

Trieb, Thomas; Kumbhakar, Subal C.

**Working Paper**

## Productivity with General Indices of Management and Technical Change

ifo Working Paper, No. 144

**Provided in Cooperation with:**

Ifo Institute – Leibniz Institute for Economic Research at the University of Munich

*Suggested Citation:* Trieb, Thomas; Kumbhakar, Subal C. (2012) : Productivity with General Indices of Management and Technical Change, ifo Working Paper, No. 144, ifo Institute - Leibniz Institute for Economic Research at the University of Munich, Munich

This Version is available at:

<https://hdl.handle.net/10419/73728>

**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.*

# **ifo** Working Papers

## Productivity with General Indices of Management and Technical Change

Thomas P. Triebs  
Subal C. Kumbhakar

Ifo Working Paper No. 144

October 2012

An electronic version of the paper may be downloaded from the Ifo website  
[www.cesifo-group.de](http://www.cesifo-group.de).

## Productivity with General Indices of Management and Technical Change

### Abstract

We propose a model of production where technical change is both time and management induced. We define a general management index in addition to the general time index of Baltagi and Griffin (1988) and use them as arguments in the translog production function. Time and management induced technical change are then defined in terms of these general indices. For comparison, we also consider models in which time and management are specified as continuous variables. We report empirical results for a sample of manufacturing firms in the US, UK, Germany and France.

JEL Code: M11, D24, O33.

Keywords: General management index, general time index, technical change.

Thomas P. Triebs\*  
Ifo Institute – Leibniz Institute for  
Economic Research  
at the University of Munich  
Poschingerstr. 5  
81679 Munich, Germany  
Phone: +49(0)89/9224-1258  
triebs@ifo.de

Subal C. Kumbhakar  
State University of New York  
at Binghamton  
Department of Economics  
PO Box 6000  
Binghamton, New York 13902-6000  
Phone: +1(0)607/777-2572  
kkar@binghamton.edu

\* Corresponding author.

# 1 Introduction

Business scholars have long maintained that management is an important factor in production. And it is often perceived to be qualitatively different from conventional input factors and attracts special attention. Yet, there is little empirical evidence on how management contributes to production and productivity. To better understand how management affects production we let technical change vary with the level of managerial capability of the firm. That is, we do not only associate technical change with time but also with management.

Empirical modeling of technical change (i.e., the shift in the production function over time) faces a challenge in terms of a trade-off between the flexibility of the production technology and the flexibility with which technical change is characterized (Baltagi and Griffin, 1988; Kumbhakar and Heshmati, 1996; Kumbhakar and Sun, 2012). Index number models (Solow, 1957; Diewert, 1976) allow a fully flexible representation of technical change at the cost of a very restricted model of production (e.g.: constant returns to scale, competitive input and output markets, neutral technical change). Alternatively, econometric models (Tinbergen, 1942; Gollop and Roberts, 1983) offer flexibility for the production technology but require technical change to be a function of time only. In their seminal paper Baltagi and Griffin (1988) overcame this trade-off and introduced an econometric model in which technical change is represented by a general index of time. We generalize their model further by including a management index in addition to the general time index. Just like a general time index model can free technical change from the straitjacket of the time trend, our management index model can free an ordinal variable from the straitjacket of modeling it as a continuous variable. Our model allows us to define technical change in terms of a time trend (the traditional one) as well as management (which we call management-induced technical change). This is because the technology (production function in our case) shifts over time as well as with the level of management.

Our results show that the highest level of management practice does not correlate with the highest level of technical change. Also, constraining technical change to a time trend overemphasizes the contribution of management to output. For management-induced technical change we find that it decreases in the level of management as well as over time.

## 2 Model

We start from the following specification of the production function

$$y = f(x, z, t), \tag{1}$$

where  $y$  is output,  $x$  is a vector of conventional inputs,  $z$  is a management variable and  $t$  is time trend. Since the management variable is reported on a 1 to 5 scale we can specify it as either continuous or as an index defined from different discrete levels of management. Similarly, time can be treated as a continuous variable or specified as

an index from time dummies. These models are known as the time trend and general index models. Since we view management as a shift variable like a time trend, technical change (a measure of the shift in the production function) can be driven by time and/or induced by management. Parametric versions of (1) can be specified in several ways depending on how time and management variables are treated. We alternatively treat technical change and/or management as either continuous or as a general index. That is the management variable is treated as continuous (1 to 5), or for our general index specification we define 5 management dummies  $D_m$ ,  $m = 1, \dots, 5$ .

Model 1 (the baseline model): here both management  $z$  and time  $t$  are treated as continuous variables. The resulting translog form of (1) is

$$\begin{aligned} \ln y_{it} = & \beta_0 + \sum_j \beta_j \ln x_{jit} + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + \beta_t t + \frac{1}{2} \beta_{tt} t^2 + \\ & \sum_j \beta_{jt} \ln x_{jit} t + \beta_z z_i + \frac{1}{2} \beta_{zz} z_i^2 + \sum_j \gamma_{jz} \ln x_{jit} z_i + \delta z_i t, \end{aligned} \quad (2)$$

where the subscripts  $i$  and  $t$  represent firm and time. Since the management variable in our data is time invariant it does not have a time subscript. However, in general, the  $z$  variable is likely to vary in both  $i$  and  $t$  dimensions.

In Model 1 technical change (TC), which is the derivative of  $\ln y_{it}$  with respect to time, is

$$TC_{1it} = \beta_t + \beta_{tt} t + \sum_j \beta_{jt} \ln x_{jit} + \delta z_i. \quad (3)$$

In a similar fashion management-induced technical change (MTC) can be defined as the percentage change in output with respect to a change in management, *ceteris paribus*,

$$MTC_{1it} = \beta_z + \beta_{zz} z_i + \sum_j \gamma_{jz} \ln x_{jit} + \delta t. \quad (4)$$

Model 2: time is continuous but the management variable is an index, defined as  $M(z_i) = \sum_{m=1}^5 \theta_m D_{mi}$  where  $\theta_m$  are unknown parameters. The translog form of it is

$$\begin{aligned} \ln y_{it} = & \beta_0 + \sum_j \beta_j \ln x_{jit} + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + \beta_t t + \\ & \frac{1}{2} \beta_{tt} t^2 + \sum_j \beta_{jt} \ln x_{jit} t + M(z_i) + \sum_j \gamma_j \ln x_{jit} M(z_i) + \delta M(z_i) t. \end{aligned} \quad (5)$$

Unlike in (2), the management index model in (5) is non-linear because of the interaction terms between inputs and the management index function. Note the difference between this model and a model in which the management dummies appear additively as well as interactively with all other regressors. The latter model is more general and is equivalent to running separate regressions for each level of management which assumes that the

production technology differs with the level of management. In the general index model management is treated like any other covariate. The model in (5) is more parsimonious than a dummy model specification, especially when management is constructed from Likert scale variables containing a fairly large number of groups. Technical change in this model is

$$TC_{2it} = \beta_t + \beta_{tt}t + \sum_j \beta_{jt} \ln x_{jit} + \delta M(z_i). \quad (6)$$

And management-induced technical change is

$$MTC_{2it} = (M(z) - M(z-1)) \left( 1 + \sum_j \gamma_j \ln x_{jit} + \delta t \right). \quad (7)$$

Compared to (4) this allows the effect of management to be more “erratic” (not smooth). Also factor inputs and the time trend have no impact on management-induced technical change in the absence of pure management-induced technical change. That is there can be no factor bias or scale augmentation in the absence of pure management-induced technical change which is represented by  $M(z) - M(z-1)$ .

Model 3: management is continuous but the time trend in Model 1 is replaced by a time index  $A(t) = \sum_{t=1}^T \lambda_t D_t$  à la Baltagi and Griffin (1988)

$$\begin{aligned} \ln y_{it} = & \beta_0 + \sum_j \beta_j \ln x_{jit} + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + A(t) + \\ & \sum_j \beta_{jt} \ln x_{jit} A(t) + \beta_z z_i + \beta_{zz} z_i^2 + \sum_j \gamma_{jz} \ln x_{jit} z_i + \delta z_i A(t). \end{aligned} \quad (8)$$

The original motivation for this model stems from Solow (1957) who replaced the time trend in a parametric model by an index  $A(t)$ . Baltagi and Griffin (1988) replaced  $A(t)$  by a set of time-specific dummies and by imposing certain restrictions obtained the equivalent of (8). The model in (8) is more parsimonious than a dummy model, especially when  $T$  is large (see Baltagi and Griffin (1988, p. 27) for more on this point).

Technical change in Model 3 is

$$TC_{3it} = (A(t) - A(t-1)) \left( 1 + \sum_j \beta_{jt} \ln x_{jit} + \delta z_i \right), \quad (9)$$

and management-induced technical change is

$$MTC_{3it} = \beta_z + \beta_{zz} z_i + \sum_j \gamma_{jz} \ln x_{jit} + \delta A(t). \quad (10)$$

Finally, Model 4 specifies both management and technical change in terms of indices

$$\begin{aligned} \ln y_{it} = & \beta_0 + \sum_j \beta_j \ln x_{jit} + \frac{1}{2} \sum_j \sum_k \beta_{jk} \ln x_{jit} \ln x_{kit} + A(t) + \\ & \sum_j \beta_{jt} \ln x_{jit} A(t) + M(z_i) + \sum_j \gamma_j \ln x_{jit} M(z_i) + \delta M(z_i) A(t). \end{aligned} \quad (11)$$

Technical change in this model is

$$TC_{4it} = (A(t) - A(t-1)) \left( 1 + \sum_j \beta_{jt} \ln x_{jit} + \delta M(z_i) \right), \quad (12)$$

and management-induced technical change is

$$MTC_{4it} = (M(z) - M(z-1)) \left( 1 + \sum_j \gamma_j \ln x_{jit} + \delta A(t) \right). \quad (13)$$

Note that the models in (2), (5), and (8) are nested in (11).

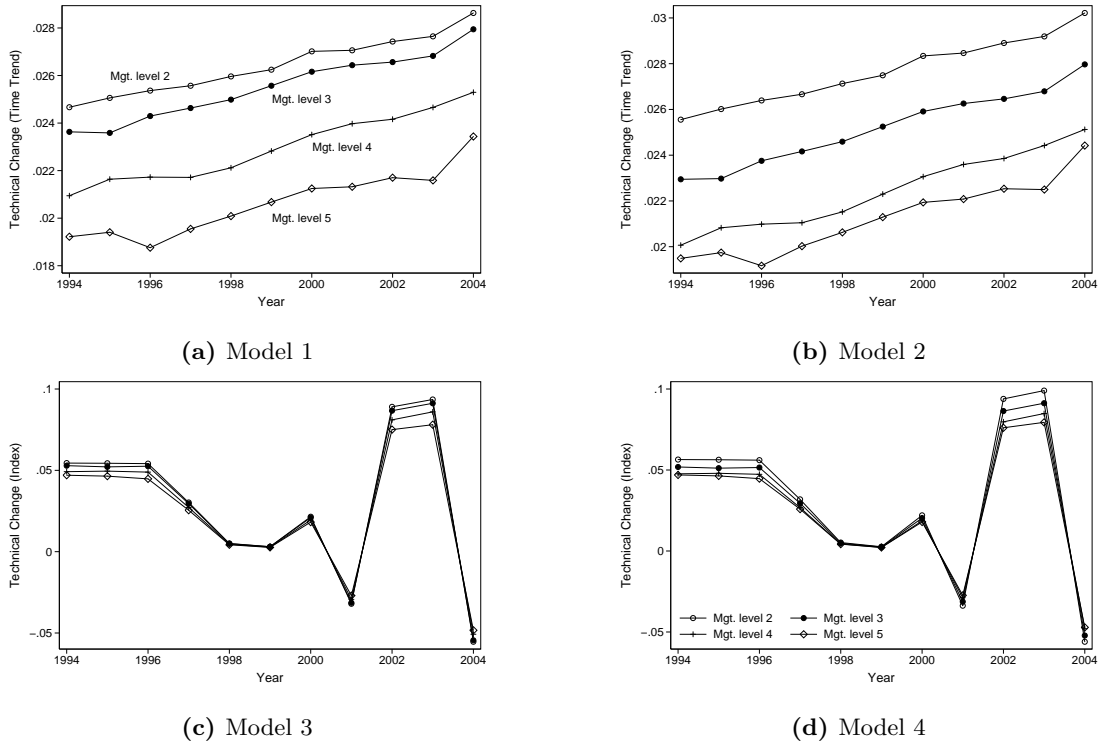
### 3 Data

The data is for an unbalanced panel of about 620 companies for the years 1994 to 2004. The total number of observations is 5,336. All companies are medium-sized manufacturing firms from the United States, the United Kingdom, Germany, and France. The data was originally collected by Bloom and Van Reenen (2007). Accounting data on these firms were gathered from the Amadeus data base for the European countries and Compustat for the US. The firms were surveyed on their management practices in 2004 using a practice evaluation tool developed in collaboration with a leading international management consulting firm. The tool defines and scores 18 separate management practices or categories. Each practice was scored using several questions. The original responses were given a score from 1 (worst) to 5 (best). Bloom and Van Reenen (2007) use the average across all 18 practices as their management variable. Since our general index specification requires discrete values we rounded the average management variables to their nearest integer values. We measure output as deflated sales net of material input. Capital is measured as tangible fixed assets and labor as employee expenses.

### 4 Results

We first present technical change results from our four models. Figure 1 plots the firm averages of technical change; formulae of which are given in (3), (6), (9), and (12) for the management levels 2 to 5. Level 1 is the base level in the index models and for better comparison we drop it from all model results. In Figure 1a technical change is trending upward for all levels of management but technical change clearly differs with the level of management practice. The level of technical change is not higher for

higher levels of management practice. Actually technical change is higher the lower the level of management practice. Technical change is highest for management practice level 2, the second lowest level. And technical change is lowest for the highest level of management practice. This might seem surprising but we believe there are good (competing) explanations. It is possible that a lower quality of management correlates with more organizational flexibility which in turn makes it easier to exploit opportunities for technical change. Alternatively, well managed firms might already have exploited their potential and therefore have lower technical change.



**Figure 1:** Plots of unweighted firm averages of technical change for different levels of management practice. Management level 1 is the omitted base level.

In Figure 1b management is specified as a general index as in (6). The results are mostly unchanged. Only the relative differences between the different levels of management differ.

Next, Figures 1c and 1d plot technical change for Model 3 and 4 based on the formula in (9) and (12), respectively. Unlike Models 1 and 2 technical change is now specified by a general index. Thus, technical change no longer follows a smooth linear trend but fluctuates widely and in particular is negative during the economic crisis around the year 2000 and for some unknown reason in 2004. These figures clearly show that when technical change is specified as a general index the variance across time clearly dominates the variance across levels of management. But for all the models, the pattern of technical change is quite similar across the levels of management. To further investigate this we



Year	Management level				Total
	2	3	4	5	
1994	0.026	0.023	0.020	0.019	0.022
1995	0.026	0.023	0.021	0.020	0.023
1996	0.026	0.024	0.021	0.019	0.023
1997	0.027	0.024	0.021	0.020	0.023
1998	0.027	0.025	0.022	0.021	0.024
1999	0.027	0.025	0.022	0.021	0.024
2000	0.028	0.026	0.023	0.022	0.025
2001	0.028	0.026	0.024	0.022	0.026
2002	0.029	0.026	0.024	0.023	0.026
2003	0.029	0.027	0.024	0.022	0.026
2004	0.030	0.028	0.025	0.024	0.027
<b>Total</b>	0.028	0.025	0.023	0.021	0.025

*Source:* own calculations

**Table 1:** This table gives the unweighted firm averages of technical change for different levels of management practice (Model 2).

report technical change associated with Figures 1b and 1d in Tables 1 and 2, respectively. We see that for Model 4 the variance across levels of management is still important in absolute terms. Also we see that the gap between the levels of management varies from year to year and is lower when the overall level of technical change is low. It seems that removing restrictions on the time trend changes the impact of management on technical change which might be due to a correlation between the misspecification of technical change and management (Baltagi and Griffin, 1988, p. 26).

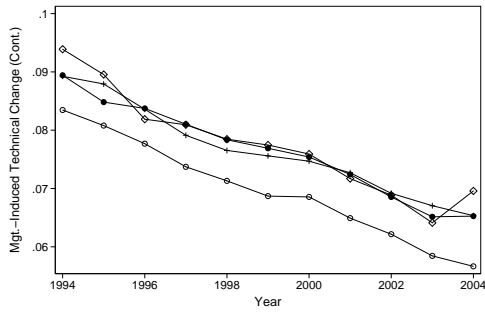
Now we turn to management-induced technical change, i.e., the productivity change between two levels of management given in (4), (7), (10), and (13). Figure 2 plots the average management-induced technical change over the years. In Model 1 (Figure 2a), our baseline model, management-induced technical change does not vary greatly between the different levels of management (with the exception of level 2). However, there is a sizable downward trend implying that the marginal productivity increases when improving management but at a decreasing rate over time. When we ease the restriction on the time trend specification in Model 3 we find that there is still little difference between the levels of management but the change over time takes a different form. The decrease of management-induced technical change is concentrated in the early and late years of our sample with no change between the years 1997 and 2001. When looking at the models that specify management as a general index (Figure 2b and 2d) we see that the variation across levels of management increases and dominates variation across years. Just like a general index specification for technical change increases the variability of

Year	Management level				Total
	2	3	4	5	
1994	0.056	0.052	0.048	0.047	0.051
1995	0.056	0.051	0.048	0.046	0.051
1996	0.056	0.052	0.047	0.045	0.051
1997	0.032	0.029	0.027	0.026	0.029
1998	0.005	0.005	0.004	0.004	0.005
1999	0.003	0.002	0.002	0.002	0.002
2000	0.022	0.020	0.019	0.018	0.020
2001	-0.034	-0.031	-0.029	-0.027	-0.031
2002	0.094	0.086	0.080	0.076	0.085
2003	0.099	0.091	0.085	0.079	0.090
2004	-0.056	-0.052	-0.048	-0.047	-0.051
<b>Total</b>	0.035	0.030	0.027	0.027	0.030

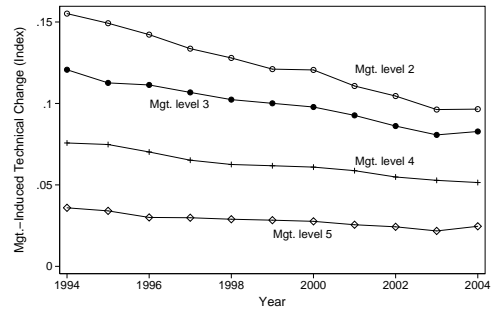
*Source:* own calculations

**Table 2:** This table gives the unweighted firm averages of technical change for different levels of management practice (Model 4).

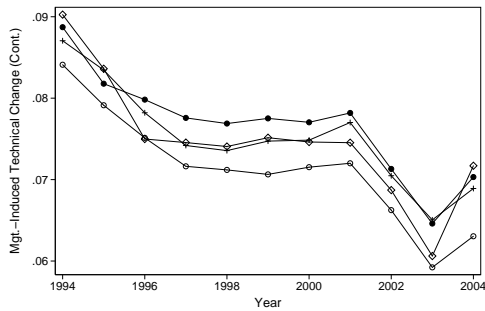
technical change over time the general index specification also increases the variability of management-induced technical change over the levels of management. The ranking in the levels of management changes, too. With the more flexible management specification it is the move from management level 1 to 2 that shows the highest management induced-technical change. And moving from management level 4 to 5 (the highest level of management), has the lowest marginal impact on productivity. However, the decrease over time is lower for higher levels of management. The intuition is that more or better management does not always increase productivity. Just like with other factor inputs the marginal product of management is decreasing.



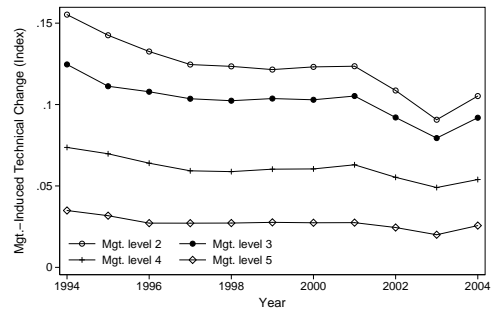
(a) Model 1



(b) Model 2



(c) Model 3



(d) Model 4

**Figure 2:** Plots of unweighted firm averages of management-induced technical change for the difference between two adjacent levels of management practice. For example, the line labeled “Mgt. level 2” gives the productivity increase from management levels 2 to 1.

## 5 Conclusion

Just like a general index model can free technical change from the straitjacket of the time trend it can free ordinal variables from the straitjacket of a continuous variable specification. Our general index models allow technical change to be induced by time and management. We find that technical change varies with the level of management. But the effect of time dominates the effect of management when looking at time induced technical change. When looking at management-induced technical change we find a decreasing marginal impact of management. Our results contribute to the nascent literature on the inclusion of observed management into models of production.

## References

Baltagi, B. H. and Griffin, J. M. (1988). A general index of technical change. *Journal of Political Economy*, 96(1):20–41.

- Bloom, N. and Van Reenen, J. (2007). Measuring and explaining management practices across firms and countries. *Quarterly Journal of Economics*, 122(4):1351–1408.
- Diewert, W. (1976). Exact and superlative index numbers. *Journal of Econometrics*, 4(2):115–145.
- Gollop, F. M. and Roberts, M. J. (1983). Environmental regulations and productivity growth: The case of fossil-fueled electric power generation. *Journal of Political Economy*, 91(4):654–674.
- Kumbhakar, S. and Sun, K. (2012). Estimation of TFP growth: a semiparametric smooth coefficient approach. *Empirical Economics*, 43(1):1–24.
- Kumbhakar, S. C. and Heshmati, A. (1996). Technical change and total factor productivity growth in swedish manufacturing industries. *Econometric Reviews*, 15(3):275–298.
- Solow, R. M. (1957). Technical change and the aggregate production function. *The Review of Economics and Statistics*, 39(3):312–320.
- Tinbergen, J. (1942). Zur theorie der langfristigen wirtschaftsentwicklung. *Weltwirtschaftliches Archiv*, 55:511–549.

## Ifo Working Papers

- No. 143 Ketterer, J.C., The Impact of Wind Power Generation on the Electricity Price in Germany, October 2012.
- No. 142 Triebs, T.P., D.S. Saal, P. Arocena and S.C. Kumbhakar, Estimating Economies of Scale and Scope with Flexible Technology, October 2012.
- No. 141 Potrafke, N. und M. Reischmann, Fiscal Equalization Schemes and Fiscal Sustainability, September 2012.
- No. 140 Fidrmuc, J. and C. Hainz, The Effect of Banking Regulation on Cross-Border Lending, September 2012.
- No. 139 Sala, D. and E. Yalcin, Export Experience of Managers and the Internationalization of Firms, September 2012.
- No. 138 Seiler, C., The Data Sets of the LMU-ifo Economics & Business Data Center – A Guide for Researchers, September 2012.
- No. 137 Crayen, D., C. Hainz and C. Ströh de Martínez, Remittances, Banking Status and the Usage of Insurance Schemes, September 2012.
- No. 136 Crivelli, P. and J. Gröschl, The Impact of Sanitary and Phytosanitary Measures on Market Entry and Trade Flows, August 2012.
- No. 135 Slavtchev, V. and S. Wiederhold, Technological Intensity of Government Demand and Innovation, August 2012.
- No. 134 Felbermayr, G.J., M. Larch and W. Lechthaler, The Shimer-Puzzle of International Trade: A Quantitative Analysis, August 2012.
- No. 133 Beltz, P., S. Link and A. Ostermaier, Incentives for Students: Evidence from Two Natural Experiments, August 2012.
- No. 132 Felbermayr, G.J. and I. Reczkowski, International Student Mobility and High-Skilled Migration: The Evidence, July 2012.

- No. 131 Sinn, H.-W., Die Europäische Fiskalunion – Gedanken zur Entwicklung der Eurozone, Juli 2012.
- No. 130 Felbermayr, G.J., A. Hauptmann and H.-J. Schmerer, International Trade and Collective Bargaining Outcomes. Evidence from German Employer-Employee Data, March 2012.
- No. 129 Triebs, T.P. and S.C. Kumbhakar, Management Practice in Production, March 2012.
- No. 128 Arent, S., Expectations and Saving Behavior: An Empirical Analysis, March, 2012.
- No. 127 Hornung, E., Railroads and Micro-regional Growth in Prussia, March, 2012.
- No. 126 Seiler, C., On the Robustness of the Balance Statistics with respect to Nonresponse, March 2012.
- No. 125 Arent, S., A. Eck, M. Kloss and O. Krohmer, Income Risk, Saving and Taxation: Will Precautionary Saving Survive?, February 2012.
- No. 124 Kluge, J. and R. Lehmann, Marshall or Jacobs? Answers to an Unsuitable Question from an Interaction Model, February 2012.
- No. 123 Strobel, T., ICT Intermediates, Growth and Productivity Spillovers: Evidence from Comparison of Growth Effects in German and US Manufacturing Sectors, February 2012.
- No. 122 Lehwald, S., Has the Euro Changed Business Cycle Synchronization? Evidence from the Core and the Periphery, January 2012.
- No. 121 Piopiunik, M. and M. Schlotter, Identifying the Incidence of “Grading on a Curve”: A Within-Student Across-Subject Approach, January 2012.
- No. 120 Kauppinen, I. and P. Poutvaara, Preferences for Redistribution among Emigrants from a Welfare State, January 2012.
- No. 119 Aichele, R. and G.J. Felbermayr, Estimating the Effects of Kyoto on Bilateral Trade Flows Using Matching Econometrics, December 2011.
- No. 118 Heid, B., J. Langer and M. Larch, Income and Democracy: Evidence from System GMM Estimates, December 2011.