eventually lead to match termination (Jovanovic (1979)). I use the model to study the CEO - firm matching problem, an issue that has taken a lot of attention in recent work. (See for instance, Gabaix and Landier (2008) and Tervio (2008))

Resumen

En este artículo se desarrolla un modelo dinámico de asignación, donde las parejas son sujetas a perturbaciones idiosincrásicas con persistencia. El modelo anida dos tipos de modelo de uso común en la literatura para analizar diferentes aspectos de los datos. Por un lado, se considera la heterogeneidad ex ante como es tradicional en los modelos tradicionales de asignación, por lo que en equilibrio la distribución de las rentas entre los miembros de una pareja depende de la distribución de las características de los agentes en la economía (Roy (1951), Tinbergen, (1951) y Koopmans y Beckmann (1957)). Por otra parte, el modelo incorpora el hecho de que el producto de una pareja está sujeto a perturbaciones específicas a la misma que pueden eventualmente conducir a terminar la relación (Jovanovic (1979)). El artículo utiliza el modelo para estudiar la relación gerente - firma, una cuestión a la que se le ha prestado mucha atención en trabajos recientes. (Véase, por ejemplo, Gabaix y Landier (2008) y Tervio (2008)

I wish to thank Hugo Hopenhayn for his invaluable advice and guidance. I also thank Lee Ohanian, Pierre-Olivier Weill, and Roberto Fattal-Jaef for many helpful suggestions and insights. Address: Banco Central de Chile, Agustinas 1180, Santiago, Chile; email: anaudon@bcentral.cl.

1 Introduction

In this article I develop a dynamic assignment model where matches are subjected to persistent idiosyncratic shocks. In my model there are two types of heterogeneous agents that have to match in order to produce. Production depends on agents' ex ante characteristics, but is also subjected to match - specific productivity shocks following a geometric Brownian motion. Eventually, matches are destroyed, and agents go back to the market to search for a new partner. The model is very tractable, allowing me to provide closed form solutions that characterize both the equilibrium values of the agents and the equilibrium assignment function.

The model nests two independent models commonly used in the matching literature that have highlighted different aspects of the data. On one hand, there is ex ante heterogeneity as in traditional assignment models, so the equilibrium distribution of the match surplus between partners depends on the distributions of both types of agent characteristics in the economy (Roy (1951), Tinbergen (1951) and Koopmans and Beckmann (1957)). On the other hand, the model incorporates the fact that match outcomes are subjected to match–specific shocks, which may eventually lead to match termination (Jovanovic (1979)). The model allows me to study the interaction between these two aspects of the matching problem and enrich the number of facts that may be explained.

In particular, the model is useful for jointly understanding the cross section and time series properties of partner incomes (i.e. how the surplus of the match is shared between partners) and the evolution of matches. The model allows for partners' incomes to vary conditional on the other partner characteristics and over time. These are two features that are prevalent in many situations, and that are ruled out in standard assignment models. The model also permits me to study the interaction between partner characteristics and the decision to break a match since, at least, match members outside options will be different across agents.

These are implications that are relevant for a variety of applications. As an example, consider the case of an inventor that needs venture capital to transform his idea in a commercial product. The success of the inventor-investor partnership depends on both the quality of the inventor's ideas and on the investor's capacity to commercialize it, but it is also subject to random shocks that will determine both the value and the life span of the partnership. A similar problem arises when a firm is planning to invest in a new plant. Here the final output of the investment will depend on both the quality of the firm and the quality of the plant. However, the final outcome of the investment and how long the firm will keep the plant will also depend on some match - specific shocks.

The application analyze in this article is the CEO - firm matching problem. In particular, I use the model to characterize the equilibrium in the CEO - firm relationship, an issue that has taken a lot of attention in recent work. For instance, Gabaix and Landier (2008) and Tervio (2008) use assignment models to explain the huge and controversial increase in CEO payments during the last 25 years. Both studies found that the large increase in CEO payments is consistent with a competitive equilibrium where the rise in CEO compensation is driven by the remarkable increase in firm size during the same period of time. Besides the positive association between CEO compensation and firm size addressed by those papers, the data show large volatility and some degree of turnover. In fact, the data show that firm size explain only around 15% of the variance in CEO earnings, that CEO turnover is around 10% every year, and that time series volatility of the growth of firm production (measure by sales) is around 15%.

I calibrate the model to match aspects of both the cross section and time series behavior of the top 1000 public traded firms in United States. More precisely, the idiosyncratic productivity process is calibrated to match time series aspects of the data like CEO tenure and the time series behavior of sales. As is common in the assignment literature, the distributions of CEO and firm characteristics are calibrated to match the cross section relationship between firm size, measured by its market value, and CEO compensation. The calibrated model matches some key qualitative facts in the data, such as the positive skewed distribution of firm value and CEO earnings, "Robert's Law" (the elasticity between CEO earnings and firm value), and the high volatility of CEO earnings conditional on firm size and volatility. On the down side, the calibrated model generates too–fat right tails in the distribution of both firm values and CEO earnings.

The article is organized as follows. In section 2 I present the model. In section 3 I analyze a positive assortative equilibrium and proves its existence. In section 4 I calibrate the model, present the results, and discuss the data. Finally, section 5 concludes. Proofs that are not in the main text are provided in the appendix.

2 The Model

Time is continuous and lasts forever. The economy is populated by two classes of risk neutral agents, that with an eye on the quantitative exercise below, I call firm owners (for short "firms") and managers. Both classes of agents discount future flows using the same discount rate r. Without loss of generality, the mass of both class of agents is normalized to one. Managers differ in their capacity to manage a firm. In particular, throughout the paper I assume that managers are characterized by a time invariant type $m \in \mathcal{M} \subseteq \mathbb{R}_+$ that is distributed according to the distribution function $H(m)$. Firms are also heterogeneous. Specifically, productivity types $z \in \mathcal{Z} \subseteq \mathbb{R}_+$ are distributed according to the distribution function $G(z)$.

The unit of production of the single good in this economy is a matched firm - manager pair. Beyond manager and firm types, I let production depend on a match specific productivity shock a. The latter is assumed to follow a geometric Brownian motion with instantaneous drift[1] μ and instantaneous volatility σ^2. The production flow revenue of a firm - manager pair (z, m) with idiosyncratic match productivity a is denoted by $F(z, m, a)$. The next two assumptions describe characteristics of the production technology more formally.

Assumption 1 *Let t represent the time a pair (z, m) has been producing together and let $t = 0$ denote initial time. For every pair (z, m) the match specific productivity a evolves*

[1]The Brownian motion could be replaced by other diffusion process without altering any results. For example, the learning process in chapter 9 of Liptser and Shiryaev (2001) could be easily adapted.

according to

$$\frac{da_t}{a_t} = \mu dt + \sigma dB_t, \qquad (1)$$

where B_t *is a standard Wiener process and* $a_0 > 0$ *is given and the same for every new match.*

Assumption 2 *The production flow* $F(z, m, a)$ *is characterized as follows,*
(i) $F(z, m, a) = af(z, m)$*, and*
(ii) $f_{zm}(z, m) > 0$.

Match specific productivity generates a surplus that has to be divided between the manager and the firm. In this paper, as is common in the literature, I assume that any surplus is divided according to a generalized Nash bargaining procedure with δ representing the manager's bargaining power.

Firm - manager pairs face a second source of uncertainty: with probability λ a match is destroyed. This exogenous destruction rate reflects the fact that managers may leave the firm or may be dismissed for reasons unrelated to firm performance. For example, a firm could be sold or a manager may decide to leave for personal reasons.

Managers and firms meet in a competitive and frictionless matching market. Finally, for both firms and managers there is a value of staying outside of the market denoted by V_0 and W_0 respectively. I study the steady state of this economy.

2.1 Agents' problem

Agents' problem in this economy is twofold. First, any pair (z, m) decides, given their current specific productivity level a, whether to stay matched or not. Second, if a match is broken, firms and managers need to find a new match among those unmatched in the market. Below it is shown that under some mild assumptions, the solution to the first problem is given by a threshold productivity level such that whenever the match specific productivity goes below the match is broken. The solution to the second problem is the solution to an optimal assignment problem similar to the one studied by Gabaix and Landier (2008) and Tervio (2008).

Firm and manager values In steady state, firm and manager values depend only on their types and on the level of match idiosyncratic productivity a. Let $V(z)$ and $W(m)$ be type z firm and type m manager maximum expected present value at the beginning of a new match (i.e. their outside option, since it is the best they can do after leaving their current match). For any match with specific productivity a denote by $M(z, m, a)$ the expected present value of the match (z, m). Then the match surplus is given by

$$S(z, m, a) := M(z, m, a) - (V(z) + W(m)),$$

when match specific productivity is a.

Denote by $\widehat{V}(z,m,a)$ the expected present value of a firm z currently managed by a type m manager and by $\widehat{W}(z,m,a)$ the expected present value for a manager m currently working for a firm z when the specific match productivity is a. Nash Bargaining implies that

$$\widehat{V}(z,m,a) = V(z) + (1-\delta) S(z,m,a),$$

$$\widehat{W}(z,m,a) = W(m) + \delta S(z,m,a),$$

That is, firm owner and manager expected present values are the sum of two components: one exclusively related to their innate invariant characteristic and the other determined, in part, by the (stochastic) performance of the match.

Partner selection and participation constraint Agents choose partners in order to maximize their values at the beginning of the match $\widehat{V}(z,m,a_0)$ and $\widehat{W}(z,m,a_0)$. The outcome of this process are matching sets $\mathbf{M}^*(z) \in \mathcal{M}$ and $\mathbf{Z}^*(m) \in \mathcal{Z}$ containing all manager types hired by firms with productivity z and all firm types where type m managers want to work for. More formally,

$$\mathbf{M}^*(z) = \arg\max_{m'} \{V(z) + (1-\delta) S(z,m',a)\}, \tag{2}$$

and

$$\mathbf{Z}^*(m) = \arg\max_{z'} \{W(m) + (1-\delta) S(z',m,a)\}. \tag{3}$$

Of course, the outcome of the maximization problem has to be such that all agents make more value in the market than outside it. The following participation constraint should be satisfied for all z and m,

$$V(z) \geq V_0,$$

$$W(m) \geq W_0.$$

The value of a match and the termination policy Nash bargaining leads to efficient separation, and so both the firm and the manager agree when to break a match. Therefore, the total expected present value of a match $M(z,m,a)$ solves the following Hamilton-Jacobi-Bellman (HJB) equation

$$rM(z,m,a) = \begin{array}{c} F(z,m,a) + a\mu M_a(z,m,a) + \frac{1}{2}a^2\sigma^2 M_{aa}(z,m,a) \\ -\lambda\left(M(z,m,a) - V(z) - W(m)\right), \end{array} \tag{4}$$

where M_a and M_{aa} are the first and the second partial derivative of the match value with respect to a. In words, the flow value of match (z,m) is equal to the production flow $F(z,m,a)$ plus a term that represents the effects of idiosyncratic volatility, minus a third term that represents the capital loss due to an unexpected break of a good match. In the latter case, the current value of the match is replaced by the sum of firm owner and manager outside options. The match is optimally broken at a idiosyncratic productivity level $\underline{a}(z,m)$ such that $M_a(z,m,\underline{a}(z,m)) = 0$ (*smooth pasting condition*) and $M(z,m,\underline{a}(z,m)) = V(z) + W(m)$ (*match value condition*). Note that, as expected, the latter condition means that the match is optimally broken when match surplus (i.e. match value minus outside options) is 0. The following proposition describes the value function and the termination policy for any pair (z, m).

Proposition 3 *Assume (2.i) and let* $\varrho_2 = \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} - \mu - J\right]$ *and*

$$J = \sqrt{\left(\mu - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2 (r + \lambda)}.$$

The solution to equation (4) is given by

$$M(z, m, a) = \frac{af(z, m)}{r + \lambda}\left[1 - \frac{1}{\varrho_2}\left(\frac{\underline{a}}{a}\right)^{1-\varrho_2}\right] + \frac{\lambda}{r + \lambda}(V(z) + W(m)), \tag{5}$$

where $\underline{a}(z, m)$ *is given by*

$$\underline{a}(z, m) = \frac{r}{f(z, m)}\left(\frac{\varrho_2}{\varrho_2 - 1}\right)(V(z) + W(m)). \tag{6}$$

Proof. *See appendix.* ■

2.2 A positive assortative steady state equilibrium

Denote the worst (best) manager and the worst (best) firm in the support by z_L (z_H) and m_L (m_H) respectively. In a positive assortative equilibrium there exists an invertible assignment function $z^*(m)$, with $z^*(m_L) = z_L$, $z^*(m_H) = z_H$ and $z^{*\prime}(m) > 0$ for all $m \in \mathcal{M}$ that indicates for which firm a type m manager will work for. The inverse of this function, the function $m^*(z_L) := z^{*-1}(z_L)$, describes which manager will match a type z firm. The steady state nature of the equilibrium means that this assignment does not change over time.

Definition 4 (Equilibrium) *An equilibrium for this economy consists of the following objects: (1) an assignment function* $z^* : \mathcal{M} \to \mathcal{Z}$*, and (2) a termination rule* $\underline{a} : \mathcal{Z} \times \mathcal{M} \to \mathbb{R}$ *specifying when a match* (z, m) *is broken, such that (i)* $z^*(m) \in \mathbf{Z}^*(m)$ *for all* m *and (ii)* $m^*(z) \in \mathbf{M}^*(z)$ *for all* z*.*

Two comments are useful at this point. First, as it is shown below, under the assumptions above, the unique steady state equilibrium is positive assortative. Therefore, defining a positive assortative steady state equilibrium is without loss of generality. Second, in a positive assortative steady state equilibrium, when a match (z, m) is broken, a match of the same type will be formed. Hence, the joint distribution of matches destroyed is identical to the one corresponding to matches created.

3 A positive assortative equilibrium

In this section I construct and prove the existence of an equilibrium characterized by a positive assortative matching between manager types and firm productivity levels determined by the following function $z^* (m) = G^{-1} (H (m))$. In what follows I will denote the worst (best) manager and the worst (best) firm in the support by z_L (z_H) and m_L (m_H) respectively. As was mentioned above, a positive assortative matching means that equilibrium assignment is given by a function $z^* (m)$, with $z^* (m_L) = z_L$, $z^* (m_H) = z_H$ and $z^{*\prime} (m) > 0$ for all $m \in \mathcal{M}$. In equilibrium the assignment function $z^* (m_L)$ correspond to the optimal selection of firms by managers. The inverse of this function, the function $m^* (z_L) := z^{*-1} (z_L)$, is then the optimal selection of managers by firms. First I describe the equilibrium and then I show that it is an equilibrium by showing that markets clear and nobody wants to deviate from the equilibrium assignment.

3.1 Equilibrium description

Match value and break up decision If $z^* (m)$ is an equilibrium assignment, then $V (z^* (m)) + W (m) = M (z^* (m), m, a_0)$. That is, the initial expected present value of any equilibrium match has to be equal to the sum of the unmatched values of the firm and the manager. Otherwise either the match would not incentive compatible (i.e. the total value of the match is less than the sum of agents' outside options) or part of the value would not be assigned to any side of the match. Replacing this equality in equations (5) and (6) plus a little of algebra, it is possible to compute the value and the termination decision rule of an equilibrium match. In particular, it is easy to see that, as would be expected since rematching is free, the cutoff value is $\underline{a} = a_0$ for all equilibrium pairs and that the equilibrium value of any equilibrium match is given by,

$$M (z^* (m), m, a) = f (z^* (m), m) \Phi (a), \tag{7}$$

where

$$\Phi (a) = \frac{1}{r + \lambda} \left\{ \left[a - \frac{a_0^{1-\varrho_2}}{\varrho_2} a^{\varrho_2} \right] + \frac{\lambda}{r} \left[a_0 \frac{\varrho_2 - 1}{\varrho_2} \right] \right\},$$

is the same for all equilibrium pairs $(z^* (m), m)$.

An obvious concern in what follows is if participation constraints will be binding or not. There are several ways to address this issue. Here, as in Tervio (2008), I took the following shortcut. Note that $M (z^* (m), m, a_0)$ is decreasing in the quality of both factors and assume that production function $f (.)$ goes to zero for very low values of z and m. Then, because the match is positive assortative there is a pair (z, m) such that $M (z, m, a_0) = V_0 + W_0$. I call those levels z_L and m_L and re normalized the mass of types above them to 1. Then, the participation constraint will be binding always for the lower types and only for them.

The value of unmatched firm and unmatched managers In order to find the values $V (z)$ and $W (m)$ consider the problem of an unmatched type z firm hiring a manager. They know that in equilibrium a type m manager will require an expected present value equal to

$W(m)$. In this case, the owner of the firm will get a value (at the beginning of the match) equal to $M(z,m,a_0)-W(m)$. In equilibrium it should be true that the owner of firm $z^*(m)$ is better off hiring manager m than any other else, then for any $\varepsilon>0$,

$$M(z^*(m),m,a_0)-W(m)\geq M(z^*(m),m+\varepsilon,a_0)-W(m+\varepsilon).$$

Dividing both side by ε and letting $\varepsilon\to 0$, I get the following equilibrium condition

$$W'(m)=M_m(z^*(m),m,a_0),$$

which is just the FOC of the problem in equation (2). In order to obtain the equilibrium value of an unmatched type m manager, I integrate last expression over m, and use the fact that in equilibrium the value of the match is $M(z^*(m),m,a_0)=f(z^*(m),m)\Phi(a_0)$ and that the assignment is positive assortative. Then, the present expected value of an unmatched manager should be equal to,

$$W(m)=W_0+\Phi(a_0)\int_{m_L}^{m}f_m(z^*(x),x)\,dx. \tag{8}$$

As noted above, participation constraint is exactly binding for the manager with the lowest talent m_L. A similar procedure implies that a type z firm has a value when unmatched equal to

$$V(z)=V_0+\Phi(a_0)\int_{z_L}^{z}f_z(x,m^*(x))\,dx, \tag{9}$$

where $m^*(x):=z^{*-1}(x)$.

The equilibrium assignment function Before describing the assignment function, it is necessary to find the intensity at which match are terminated. The next proposition describes the specific productivity steady state density and the aggregate turn over rate.

Proposition 5 *Let* $J^*=\sqrt{\left(-\mu-\frac{\sigma^2}{2}\right)^2+2\sigma^2(\lambda-\mu)}$ *and* $R_2=\frac{1}{\sigma^2}\left[\frac{\sigma^2}{2}+\mu-J^*\right]$ *and assume* $\frac{1}{\sigma^2}\left[\frac{\sigma^2}{2}+\mu+J^*\right]>2$, *then the ergodic distribution of the idiosyncratic shock is*

$$\gamma(a)=(1-R_2)\,a_0^{1-R_2}a^{R_2-2},\qquad a\in(a_0,\infty)$$

for every pair (z,m). *And in steady state the endogenous turn over rate is equal to,*

$$\omega=\lambda\left(1+\frac{R_2-1}{P_2}\right),$$

where $P_2=\frac{1}{\sigma^2}\left[\frac{\sigma^2}{2}-\mu-J^{**}\right]$ *and* $J^{**}=\sqrt{\left(\mu-\frac{\sigma^2}{2}\right)^2+2\sigma^2\lambda}$.

Proof. *See appendix.* ■

As was stated above, every match starts with a productivity level a_0 that evolves according to equation (1). Matches are "killed" at rate λ by exogenous separations and are endogenously stopped when the idiosyncratic productivity falls from a_0. My interpretation of this two types of turnover is the following. The first is "voluntary" turn over (i.e. turn over that is not related with firm performance) and the second is the so called "forced" turn over (i.e. the one related with poor performance of the firm).

Markets clear when the unmatched mass of any subset of manager types equals the mass of unmatched firms looking for those managers. Since matches are broken at intensity ω, positive assortative matching between managers and firms implies that market clearing condition is given by

$$\int_{m_L}^{m} \omega h(x)\, dx = \int_{z_L}^{z^*(m)} \omega g(x)\, dx,$$

where m_L and z_L are the lowest talent manager and the lowest quality firm respectively. Taking derivative with respect to m, it is clear that the matching function has to solve the following standard differential equation,

$$z^{*\prime}(m) = \frac{h(m)}{g(z(m))},$$

with boundary conditions given by the value of the assignment at each extreme of the support of m. The solution to this equation is given by,

$$z^*(m) = G^{-1}(H(m)),$$

which, as in standard assignment models, says that the equilibrium assignment depends only on the distributions of match side characteristics.

3.2 Equilibrium existence

Proposition 6 *A positive assortative equilibrium exists.*

To show that the equilibrium described above is actually an equilibrium, it is necessary to show that nobody wants to deviate from the equilibrium assignment.[2] That is, an unmatched manager m prefers to work for a firm $z^*(m)$ rather than for any other one, and viceversa.

I consider a permanent deviation in which an arbitrary type m manager decides to work always for a firm z different from $z^*(m)$. Under this deviation, the initial expected present value of the match (z, m) is just $f(z, m)\Phi(a_0)$, since the same match is repeated again and again. The owner of a type z firm will not accept at the moment of match creation a value less than $V(z)$. Then, the manager will get $f(z, m)\Phi(a_0) - V(z)$ instead of $W(m) = M(z^*(m), m, a_0) - V(z^*(m))$ every time she starts a new match. Therefore, in order the deviation not to be profitable the following condition is required

$$f(z, m)\Phi(a_0) - V(z) \leq M(z^*(m), m, a_0) - V(z^*(m)), \quad \forall z \in \mathcal{Z}. \tag{10}$$

[2]Of course, it is also necessary to have market in equilibrium, but this is true under the assignment proposed here.

Using equation (9) and (7), condition (10) could be written as follows

$$f(z,m) - f(z^*(m),m) \leq \int_{z^*(m)}^{z} f_z(x, m^*(x))\,dx\ , \qquad \forall z \in \mathcal{Z}. \tag{11}$$

By supermodularity of $f(.)$ equation (11) is always true. To see that, consider starting at any equilibrium pair $(z^*(m), m)$. Note that both sides of equation (11) are zero at $z = z^*(m)$ and that the the derivative of the right hand side with respect to z is $f_z(z,m)$ and the derivative of the left hand side is $f_z(z, m^*(z))$. When $z = z^*(m)$ both derivatives are equal. When $z > z^*(m)$ because the assignment is positive assortative $m^*(z) > m$ and by supermodularity $f_z(z, m^*(z)) > f_z(z,m)$. When $z < z^*(m)$ the opposite is true, since it is the case that $m^*(z) < m$ and by supermodularity $f_z(z, m^*(z)) < f_z(z,m)$.

Note this also implies that in any stationary equilibrium, where firms of certain type match always with managers of the same type, the only assignment that is incentive compatible is the one proposed in this section. Therefore, as was claimed above, the unique stationary equilibrium is a positive assortative one.

Finally, note that since the outside option of both managers and firm owners is independent of their current match, it should be the case that if a permanent deviation is not profitable, neither is any transitory deviation. So the above argument is enough to established the optimality of the equilibrium assignment.

4 An application to CEO compensation and turn over

Empirical studies of CEO compensation (see Murphy (1999) for a survey) have been mostly model - free. Only recently have there been some attempts to write down models that could be calibrated and used in empirical analysis. In particular, Gabaix and Landier (2008) and Tervio (2008) use assignment models to explain the huge and controversial increases in CEO pay during the last years. Both studies found that the large increase in CEO pay could be a phenomenon ocurring in a competitive equilibrium, driven by the increase in firm size during the same period of time. In spite of their success, those models are still very abstract and mute on some important issues like manager turnover and compensation volatility. Another aspect of recent assignment models that is at odds with the data is that those models predict, conditional on firm size, no variance in CEO pay. The introduction of match - specific productivity allows me to explore these dimensions of the data.

First, I present the data that motives the use of this model to study the behavior of CEO earnings and firm values. Then I calibrate the model and present the results. Before that, I briefly discuss how I to compute the per period flow in the model, since the model gives equations for present expected values, while the CEO earnings data are in per period payments.

Per period payments The model gives equations for expected present values for firm and managers. However, in the case analyzed here and in other applications, there are only data on per period payments. There is no unique way of converting those expected present values into per period flows, since the model does not specify how such a division should be done. The method that I use in the quantitative application below is to exploit the HJB equation of each agent. For example, in the case of the manager, it has to be true that the solution above solves the following HJB equation

$$r\widehat{W}(z,m,a) = \begin{array}{c} w(z,m,a) + a\mu\widehat{W}_a(z,m,a) + \frac{1}{2}a^2\sigma^2\widehat{W}_{aa}(z,m,a) \\ -\lambda\left(\widehat{W}(z,m,a) - W(m)\right) \end{array}, \tag{12}$$

where $w(z,m,a)$ is the per period flow, which could be calculated from the equations above that describe $\widehat{W}(z,m,a)$ and $W(m)$.

4.1 CEO's payment and firm value data

For calibration I consider the top 1000 public traded US companies in 2004 ExecuComp database[3]

CEO compensation includes options, which are priced using the standard Black-Scholes formula. The same data have been used in many other studies of CEO compensation including Gabaix and Landier (2008) and Tervio (2008). Table 1 presents some statistics. Average CEO total compensation in 2004 was \$7.12 million, ranging between zero and slightly more than \$120 million. The standard deviation is huge: around 8.4 million, that is, 1.18 times the average. The distribution of wages is positive skewed (skewness coefficient is equal to 5.14) reflecting that there is a larger than normal mass of very well paid CEOs. Table 1 also presents some summary statistics of firm value. The average top 1000 firm in 2004 has a value around \$12,500 million. As with CEO compensation, there is a huge variance within this group of top firms. Firm values range from 1,172 to 385,882 million, with a standard deviation equal to 29,949 million, that is 2.4, times the average. Firm value distribution is also very positive skewed (skewness coefficient is equal to 6.69) reflecting that there is a larger than normal mass of very large firms.

It has been argued, both theoretically and empirically, that CEO compensation should be positive correlated with the size of the firm. In particular, it is commonly assumed that a CEO compensation to firm market value elasticity around 0.33 is a good description of the data. Based on this review of the literature, Gabaix and Landier (2008) named this relationship "Robert's Law". To evaluate the relationship between firm size and CEO payments I run the following regression

$$\log(CEO\ wages) = \beta_0 + \beta_1 \log(Firm\ Value).$$

The estimated value of β_1 is 0.4083 with a standard deviation of 0.0301. As expected, there is a strong and clear relationship between firm size and CEO compensation. However, the R^2 of the regression is only 0.1557, meaning that a huge part of CEO compensation variance can not be explained by variation in market value. Figure 1 plots the log of CEO compensation against the log of firm market value, as well as the fitted values from the above regression. It is clear from the figure that conditional on market value there is a large variance in CEO compensation.

[3]For comparability purpose, data used in this paper is the same data as in Tervio (2008).

	CEO Pay	Firm Value
Mean*	7.12	12,584.64
Standard deviation*	8.40	29,949.02
Skewness	5.14	6.69
Minimum*	0	1,172.72
Maximum*	120.10	385,882.80
*millions of dollars		

Table 1: Summary statistics

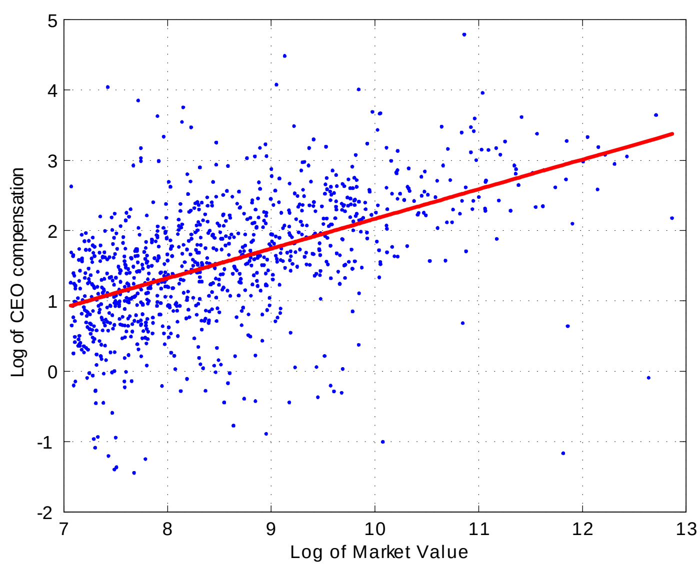

Figure 1: Log of CEO's compensation and firms value.

With respect to CEO turn over, studies reveal that some number between 10% and 15% of CEOs leave their position in a typical year. The numbers differ because samples are different and because different definitions of "leave" are used. For example, Kaplan and Minton (2006) find that CEO turnover is around 14.9% a year when external turnover (turnover primarily related to firm acquisitions) is taken into account, and only 11.8% when external turn over is not considered, as is common in most of the literature. A related definitional issue has been the difference between forced and unforced turnover. From a theoretical point of view it is not the same if a CEO leaves the firm because of she retires or other personal reasons or because he was fired (see Parrino (1997) for a commonly used definition of forced and unforced turnover). Studies that have tried to identify both types of turnover in the data have found that unforced turnover is much larger than forced. Jenter and Kanaan (2006) report that in their sample the average percentage of firms with at least one CEO turnover in a year was 9.47%, while the same statistic considering only forced turnover gives a number around 2.36%.

4.2 Calibration and results

There are three types of objects to be calibrated to bring the model to the data. First, it is necessary to make assumptions about functional forms, including CEO talent and firm quality distributions across the economy. Second, since the idea is to match the very top valued firms and CEO wages, it is necessary to specify which part of those distributions to use. Finally, there are a number of parameters to calibrate including those governing the evolution of the idiosyncratic match productivity.

Functional forms Functional forms are taken, unless otherwise mentioned, from Gabaix and Landier (2008). The production function is given by

$$F\left(z,m,a\right)=Az\left(\psi+m\right)a,$$

where A and ψ are constants and, as before, parameters z, m and a are firm type, manager talent and idiosyncratic productivity respectively. Note that A is just an scale parameter, but that parameter ψ affects the marginal productivity of firm quality (conditional on manager talent) without affecting manager marginal productivity[4]. With respect to factor type distributions the functional forms used are

$$H\left(m\right)=1-\left(1-m\right)^{\frac{1}{\mathbf{a}}},$$

with $\mathbf{a}=0.6$ and $m\in[0,1]$ for managerial talent and

$$G\left(z\right)=1-\left(\frac{z_0}{z}\right)^{\frac{1}{\mathbf{b}}},$$

with $\mathbf{b}=1$ and $z\in[1,\infty)$ for firm productivity.

[4]At this point it is useful to remember that in assignment models the term marginal productivity should be used with caution, since production factors (firm quality and managerial talent) are not divisible.

In Gabaix and Landier (2008) the authors interpreted z directly as the size of the firm, and so $G(z)$ is by definition the size distribution of firms. Here I depart from Gabaix and Landier (2008) by thinking about z as a non observable firm characteristic and calibrating the model such that the resulting firm size, measured by firm value, is consistent with the actual size distribution.

In calibrating the model it is easier to work with the quantiles rather than the levels of talent and productivity. In particular, let n_z and n_m be numbers between 0 and 1 that represent the rank of the firm and the manager, being 0 the highest rank and 1 the lowest. Note that by inverting the distribution function above it is possible to write the talent and the type of the firm in terms of the rank. Using the fact that assortative matching implies that in equilibrium $n_z = n_m = n$, the CEO talent and firm productivity could be written as a function of the rank n as follows,

$$m(n) = 1 - n^{\mathbf{a}},$$

$$z(n) = z_0 n^{-\mathbf{b}},$$

It is important to note that, because of the idiosyncratic productivity component that has been added to the model, the rank n could not be mapped to the actual rank of firm value or CEO compensation as was done by Gabaix and Landier (2008) and Tervio (2008).

With this transformation in mind it is possible to rewrite the equations in the model in the following way. Remember that $M(z, m, a) = f(z, m)\Phi(a)$ then, using equations in section 3.1, it is possible to write the value of unmatched CEO and unmatched firm as follows,

$$\widetilde{W}(n) = W_0 + \Phi(a_0)\frac{\mathbf{a}}{\mathbf{b}-\mathbf{a}}\left(n^{\mathbf{a}-\mathbf{b}} - 1\right)$$

$$\widetilde{V}(n) = V_0 + A\Phi(a_0)\left(n^{-\mathbf{b}}\left[\psi + 1 - \frac{\mathbf{b}}{\mathbf{b}-\mathbf{a}}n^{\mathbf{a}}\right] - \left[\psi + 1 - \frac{\mathbf{b}}{\mathbf{b}-\mathbf{a}}\right]\right)$$

where the tilda means that the functions depend on n instead of z and m. As in Gabaix and Landier (2008) this expression could be simplified by noting that for very low n (that is for the top firms in the economy) both W_0 and V_0, the value of the lowest manager in the economy and the value of the smallest firm (both conditional on starting a new match at a_0), are very low compared to the value of the top ranked firm and and the compensation of the top ranked CEO. Then I set both values equal to 0.

The rank of the worst firm - manager pair (n^*) As was mentioned above, n represents the rank of both CEO talent and firm type. This is a number that goes from 0, representing the largest firm in the economy, to 1, representing the smallest one. The question is which is the rank of the top 1000 firm in United States, the smallest firm in the sample, but not the smallest in the economy. To calibrate this number I match the ratio of the standard deviation of firm value to the average firm value. In the model, for a given value of δ, this ratio depends only on the distribution of a, which parameters are pinned down independently from firm quality and CEO talent distributions as shown below, and on n^*. The ratio is equal to 2.3807 in the data.

	Firm size		CEO pay	
	Data	Simulation	Data	Simulation
mean*	12627.25	12627	7.1763	7.1623
median*	4143.97	6890	4.8128	6.3499
standard deviation*	30061.09	30137	8.4039	8.3612
skewness	6.6692	73.1443	5.1471	89.9540
* millions of dollars				
	Data	Simulation		
Forced CEO turn over	2.36%	2.36%		
Total CEO turn over	9.47%	9.63%		

Table 2: Matched moments

Parameters The remaining parameters are calibrated as follows. Starting with parameters governing the idiosyncratic process, σ is set to 14% to match the weighted standard deviation of the growth rate of nominal sales of 14% (see Comin and Mulani (2006)) and μ is set to match forced turnover which is around 2.36% a year. Parameter λ is set to match total turnover of 9.47%. Production function parameters are selected to match other moments of the data. In particular, A is chosen to match the average wage and ψ to match, given A, the size of the average firm. Finally, manager's bargaining power δ is set at 0.00362 to match the volatility of CEO compensation.

Firm and wage distribution Table 2 presents the moments matched in the calibration: means and standard deviations of firm size and CEO compensation. The median and the skewness are also presented. Numbers in data column differ a little bit from Table 1 because I exclude firms paying less than $0.1 million.

The model results show that both the predicted median and the predicted skewness coefficients are greater than in the data, meaning that the calibrated distribution of firm values and CEO earnings are more concentrated on the right tail than in the data. The reason is that, in order to match a turnover rate of 9.47% when the standard deviation of the shock is set at 14%, I need a high level of μ (the drift of the process) , so there are a bunch of firms that grow a lot (i.e. there are a lot of them in the upper tail of the distribution).

CEO compensation and firm value As before, to evaluate the relationship between firm size and CEO payments I run the following regression

$$\log\left(CEO\ wages\right) = \beta_0 + \beta_1 \log\left(Firm\ Value\right).$$

Using the data generated by the model, the value of β_1 is 0.2166 (standard deviation 0.001). That means that, on average, an increase of 1% in the value of a firm will raise CEO compensation by around 0.21%. This elasticity is lower than the 0.33 that has been found in the literature. Again, the reason is the presence of a positive drift that, since the largest part of the surplus goes to firms (δ is very low), affects the value of firms more than it does CEO compensation. The R^2 of this regression is 33%, meaning that in the model as in the data there is a lot of variance in CEO compensation conditional firm size.

As a summary, the calibrated model matches qualitative key facts in the data, such as the positively skewed distributions of firm value and CEO earnings, "Robert's Law" describing the sensitivity between CEO earnings and firm value, and the high volatility of CEO earnings conditional on firm size and volatility. Quantitatively, the calibrated model highlights the trade off between matching low managerial turnover and having a firm size distribution closer to the data when a geometric Brownian motion is used to describe the evolution of match - specific shocks. The main issue is that with a geometric Brownian motion characterizing the evolution of specific match productivity, the only way to obtain a low turnover is by having a positive drift term that increase the mass of the right tail of the distribution. One way to solve this problem in future empirical applications of this model could be to replace the geometric Brownian motion process by a mean reverting one, like the Ornstein–Uhlenbeck process.

5 Conclusions

In this chapter I present a tractable and calibratable model that puts together the two main models used to explain economic situations where agents needs to match in order to produce: the assignment and the match idiosyncratic productivity literature. I show that, in the model, supermodularity of the production function is a sufficient condition for a positive assortative stationary equilibrium to exist. The model could be solved analytically, and so I provide equations that characterize both equilibrium agent values and equilibrium assignment function.

The model could be used to explain jointly cross sectional and time series dimensions of the data. In the quantitative part of the chapter, the model is calibrated to match aspects of both the cross sectional and time series behavior of the top 1000 public traded firms in the United States. In particular, the idiosyncratic productivity process is calibrated to match time series aspects of the data CEO turnover rate and the behavior of firm growth sales. As is common in the assignment literature, the distributions of CEO and firm characteristics are calibrated to match the cross sectional relationship between firm size, measured by its market value, and CEO compensation. The calibrated model matches qualitatively the main facts in the data, but generates too fat right tails in the distribution of both firm values and CEO earnings.

There are many possible future applications of the model. For example, one of the more surprising findings of recent assignment models is that, in spite of the immense difference among top paid CEOs, the "implicit" difference in CEO talent is very small. That is, a large portion of the difference in CEO earnings comes from the fact that top paid CEOs are assigned to larger firms and not from differences in their innate talent. From a quantitative point of view, allowing for compensation volatility conditional on manager talent could be important when backing out the managers' talent distribution from wage and firm size data. The literature has basically to filtered out cases of small (large) firms that pay large (small) compensation to their CEO. However, this requires a mechanism to relate directly the distribution of talent and firm characteristics to observable data when the outcome of the match also depends on some idiosyncratic shock.

Bibliography

Comin, D. and Mulani, S. (2006). Diverging trends in aggregate and firm volatility. *The Review of Economics and Statistics*, 88(2):374–383.

Gabaix, X. and Landier, A. (2008). Why has ceo pay increased so much? *The Quarterly Journal of Economics*, 123(1):49–100.

Jenter, D. and Kanaan, F. (2006). Ceo turnover and relative performance evaluation. Working Paper 12068, National Bureau of Economic Research.

Jovanovic, B. (1979). Job matching and the theory of turnover. *Journal of Political Economy*, 87(5):972–90.

Kaplan, S. N. and Minton, B. (2006). How has ceo turnover changed? increasingly performance sensitive boards and increasingly uneasy ceos. NBER Working Papers 12465, National Bureau of Economic Research, Inc.

Karlin, S. and Taylor, H. (1981). *A second course in stochastic processes*. Academic Press.

Koopmans, T. and Beckmann, M. (1957). Assignment problems and the location of economic activities. *Econometrica*, 25(1):53–76.

Liptser, R. and Shiryaev, A. (2001). *Statistics of Random Processes*. Springer.

Murphy, K. J. (1999). Executive compensation. In Ashenfelter, O. and Card, D., editors, *Handbook of Labor Economics*, volume 3 of *Handbook of Labor Economics*, chapter 38, pages 2485–2563. Elsevier, 1 edition.

Parrino, R. (1997). Ceo turnover and outside succession a cross-sectional analysis. *Journal of Financial Economics*, 46(2):165–197.

Roy, A. (1951). Some thoughts on the distributions of earnings. *Oxford Economic Papers*, 3(2):135–146.

Stokey, N. (2009). *Economics of Inaction: Stochastic Control Models With Fixed Costs*. Princeton University Press.

Tervio, M. (2008). The difference that ceos make: An assignment model approach. *American Economic Review*, 98(3):642–68.

Tinbergen, J. (1951). Some remarks on the distribution of labour incomes. *International Economic Papers*, 1:195–207.

A Proof of proposition 3

For every pair (z, m) the value of the match solves[5]

$$\begin{aligned} rM(z,m,a) &= af(z,m) + \left\{ \begin{array}{c} \mu x M_a(z,m,a) \\ +\frac{1}{2}a^2\sigma^2 M_{aa}(z,m,a) \\ +\lambda(V(z)+W(m)) \end{array} \right\}, \qquad if \quad a > \underline{a}(z,m) \\ M(z,m,a) &= V(z) + W(m), \qquad if \quad a \leq \underline{a}(z,m) \end{aligned} \tag{13}$$

with value matching conditions

$$M(z,m,\underline{a}) = V(z) + W(m), \tag{14}$$

smooth pasting conditions

$$M_a(z,m,\underline{a}) = 0, \tag{15}$$

and no bubble condition

$$\lim_{a\to\infty}\left[\widehat{M}(z,m,a) - M(z,m,a)\right] = 0, \tag{16}$$

with

$$\widehat{M}(z,m,a) = \frac{1}{r}\left[af(z,m) + \lambda(V(z)+W(m))\right].$$

By inspection it is easy to see that for some constants c_1 and c_2 the following equation satisfies (13)

$$M(z,m,a) = \frac{f(z,m)}{r+\lambda}\left[a + c_1 a^{\varrho_1} + c_2 a^{\varrho_2}\right] + \frac{\lambda}{r+\lambda}(V(z)+W(m)),$$

where

$$\begin{aligned} \varrho_1 &= \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} - \mu + J\right] > 0, \\ \varrho_2 &= \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} - \mu - J\right] < 0, \end{aligned}$$

and

$$J = \sqrt{\left(\mu - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(r+\lambda)}.$$

Condition (16) implies that $c_1 = 0$. Using the smooth pasting condition (15), I get

$$c_2 = -\frac{\underline{a}^{1-\varrho_2}}{\varrho_2},$$

[5]Unless otherwise pointed out, all mathematical results are from Stokey (2009) and Karlin and Taylor (1981).

therefore

$$M(z,m,a) = \frac{af(z,m)}{r+\lambda}\left[1 - \frac{1}{\varrho_2}\left(\frac{\underline{a}}{a}\right)^{1-\varrho_2}\right] + \frac{\lambda}{r+\lambda}\left(V(z) + W(m)\right). \tag{17}$$

Finally, condition (14) implies

$$\underline{a} = \frac{r}{f(z,m)}\left(\frac{\varrho_2}{\varrho_2 - 1}\right)\left(V(z) + W(m)\right). \tag{18}$$

B Proof of proposition 5

The Kolmogorov forward equation in steady state is

$$0 = -\frac{d}{da}\left[a\mu\gamma(a)\right] + \frac{d^2}{da^2}\left[\frac{1}{2}a^2\sigma^2\gamma(a)\right] - \lambda\gamma(a).$$

Let $\overline{\gamma}(a) = a^2\gamma(a)$, the equation above could be written as follows

$$0 = -\frac{d}{da}\left[\frac{\mu}{a}\overline{\gamma}(a)\right] + \frac{d^2}{da^2}\left[\frac{1}{2}\sigma^2\overline{\gamma}(a)\right] - \lambda\frac{\overline{\gamma}(a)}{a^2},$$

or

$$0 = -a\mu\overline{\gamma}'(a) + \frac{1}{2}a^2\sigma^2\overline{\gamma}''(a) - (\lambda - \mu)\overline{\gamma}(a).$$

The general solution to this equation is

$$\overline{\gamma}(a) = c_{11}a^{R_1} + c_{12}a^{R_2},$$

where

$$R_1 = \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} + \mu + J\right] > 0,$$

$$R_2 = \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} + \mu - J\right] < 0,$$

and

$$J = \sqrt{\left(-\mu - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2(\lambda - \mu)}.$$

Then

$$\gamma(a) = c_1a^{R_1-2} + c_2a^{R_2-2}, \qquad a \in (a_0, \infty).$$

Because it is a density function it has to be the case that,

$$\gamma(a) \geq 0, \tag{19}$$

$$\int \gamma(a) = 1, \tag{20}$$

by assumption $R_1 > 2$ then $c_1 = 0$ and

$$\int \gamma(a) = \int_{a_0}^{\infty} c_2 a^{R_2-2} da \tag{21}$$

$$= \frac{c_2}{1-R_2} a_0^{R_2-1}, \tag{22}$$

then

$$c_2 = (1-R_2)\, a_0^{1-R_2},$$

and then stationary density function is given by,

$$\gamma(a) = (1-R_2)\, a_0^{1-R_2} a^{R_2-2}, \qquad a \in (a_0, \infty).$$

C Aggregate turnover

Note that the expected conditional tenure solves the following differential equation

$$-1 = \mu a \tau'(a) + a^2 \frac{\sigma^2}{2} \tau''(a) - \lambda \tau(a) = 0.$$

By inspection the general solution is

$$\tau(a) = c_1 a^{P_1} + c_2 a^{P_2} + \frac{1}{\lambda},$$

where

$$P_1 = \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} - \mu + J\right] > 0,$$

$$P_2 = \frac{1}{\sigma^2}\left[\frac{\sigma^2}{2} - \mu - J\right] < 0,$$

and

$$J = \sqrt{\left(\mu - \frac{\sigma^2}{2}\right)^2 + 2\sigma^2\lambda},$$

the boundary conditions are

$$\tau(\infty) = \frac{1}{\lambda},$$

$$\tau(a_0+) = 0.$$

When $a = \infty$ the tenure depends only on the exogenous destruction rate λ. When $a = a_0$ tenure is zero, therefore, $c_1 = 0$. Then

$$\tau(a_0+) = c_2 a_0^{P_2} + \frac{1}{\lambda} = 0,$$

and therefore

$$c_2 = -\frac{a_0^{-P_2}}{\lambda}.$$

So expected conditional tenure is

$$\tau(a) = \frac{1}{\lambda}\left(1 - \left(\frac{a}{a_0}\right)^{P_2}\right).$$

Integrating over a, it ia possible to obtain the unconditional expected time before hitting the boundary a_0

$$\begin{aligned}
\int_{a_0}^{\infty} \tau(a)\gamma(a)\,da &= \int_{a_0}^{\infty} \frac{1}{\lambda}\left(1 - \left(\frac{a}{a_0}\right)^{P_2}\right)(1-R_2)\,a_0^{1-R_2} a^{R_2-2} da \\
&= \frac{1}{\lambda}(1-R_2)\,a_0^{1-R_2}\int_{a_0}^{\infty}\left(a^{R_2-2} - a_0^{-P_2} a^{P_2+R_2-2}\right) da \\
&= \frac{1}{\lambda}(1-R_2)\,a_0^{1-R_2}\left(\frac{a^{R_2-1}}{R_2-1} - a_0^{-P_2}\frac{a^{P_2+R_2-1}}{P_2+R_2-1}\right|_{a_0}^{\infty} \\
&= \frac{1}{\lambda}(1-R_2)\,a_0^{1-R_2}\left(\frac{a^{R_2-1}}{R_2-1} - a_0^{-P_2}\frac{a^{P_2+R_2-1}}{P_2+R_2-1}\right|_{a_0}^{\infty} \\
&= \frac{1}{\lambda}\left(1 - \frac{1-R_2}{1-P_2-R_2}\right).
\end{aligned}$$

I compute the aggregate unconditional turnover as $\frac{1}{\tau}$.

Documentos de Trabajo Banco Central de Chile	**Working Papers Central Bank of Chile**
NÚMEROS ANTERIORES	PAST ISSUES

La serie de Documentos de Trabajo en versión PDF puede obtenerse gratis en la dirección electrónica: www.bcentral.cl/esp/estpub/estudios/dtbc. Existe la posibilidad de solicitar una copia impresa con un costo de $500 si es dentro de Chile y US$12 si es para fuera de Chile. Las solicitudes se pueden hacer por fax: (56-2) 6702231 o a través de correo electrónico: bcch@bcentral.cl.

Working Papers in PDF format can be downloaded free of charge from: www.bcentral.cl/eng/stdpub/studies/workingpaper. Printed versions can be ordered individually for US$12 per copy (for orders inside Chile the charge is Ch$500.) Orders can be placed by fax: (56-2) 6702231 or e-mail: bcch@bcentral.cl.

DTBC-559 Marzo 2010
El Escaso Poder Predictivo de Simples Curvas de Phillips en Chile: Una Evaluación en Tiempo Real
Pablo Pincheira y Hernán Rubio

DTBC-558 Marzo 2010
A Stochastic Assignment Model
Alberto Naudon

DTBC-557 Marzo 2010
Valorización Por Arbitraje De Bonos Y Acciones Chilenas Mediante El Método De Componentes Principales
Natalia Gallardo y Andrés Sagner

DTBC-556 Febrero 2010
A Real Time Evaluation of the Central Bank of Chile GDP Growth Forecasts
Pablo Pincheira

DTBC-555 Diciembre 2009
Funding Liquidity Risk in a Quantitative Model of Systemic Stability
David Aikman, Piergiorgio Alessandri, Bruno Eklund, Prasanna Gai, Sujit Kapadia, Elizabeth Martin, Nada Mora, Gabriel Sterne y Matthew Willison

DTBC-554 Diciembre 2009
Financial Stability, Monetary Policy and Central Banking: An Overview
Rodrigo Alfaro A. y Rodrigo Cifuentes S.

DTBC-553 Diciembre 2009
Incorporating Financial Sector Risk into Monetary Policy Models: Application to Chile
Dale F. Gray, Carlos García, Leonardo Luna y Jorge Restrepo

DTBC-552 Diciembre 2009
Crisis Financiera y Uso de Derivados Cambiarios en Empresas Exportadoras
María Gabriela Acharán, Roberto Alvarez y José Miguel Villena

DTBC-551 Diciembre 2009
Efectos de la Emisión de Bonos del Banco Central Sobre las Tasas de Interés
Marco Batarce

DTBC-550 Diciembre 2009
Defining Financial Stability And A Framework For Safeguarding It
Garry J. Schinasi

DTBC-549 Diciembre 2009
Determinantes del Precio de Viviendas en Chile
Andrés Sagner

DTBC-548 Diciembre 2009
A Historical Perspective On The Crisis Of 2007–08
Michael D. Bordo

DTBC-547 Diciembre 2009
Modeling a Housing and Mortgage Crisis
Charles A.E. Goodhart, Dimitrios P. Tsomocos y Alexandros P. Vardoulakis

DTBC-546 Diciembre 2009
Policy Reform Under Electoral Uncertainty
Dalibor Eterovic