

Schöttner, Anja; Deffains, Bruno

Working Paper

Technological choice under organizational diseconomies of scale

SFB 649 Discussion Paper, No. 2006,028

Provided in Cooperation with:

Collaborative Research Center 649: Economic Risk, Humboldt University Berlin

Suggested Citation: Schöttner, Anja; Deffains, Bruno (2006) : Technological choice under organizational diseconomies of scale, SFB 649 Discussion Paper, No. 2006,028, Humboldt University of Berlin, Collaborative Research Center 649 - Economic Risk, Berlin

This Version is available at:

<https://hdl.handle.net/10419/25111>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.

SFB 649 Discussion Paper 2006-028

Technological Choice under Organizational Diseconomies of Scale

Dominique Demougin*
Anja Schöttner*



* School of Business and Economics, Humboldt-Universität
zu Berlin, Germany

This research was supported by the Deutsche
Forschungsgemeinschaft through the SFB 649 "Economic Risk".

<http://sfb649.wiwi.hu-berlin.de>
ISSN 1860-5664

SFB 649, Humboldt-Universität zu Berlin
Spandauer Straße 1, D-10178 Berlin



SFB 649 ECONOMIC RISK BERLIN

Technological Choice under Organizational Diseconomies of Scale*

Dominique Demougin and Anja Schöttner[†]

This version: April 2006

Abstract

With adverse selection, diseconomies of scale associated with hierarchies may induce the implementation of a second-best technology. This occurs whenever rents to lower tiers of the hierarchy increase faster than total surplus. This is more likely with longer hierarchies.

JEL Classification: D82, L23, O33

Keywords: Adverse Selection, Hierarchies, Technology

*This research was supported by the Deutsche Forschungsgemeinschaft through the SFB 649 “Economic Risk”.

[†]Humboldt University at Berlin, School of Business and Economics, Ziegelstr. 13a, D-10099 Berlin, Germany, Tel: +49 30 2093-1592 and -1345, Fax: +49 30 2093-1343, e-mails: demougin@wiwi.hu-berlin.de and schoettner@wiwi.hu-berlin.de.

1 Introduction

We analyze how a firm's hierarchy length affects its technological choice in the presence of hidden information. We find that diseconomies of scale associated with multi-tier hierarchies may induce the firm owner to adopt a second-best technology, thereby not maximizing overall surplus.

To model diseconomies of scale, we use the same approach as McAfee and McMillan (1995) (hereafter MM). In a given hierarchy, production workers privately observe a valuable information while managers, acting as contracting intermediaries, face a limited liability constraint. In such a framework, MM show that the optimal mechanism leaves rents to all the intermediary echelons.

We extend their model by introducing a technological choice. We find that implementing a better technology has two countervailing effects on the firm owner's profit: While average production costs decrease, expected informational rents along the hierarchy increase. Consequently, the longer the hierarchy chain, the less beneficial the implementation of a more effective technology from the owner's point of view.

2 The model

Following MM, we consider an organization with an exogenously given multi-tier hierarchy. The hierarchy consists of a worker (hierarchy level 0) and k principals (hierarchy levels $1, \dots, k$). All parties are risk-neutral with an outside option of zero. The top principal (level k) is the owner of the firm.

All other principals should be interpreted as middle managers, who play no direct role in production other than passing on information. The worker produces an output $q \geq 0$ which accrues to the owner.

The owner's valuation for output is $v(q) \geq 0$ with $v' > 0$ and $v'' \leq 0$. The worker's production costs are $C^0(q, t)$. His type $t \geq 0$ is drawn from a commonly known distribution $F(t|\mu)$ with density $f(t|\mu)$,¹ where μ characterizes the owner's choice of technology. For simplicity, we assume that this choice is costless.²

Production costs are not verifiable and only the worker observes t . Thus, contracting with the worker is subject to an adverse selection problem. $C^0(q, t)$ satisfies standard regularity requirements in output, i.e. $C_q^0, C_{qq}^0 > 0$. Moreover, a higher type leads to lower costs and lower marginal costs, i.e. $C_t^0, C_{qt}^0 \leq 0$.

To guarantee the existence of a separating equilibrium, the inverse hazard rate

$$\frac{1 - F(t|\mu)}{f(t|\mu)} =: h(t|\mu) \tag{1}$$

is assumed to be non-increasing in t . Regarding the effect of the technological choice on the distribution of types, we assume $h_\mu > 0$. This assumption implies $F_\mu(t|\mu) < 0$,³ i.e. an increase in μ improves $F(t|\mu)$ in the sense of first-order stochastic dominance. Intuitively, by the choice of a superior technology, low-cost types become more likely. What we have in mind is that t is determined by an underlying match between the worker's unobservable

¹We assume that the functional forms are such that all integrals (expected profit etc.) converge.

²We briefly discuss a costly technological choice in section 4.

³See, e.g., Krishna (2002), p. 260.

ability and the firm's technological choice.⁴ With this interpretation, a better technology could be one which reduces the worker's costs for every ability.

Timing is as follows. First, the owner chooses the production technology μ . All parties observe μ . Then, the worker learns his type. Afterwards, contracting takes place. The details will be specified below as they depend on the length of the hierarchy. Finally, the worker produces and payments are made.

3 The two-tier hierarchy

The two-tier hierarchy consists only of the worker and the owner. Given μ , the owner's optimal contract choice is a standard adverse-selection problem. Following MM, her virtual costs of implementing output q for type t are

$$C^1(q, t|\mu) = C^0(q, t) - h(t|\mu)C_t^0(q, t), \quad (2)$$

$C^1(q, t|\mu)$ reflects that, when implementing a higher output for a worker of type \hat{t} , the owner bears not only this worker's additional production costs but also a larger rent for all the workers of type $t > \hat{t}$.

Since $h_\mu > 0$ and $C_t^0 < 0$, $C^1(q, t|\mu)$ is increasing in μ . Intuitively, a better technology increases the proportion of more efficient types, which raises expected rents. Consequently, the optimal output,

$$q^*(t|\mu) = \arg \max_q v(q) - C^1(q, t|\mu), \quad (3)$$

⁴Formally, t could be a function of technology μ and ability s , $t = m(s, \mu)$, where s is drawn from a commonly known distribution. Thus $F(t|\mu) = \text{Prob}[m(s, \mu) \leq t]$.

is decreasing in μ . Thus, increasing μ leads to countervailing effects on $C^1(q, t|\mu)$. While the direct effect captured by C_μ^1 is positive, the indirect effect $C_q^1 q_\mu^*$ is negative. Looking at the owner's expected profit,

$$\Pi(\mu) = \max_{q(t)} \int \{v(q) - C^1(q, t|\mu)\} f(t|\mu) dt, \quad (4)$$

there is an additional effect due to the change in $f(t|\mu)$. The following result shows that the overall effect on $\Pi(\mu)$ is unambiguous.

Proposition 1 *In a two-tier hierarchy, the owner's expected profit increases in μ .*

Proof By substituting (2) into (4) we obtain

$$\Pi(\mu) = \int \{[v(q^*) - C^0(q^*, t)]f(t|\mu) + [1 - F(t|\mu)]C_t^0(q^*, t)\} dt. \quad (5)$$

Applying the envelope theorem yields

$$\Pi'(\mu) = \int \{[v(q^*) - C^0(q^*, t)]\} f_\mu(t|\mu) dt - \int F_\mu(t|\mu) C_t^0(q^*, t) dt. \quad (6)$$

Partial integration of the first integral gives

$$\Pi'(\mu) = \int q_t^* h(t|\mu) C_{tq}^0(q^*, t) F_\mu(t|\mu) dt \geq 0. \quad (7)$$

The sign follows because $q_t^*, h \geq 0$ and $C_{tq}^0, F_\mu \leq 0$. \square

Implementing a better technology raises the likelihood that the worker has low production costs. Since such a worker generates a higher value added

(first integral in (6)) but also receives a larger rent (second integral in (6)), we obtain two countervailing effects on $\Pi(\mu)$. The proposition shows that, in a two-tier hierarchy, the value-added effect dominates the rent effect.

4 The multi-tier hierarchy - an example

We can anticipate how the foregoing intuition extends to a multi-tier hierarchy. MM show that the rent extraction problem becomes more severe as the hierarchy lengthens. This should aggravate the rent effect. In contrast, the value-added effect should diminish since the scope for reducing output to counteract the rent effect decreases. This suggests that there may be situations where the rent effect dominates. To verify this intuition, we transform the example discussed by MM to obtain a constant hazard rate for all types. This significantly simplifies the analysis.

Specifically, the owner's problem now takes the form⁵

$$C^0(q, t) = \exp(-t) \frac{q^2}{2}, \quad (8)$$

where types are distributed according to

$$f(t|\mu) = \begin{cases} \frac{1}{\mu} \exp\left(-\frac{t}{\mu}\right) & \text{if } t \geq 0 \\ 0 & \text{otherwise} \end{cases}, \quad (9)$$

⁵In their example, MM assume $C^0(q, t) = (z + 1 - t)c(q)$ with uniformly distributed types. In our example, substituting $\tilde{t} = z + 1 - e^{-t}$ and interpreting $\tilde{t} \in [z, z + 1]$ as the worker's type yields the same cost function.

with $\mu \in [\mu_l, \mu_h]$, $0 < \mu_l < \mu_h < 1$.⁶ Valuation of output is

$$v(q) = q. \quad (10)$$

In the contracting stage of the game, first the owner designs and implements a contract $R^{k-1}(q)$ with the manager at level $(k-1)$, who afterwards offers a contract $R^{k-2}(q)$ to the manager at level $(k-2)$ and so forth. Finally, the first-level manager offers a contract $R^0(q)$ to the worker. Thus, if $k \geq 2$, the setup imposes per assumption that the owner cannot contract directly with the worker.

Managers cannot transform the output but simply pass it up the chain. At the time of contracting they do not know the worker's type. Moreover, managers face a limited liability constraint, which means that they must be guaranteed a non-negative ex post rent for each possible t . The limited liability requirement also ensures that the owner cannot sell the production technology to a manager.

Applying MM's recursive method⁷ yields the virtual costs along the hierarchy chain. Given the constant hazard rate μ , virtual costs at level j are

$$C^j(q, t|\mu) = (1 + \mu)^j e^{-t \frac{q^2}{2}}, \quad j = 1, \dots, k. \quad (11)$$

In particular, for $j = k$, the equation gives the owner's virtual costs.⁸ As a result, the owner designs the $(k-1)$ -level manager's contract such that the

⁶The assumption $\mu_h < 1$ ensures that the requirement that all integrals converge is satisfied for our example (see footnote 1).

⁷Compare p. 408, eq. (7), in MM.

⁸It can be shown that the virtual cost functions satisfy eq. (11) in MM, i.e., managers' limited liability constraints are binding.

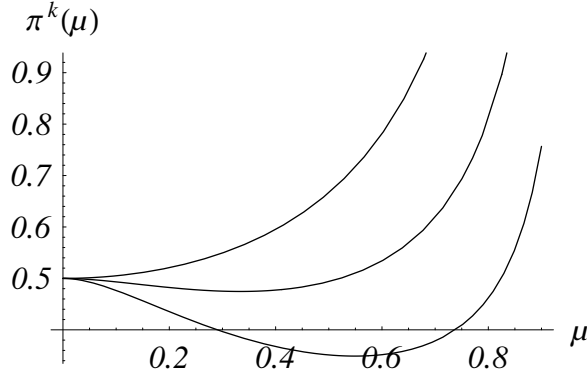


Figure 1: The owner's expected profit $\pi^k(\mu)$ for $k = 1, 2, 3$.

output

$$q^*(t|\mu) = \frac{e^t}{(1+\mu)^k} \quad (12)$$

is implemented. The payment schemes⁹ for the different hierarchy levels are:

$$R^j(q|\mu) = \frac{1}{(1+\mu)^{k-j}}q - \frac{2(1+\mu)^j - 1}{2(1+\mu)^{2k}}, \quad j = 0, 1, \dots, k-1. \quad (13)$$

They imply a strictly positive rent for every manager if $t > 0$. Substitution for the $(k-1)$ -level generates the owner's expected profit:

$$\pi^k(\mu) = \int_0^\infty [q^* - R^{k-1}(q^*|\mu)]f(t|\mu)dt = \frac{2(1+\mu)^{k-1} - (1-\mu)}{2(1+\mu)^{2k}(1-\mu)} \quad (14)$$

Figure 1 depicts $\pi^k(\mu)$ for $k = 1, 2, 3$, whereby a lower curve corresponds to a higher k .

Proposition 2 *For $k \geq 2$, the owner adopts either the best or the worst technology, i.e. $\mu \in \{\mu_l, \mu_h\}$. Moreover, a necessary condition for adopting*

⁹These schemes can be verified by checking eq. (A5)-(A7) in MM.

μ_h is that μ_h exceeds a threshold $\bar{\mu}(k)$, $0 < \bar{\mu}(k) < 1$. The threshold $\bar{\mu}(k)$ is increasing in k .

The proof of proposition 2 is given in the appendix. It shows that $\pi^k(\mu)$ is non-monotonic in μ for all $k \geq 2$. Specifically, it decreases if $\mu < \bar{\mu}(k)$, and increases if $\mu > \bar{\mu}(k)$. Thus, the owner implements the best available technology only if the expected reduction in production costs is sufficiently high. Moreover, the larger k , the higher is the required cost reduction. This verifies our intuition from the beginning of this section.

Obviously, the result that the owner may invest in a better technology only if $\mu_h > \bar{\mu}(k)$ remains valid after the introduction of technology costs that are increasing in μ . Furthermore, with linear or concave technology costs, due to the fact that $\pi^k(\mu)$ is convex for $\mu > \bar{\mu}(k)$, the owner will still implement either μ_l or μ_h . Only if technology costs are convex, an intermediate μ may be optimal.

5 Conclusion

We have shown how the optimal technological choice depends on the length of a firm's hierarchy. A better technology that lowers the worker's average production costs also increases expected rents along the hierarchy echelons. Therefore, as the number of contracting intermediaries increases, the rent effect may induce the owner to adopt a second-best technology.

Our result that a production-cost reducing technology may raise agency costs should extend to other environments exhibiting diseconomies of scale, e.g., due to hidden information and risk-averse intermediaries (Faure-Grimaud

and Martimort 2001) or moral hazard (Calvo and Wellisz 1978). Thus, altogether we conclude that informational asymmetries combined with long hierarchies will bias technological choice downwards.

6 Appendix

Proof of proposition 2. For all $k \geq 2$, define $\bar{\mu}(k) \in (0, 1)$ such that

$$\left. \frac{\partial \pi^k(\mu)}{\partial \mu} \right|_{\mu=\bar{\mu}(k)} = 0. \quad (15)$$

We first show that $\bar{\mu}(k)$ exists and is unique. It is easily verified that

$$\frac{\partial \pi^k}{\partial \mu} = 0 \quad \Leftrightarrow \quad f(\mu, k) := (1 + \mu)^{k-1} \left[\frac{2+k}{k} \mu - 1 \right] + (1 - \mu)^2 = 0, \quad (16)$$

and, furthermore, that $f(0, k) = 0$, $f(1, k) > 0$, and $\left. \frac{\partial f}{\partial \mu} \right|_{\mu=0} < 0$ for all $k \geq 2$.

Thus, $\bar{\mu}(k)$ exists.

Now define $\tilde{\mu}$ as the smallest value from $(0, 1)$ for which $f(\tilde{\mu}, k) = 0$. Thus, at $\mu = \tilde{\mu}$,

$$(1 + \mu)^{k-1} \left[1 - \frac{2+k}{k} \mu \right] = (1 - \mu)^2 \quad (17)$$

holds. The rhs of (17) is decreasing and convex in μ . The first derivative of the lhs of (17) w.r.t. μ is

$$(k-1)(1 + \mu)^{k-2} \left[1 - \frac{2+k}{k} \mu \right] - \frac{2+k}{k} (1 + \mu)^{k-1}, \quad (18)$$

which is negative if and only if $\mu > \frac{k^2 - 2k - 2}{k(2+k)}$. Thus, since (17) holds for $\mu = 0$

and the lhs may initially increase in μ , the lhs must decrease in μ at $\mu = \tilde{\mu}$.

Furthermore, its second derivative w.r.t. μ is

$$(k-1)(k-2)(1+\mu)^{k-3} \left[1 - \frac{2+k}{k}\mu \right] - 2\frac{2+k}{k}(k-1)(1+\mu)^{k-2}. \quad (19)$$

It is easily verified that negativity of (18) implies negativity of (19). Thus, the lhs of (17) is decreasing and concave for all $\mu \geq \tilde{\mu}$, while the rhs is decreasing and convex for all μ . Therefore, there is no $\mu > \tilde{\mu}$ for which (17) holds.

Hence, $\bar{\mu}(k)$ is unique and denotes the global minimum of $\pi^k(\mu)$ on $(0, 1)$. It follows that $\arg \max_{\mu} \pi^k(\mu) \in \{\mu_l, \mu_h\}$ and $\arg \max_{\mu} \pi^k(\mu) = \mu_h$ only if $\mu_h > \bar{\mu}(k)$. Furthermore, since the lhs of (17) increases in k , $\bar{\mu}(k)$ also increases in k . \square

References

- Calvo, G. A. and S. Wellisz (1978). Supervision, loss of control, and the optimum size of the firm. *Journal of Political Economy* 86(5), 943–952.
- Faure-Grimaud, A. and D. Martimort (2001). On some agency costs of intermediated contracting. *Economics Letters* 71, 75–82.
- Krishna, V. (2002). *Auction Theory*. Academic Press.
- McAfee, R. P. and J. McMillan (1995). Organizational diseconomies of scale. *Journal of Economics and Management Strategy* 4(3), 399–426.

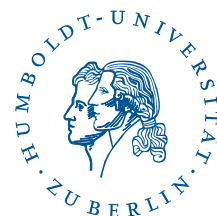
SFB 649 Discussion Paper Series 2006

For a complete list of Discussion Papers published by the SFB 649, please visit <http://sfb649.wiwi.hu-berlin.de>.

- 001 "Calibration Risk for Exotic Options" by Kai Detlefsen and Wolfgang K. Härdle, January 2006.
- 002 "Calibration Design of Implied Volatility Surfaces" by Kai Detlefsen and Wolfgang K. Härdle, January 2006.
- 003 "On the Appropriateness of Inappropriate VaR Models" by Wolfgang Härdle, Zdeněk Hlávka and Gerhard Stahl, January 2006.
- 004 "Regional Labor Markets, Network Externalities and Migration: The Case of German Reunification" by Harald Uhlig, January/February 2006.
- 005 "British Interest Rate Convergence between the US and Europe: A Recursive Cointegration Analysis" by Enzo Weber, January 2006.
- 006 "A Combined Approach for Segment-Specific Analysis of Market Basket Data" by Yasemin Boztuğ and Thomas Reutterer, January 2006.
- 007 "Robust utility maximization in a stochastic factor model" by Daniel Hernández-Hernández and Alexander Schied, January 2006.
- 008 "Economic Growth of Agglomerations and Geographic Concentration of Industries - Evidence for Germany" by Kurt Geppert, Martin Gornig and Axel Werwatz, January 2006.
- 009 "Institutions, Bargaining Power and Labor Shares" by Benjamin Bental and Dominique Demougin, January 2006.
- 010 "Common Functional Principal Components" by Michal Benko, Wolfgang Härdle and Alois Kneip, January 2006.
- 011 "VAR Modeling for Dynamic Semiparametric Factors of Volatility Strings" by Ralf Brüggemann, Wolfgang Härdle, Julius Mungo and Carsten Trenkler, February 2006.
- 012 "Bootstrapping Systems Cointegration Tests with a Prior Adjustment for Deterministic Terms" by Carsten Trenkler, February 2006.
- 013 "Penalties and Optimality in Financial Contracts: Taking Stock" by Michel A. Robe, Eva-Maria Steiger and Pierre-Armand Michel, February 2006.
- 014 "Core Labour Standards and FDI: Friends or Foes? The Case of Child Labour" by Sebastian Braun, February 2006.
- 015 "Graphical Data Representation in Bankruptcy Analysis" by Wolfgang Härdle, Rouslan Moro and Dorothea Schäfer, February 2006.
- 016 "Fiscal Policy Effects in the European Union" by Andreas Thams, February 2006.
- 017 "Estimation with the Nested Logit Model: Specifications and Software Particularities" by Nadja Silberhorn, Yasemin Boztuğ and Lutz Hildebrandt, March 2006.
- 018 "The Bologna Process: How student mobility affects multi-cultural skills and educational quality" by Lydia Mechtenberg and Roland Strausz, March 2006.
- 019 "Cheap Talk in the Classroom" by Lydia Mechtenberg, March 2006.
- 020 "Time Dependent Relative Risk Aversion" by Enzo Giacomini, Michael Handel and Wolfgang Härdle, March 2006.
- 021 "Finite Sample Properties of Impulse Response Intervals in SVECMs with Long-Run Identifying Restrictions" by Ralf Brüggemann, March 2006.
- 022 "Barrier Option Hedging under Constraints: A Viscosity Approach" by Imen Bentahar and Bruno Bouchard, March 2006.

SFB 649, Spandauer Straße 1, D-10178 Berlin
<http://sfb649.wiwi.hu-berlin.de>

This research was supported by the Deutsche
Forschungsgemeinschaft through the SFB 649 "Economic Risk".



- 023 "How Far Are We From The Slippery Slope? The Laffer Curve Revisited" by Mathias Trabandt and Harald Uhlig, April 2006.
- 024 "e-Learning Statistics – A Selective Review" by Wolfgang Härdle, Sigbert Klinke and Uwe Ziegenhagen, April 2006.
- 025 "Macroeconomic Regime Switches and Speculative Attacks" by Bartosz Maćkowiak, April 2006.
- 026 "External Shocks, U.S. Monetary Policy and Macroeconomic Fluctuations in Emerging Markets" by Bartosz Maćkowiak, April 2006.
- 027 "Institutional Competition, Political Process and Holdup" by Bruno Deffains and Dominique Demougin, April 2006.
- 028 "Technological Choice under Organizational Diseconomies of Scale" by Dominique Demougin and Anja Schöttner, April 2006.

SFB 649, Spandauer Straße 1, D-10178 Berlin
<http://sfb649.wiwi.hu-berlin.de>

This research was supported by the Deutsche
Forschungsgemeinschaft through the SFB 649 "Economic Risk".

