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Centre for Applied Economic Research

Industry Level Value Added and Productivity Decompositions

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Summary

- **Decompose nominal value added growth for the Australian Market Sector**

- **Explanatory factors are**

  - **efficiency changes,**
  - **changes in output prices,**
  - **changes in primary inputs,**
  - **changes in input prices, and**
  - **technical progress**

Summary

- **Draw on the work of Diewert and Fox (2018):**

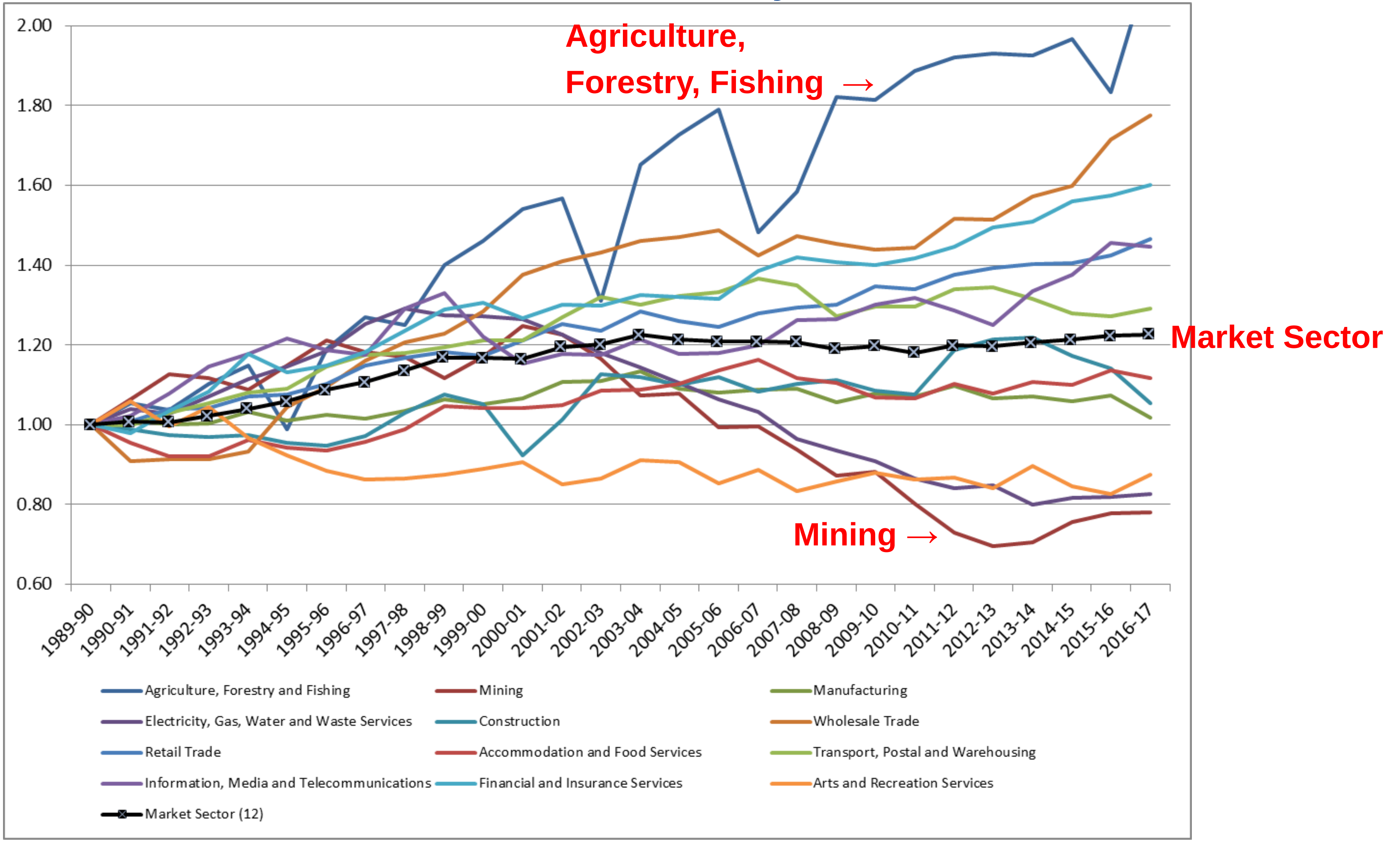
  "Decomposing Value Added Growth into Explanatory Factors," in E. Grifell-Tatjé, C.A.K. Lovell and R. Sickles (eds.), *The Oxford Handbook of Productivity Analysis*, Oxford University Press, forthcoming.

- **Use the official Australian Bureau of Statistics Multifactor Productivity data cube:**

  http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/5260.0.55.002Main+Features12016-17

- **The following slide shows the official market sector results plus the official industry sectoral results for 16 sectors back to 1995.**
- **4 industries showed very good TFP or MFP growth and 3 industries showed very poor MFP growth**

Australian Official Market Sector Multifactor Productivity Statistics: 12 Industries ABS Official MFP: Industry and market sector results



Value Added Decomposition

- **Need sector's best practice technology for the periods under consideration.**
- **Could use econometric or nonparametric (DEA) techniques**
- **Use a Free Disposal Hull approach – no convexity assumptions**
- **Our approach has the advantage that it does not involve econometric estimation, and involves only observable data.**
- **Rules out technical regress.**
- **Simple enough to be implemented by national statistical offices**

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Value Added Decomposition: Notation

- **A sector produces M net outputs, $y \equiv [y_1,\ldots,y_M]$, using N primary inputs $x \equiv [x_1,\ldots,x_N] \geq 0_N$.**

- **If $y_m > 0$, then the sector produces the m^{th} net output during period t while if $y_m < 0$, then the sector uses the m^{th} net output as an intermediate input.**

- **Strictly positive vector of net output prices $p \equiv [p_1,\ldots,p_M] >> 0_M$ and strictly positive vector of input prices $w \equiv [w_1,\ldots,w_N] >> 0_N$**

- ***Period t production possibilities set* for the sector S^t satisfies some (minimal) regularity conditions**

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Value Added Decomposition

Period t cost constrained value added function:

$$R^t(p,w,x) \equiv \max_{y,z} \{p \cdot y : (y,z) \in S^t;\ w \cdot z \leq w \cdot x\}$$

If S^t is a cone, so that production is subject to constant returns to scale, Diewert-Fox show that

$$R^t(p,w,x) \equiv w \cdot x / c^t(w,p)$$

where $c^t(w,p)$ is the unit cost function for producing a unit of value added.

Following Diewert (1980) and Diewert and Parkan (1983), we use a "sequential" approach, where past observations up to and including the current period are used to determine the technology set S^t. This approach rules out technical regress.

Value Added Decomposition: The First Explanatory Factor

Observed value added, $p^t \cdot y^t$, may not equal the optimal value added.

Value added efficiency **of the sector during period t:**

$$e^t \equiv p^t \cdot y^t / R^t(p^t, w^t, x^t) \leq 1$$

Change in value added efficiency:

$$\varepsilon^t \equiv e^t / e^{t-1}$$

If $\varepsilon^t > 1$, value added efficiency has *improved, fallen* if $\varepsilon^t < 1$.

Value Added Decomposition: The Second Explanatory Factor

Family of *input quantity indexes*:

$$\beta(x^{t-1},x^{t},w) \equiv w \cdot x^{t}/w \cdot x^{t-1}.$$

Laspeyres and Paasche type special cases:

$\beta_L{}^t \equiv w^{t-1} \cdot x^{t}/w^{t-1} \cdot x^{t-1}$;

$\beta_P{}^t \equiv w^{t} \cdot x^{t}/w^{t} \cdot x^{t-1}$.

Preferred overall measure of input quantity growth is the geometric average of the above two estimates of input growth (Fisher index):

$$\beta^t \equiv [\beta_L{}^t \, \beta_P{}^t]^{1/2}.$$

Value Added Decomposition: The Third Explanatory Factor

Family of *output price indexes*:

$$\alpha(p^{t-1},p^t,w,x,s) \equiv R^s(p^t,w,x)/R^s(p^{t-1},w,x).$$

Laspeyres and Paasche type special cases:

$\alpha_L{}^t \equiv R^{t-1}(p^t,w^{t-1},x^{t-1})/R^{t-1}(p^{t-1},w^{t-1},x^{t-1})$;

$\alpha_P{}^t \equiv R^t(p^t,w^t,x^t)/R^t(p^{t-1},w^t,x^t)$.

Preferred overall measure of output price growth:

$\alpha^t \equiv [\alpha_L{}^t \, \alpha_P{}^t]^{1/2}$

Value Added Decomposition: The 4th Explanatory Factor

Family of *input mix indexes*:

$$\gamma(w^{t-1},w^{t},p,x,s) \equiv R^{s}(p,w^{t},x)/R^{s}(p,w^{t-1},x)$$

Laspeyres and Paasche type special cases:

$$\gamma_{LPP}{}^{t} \equiv R^{t}(p^{t-1},w^{t},x^{t})/R^{t}(p^{t-1},w^{t-1},x^{t});$$

$$\gamma_{PLL}{}^{t} \equiv R^{t-1}(p^{t},w^{t},x^{t-1})/R^{t-1}(p^{t},w^{t-1},x^{t-1}).$$

Take the geometric average of the above two measures:

$$\gamma^{t} \equiv [\gamma_{LPP}{}^{t}\,\gamma_{PLL}{}^{t}]^{1/2}.$$

Value Added Decomposition: The 5th Explanatory Factor

Family *of* *technical progress indexes*:

$$\tau(t-1,t,p,w,x) \equiv R^t(p,w,x)/R^{t-1}(p,w,x)$$

$\tau_{LLP}{}^t \equiv R^t(p^{t-1},w^{t-1},x^t)/R^{t-1}(p^{t-1},w^{t-1},x^t)$.

$\tau_{PPL}{}^t \equiv R^t(p^t,w^t,x^{t-1})/R^{t-1}(p^t,w^t,x^{t-1})$.

For the cone case:

$\tau_{LLP}{}^t = c^{t-1}(w^{t-1},p^{t-1})/c^t(w^{t-1},p^{t-1})$ and $\tau_{PPL}{}^t = c^{t-1}(w^t,p^t)/c^t(w^t,p^t)$

(independent of x)

$\tau^t \equiv [\tau_{LLP}{}^t\ \tau_{PPl}{}^t]^{1/2}$.

Value Added Decomposition

With CRS, five factors that explain value added growth:

1. Change in cost constrained value added efficiency: $\varepsilon^t \equiv e^t/e^{t-1}$

2. Change in output prices: $\alpha(p^{t-1},p^t,w,x,s)$

3. Change in input quantities: $\beta(x^{t-1},x^t,w)$

4. Change in input prices: $\gamma(w^{t-1},w^t,p,x,s)$

5. Changes due to technical progress: $\tau(t-1,t,p,w,x)$

(Returns to scale factor (delta) set equal to 1 since we assume CRS)

$$\text{Value Added Growth} = \frac{p^t \cdot y^t}{p^{t-1} \cdot y^{t-1}} = \varepsilon^t \alpha^t \beta^t \gamma^t \delta^t \tau^t$$

$$\text{TFP Growth} = \left\{ \frac{p^t \cdot y^t}{p^{t-1} \cdot y^{t-1}} \Big/ \alpha^t \right\} \Big/ \beta^t = \varepsilon^t \gamma^t \delta^t \tau^t$$

Value Added Decomposition

Approximate the production unit's period t production possibilities set S^t by the conical free disposal hull of the period t actual production vector and past production vectors.

$R^t(p,w,x)$ can be estimated by solving a very simple one constraint linear programming problem:

$$R^t(p,w,x) \equiv \max_{\lambda} \{p\cdot(\Sigma_{s=1}^{t} y^s\lambda_s) \; ; \; w\cdot(\Sigma_{s=1}^{t} x^s\lambda_s) \leq w\cdot x \; ; \; \lambda_1 \geq 0 ,\ldots, \lambda_t \geq 0\}$$

$$= w\cdot x/c^t(w,p)$$

where $c^t(w,p)$ is the *period t nonparametric unit cost function that corresponds to* $R^t(p,w,x)$.

Market Sector Value Added Decomposition: The Weighted Average Industry Approach

Take value added growth as a weighted average of the industry value added growth factors. Period t industry k share of national value added:

$$s_{kt} \equiv v^{kt}/v^{t}$$

Decompositions of value added growth:

$$v^{1}/v^{0} = \Sigma_{k=1}^{K}\, s_{k0}\varepsilon^{k}\alpha^{k}\beta^{k}\tau^{k}$$

Or

$$v^{1}/v^{0} = [\Sigma_{k=1}^{K}\, s_{k1}(\varepsilon^{k}\alpha^{k}\beta^{k}\tau^{k})^{-1}]^{-1}$$

Market Sector Value Added Decomposition: The Weighted Average Industry Approach

Approximate weighted arithmetic means by weighted geometric means, and get an *approximate decomposition of the aggregate value added ratio into explanatory factors*:

$$v^1/v^0 \approx \varepsilon^*\alpha^*\beta^*\tau^*$$

where

$$\ln \varepsilon^* \equiv \Sigma_{k=1}^{K} (1/2)(s_{k0} + s_{k1})\ln \varepsilon^k \;;$$

$$\ln \alpha^* \equiv \Sigma_{k=1}^{K} (1/2)(s_{k0} + s_{k1})\ln \alpha^k \;;$$

$$\ln \beta^* \equiv \Sigma_{k=1}^{K} (1/2)(s_{k0} + s_{k1})\ln \beta^k \;;$$

$$\ln \tau^* \equiv \Sigma_{k=1}^{K} (1/2)(s_{k0} + s_{k1})\ln \tau^k$$

Note that these indexes have a Törnqvist form: weighted geometric means.

Australian Market Sector

- **The official Australian Market Sector is comprised of 16 industries, with productivity data available 1994/95-2016/17 (July-June years).**

- **We focus on a subset, the original definition of the Market Sector, which comprised of 12 industries, with productivity data available 1989/90-2016/17.**

This is because of

1. **Concerns about measurement problems with the additional four sectors (hard to measure sectors, such as Rental, Hiring & Real Estate Services)**
2. **The extra years of data available from focusing on the original 12 industries in the Market Sector.**

Australian Market Sector

Table 1: Industry classification of the market sector in Australia

Division	Industry
A	Agriculture, Forestry and Fishing
B	Mining
C	Manufacturing
D	Electricity, Gas, Water and Waste Services
E	Construction
F	Wholesale Trade
G	Retail Trade
H	Accommodation and Food Services
I	Transport, Postal and Warehousing
J	Information, Media and Telecommunications
K	Financial and Insurance Services
~~L~~	~~Rental, Hiring and Real Estate Services~~
~~M~~	~~Professional, Scientific and Technical Services~~
~~N~~	~~Administrative and Support Services~~
R	Arts and Recreation Services
~~S~~	~~Other Services~~

Notation

In the following figures, we cumulate the growth effects so that:

- **T^t : level of the technology index in period t (cumulated τ^t)**
- **E^t : level of the efficiency index in period t (cumulated ε^t)**
- **C^t : level of the input mix index in period t (cumulated γ)**

The level of productivity is then given by:

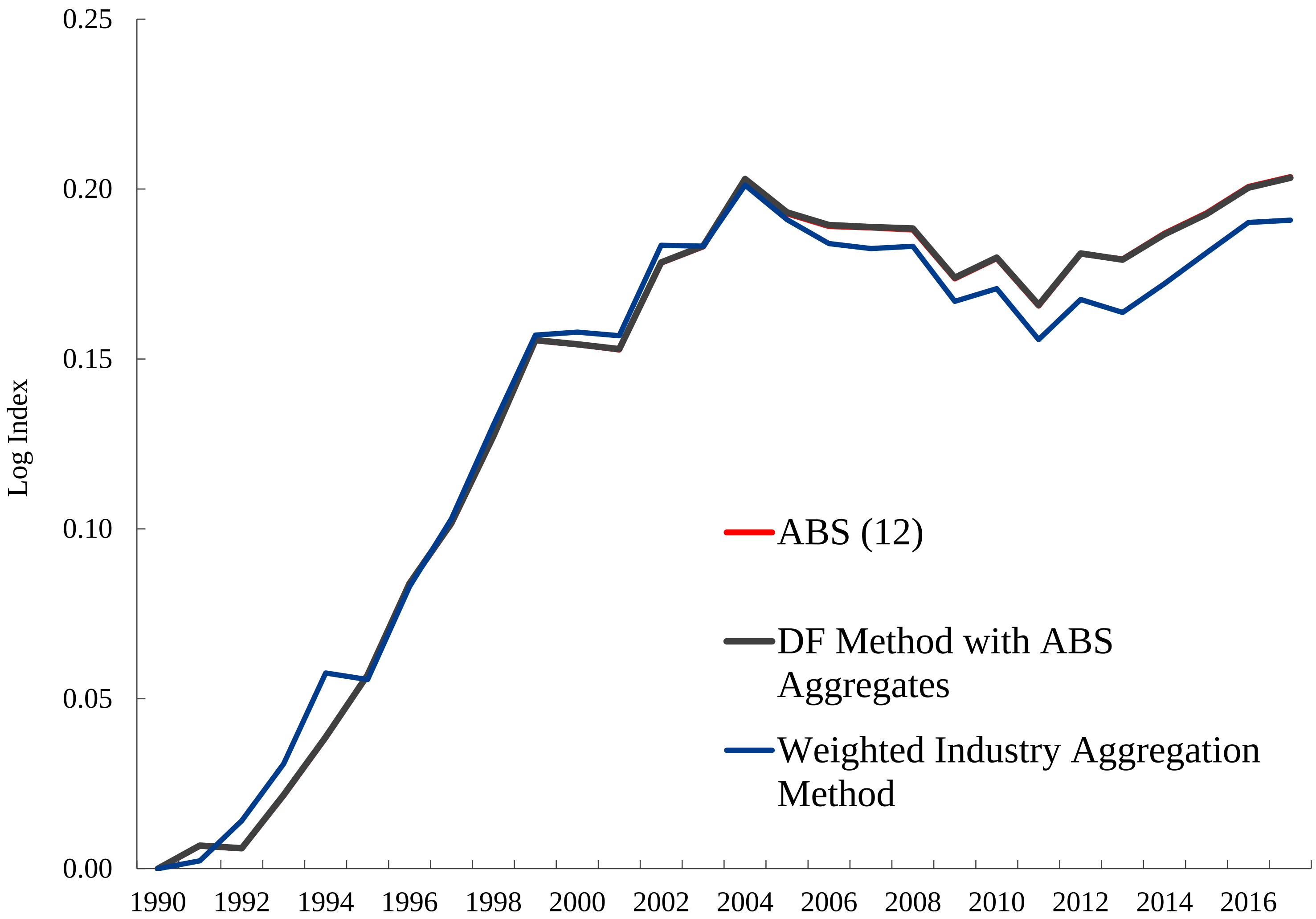
$$TFP^t = C^t E^t T^t$$

Focus on decompositions of TFP for presentation purposes.

Work in logs in what follows so that the decomposition is additive.

First plot the two aggregate Market Sector series we decompose.

Comparison of (logs of) ABS Official Market Sector Productivity with our Weighted Average Industry Approach



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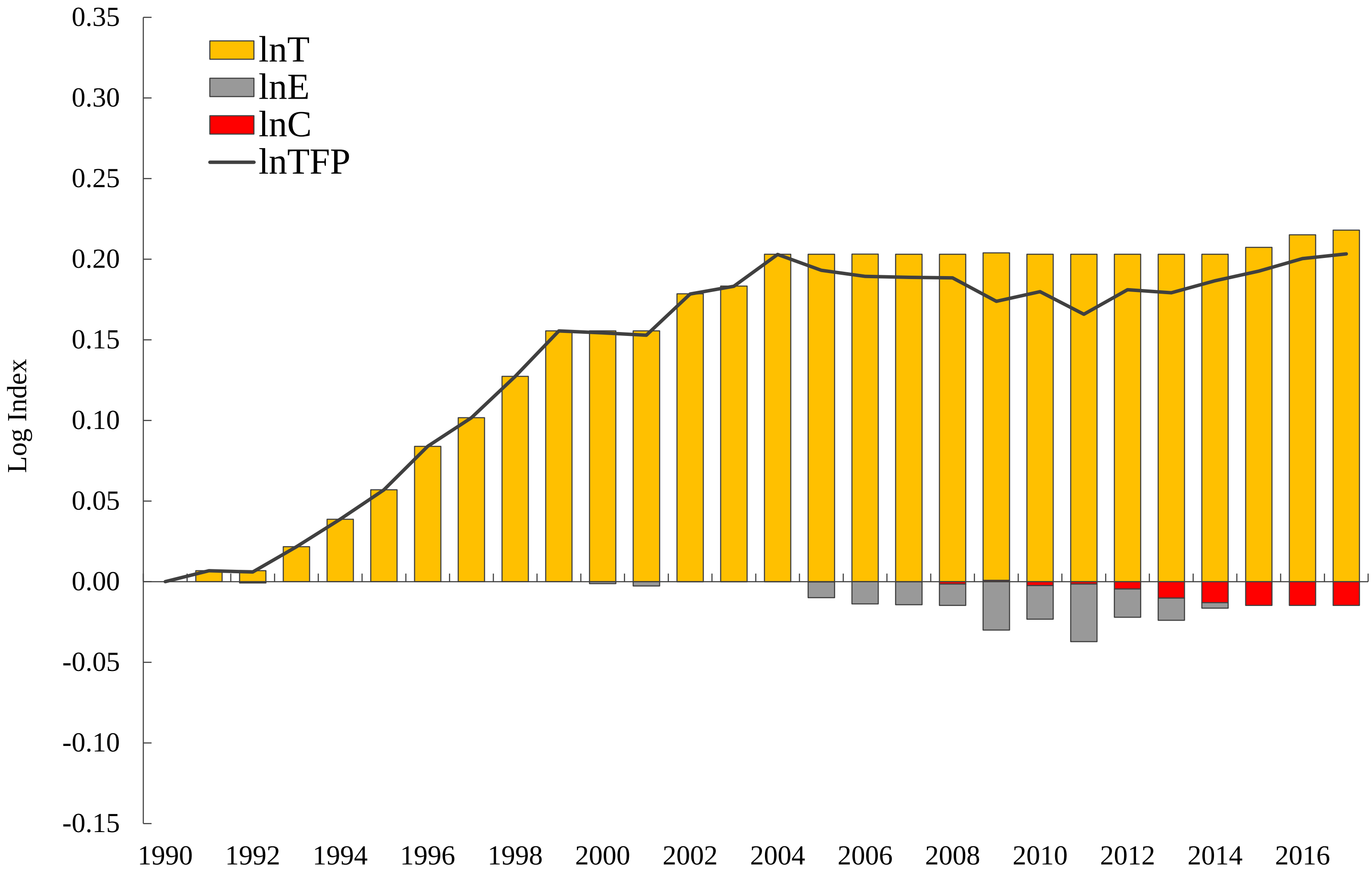
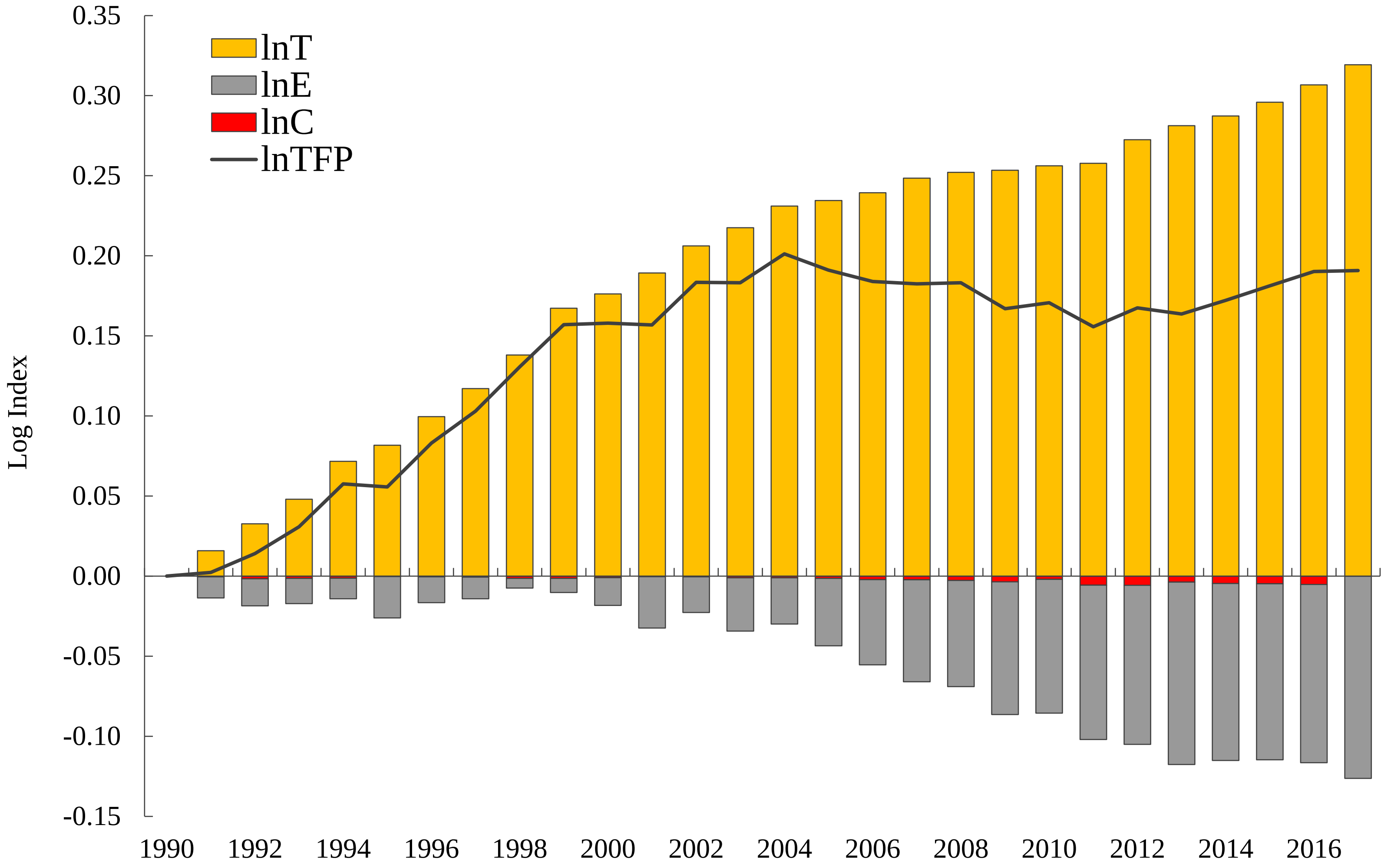
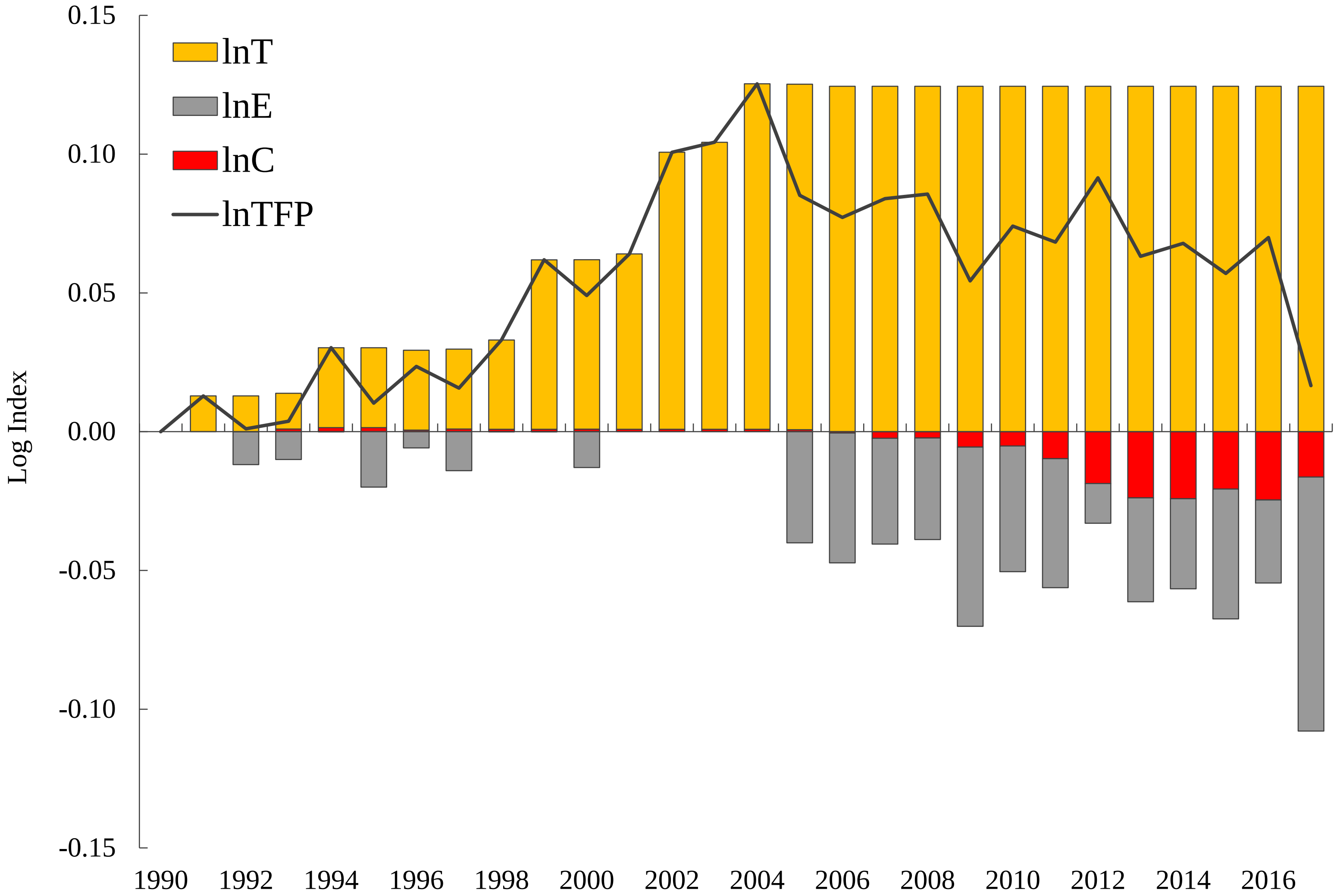
Decomposition of Aggregate ABS Market Sector Productivity (uses our decomposition on aggregate ABS data)



Decomposition from Aggregation over Industries: Using our Weighted Average Industry Approach



Decomposition of Manufacturing Productivity



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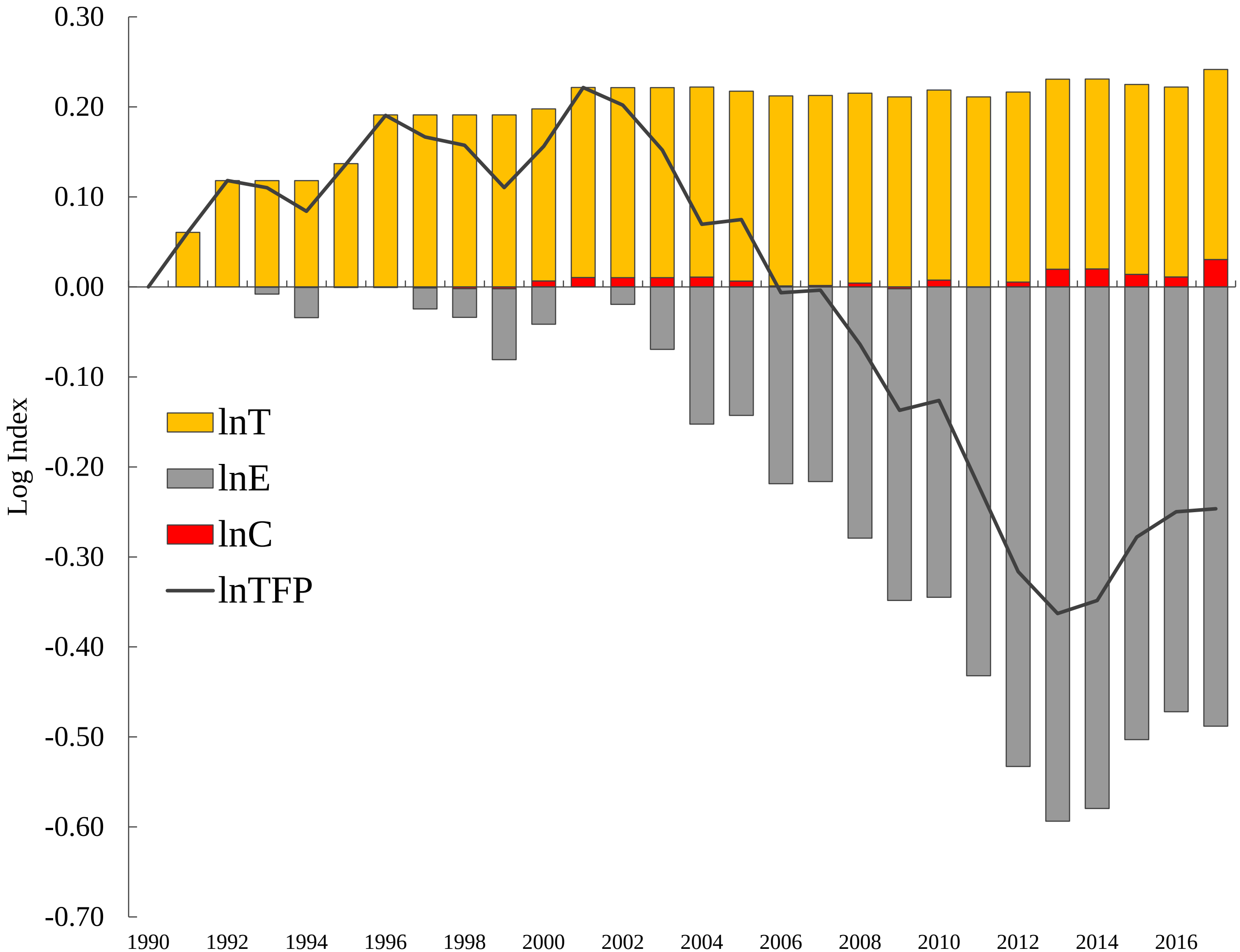
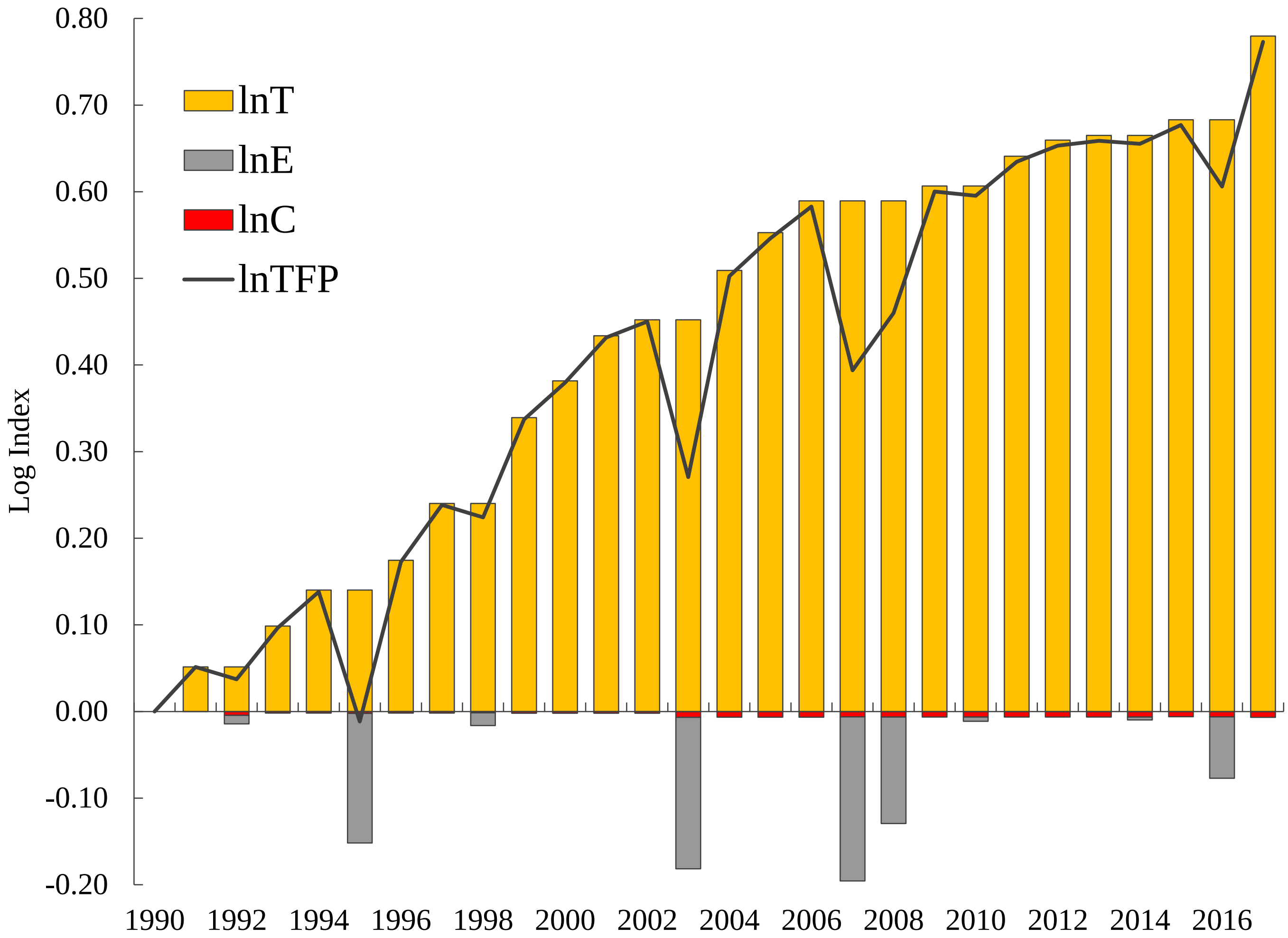
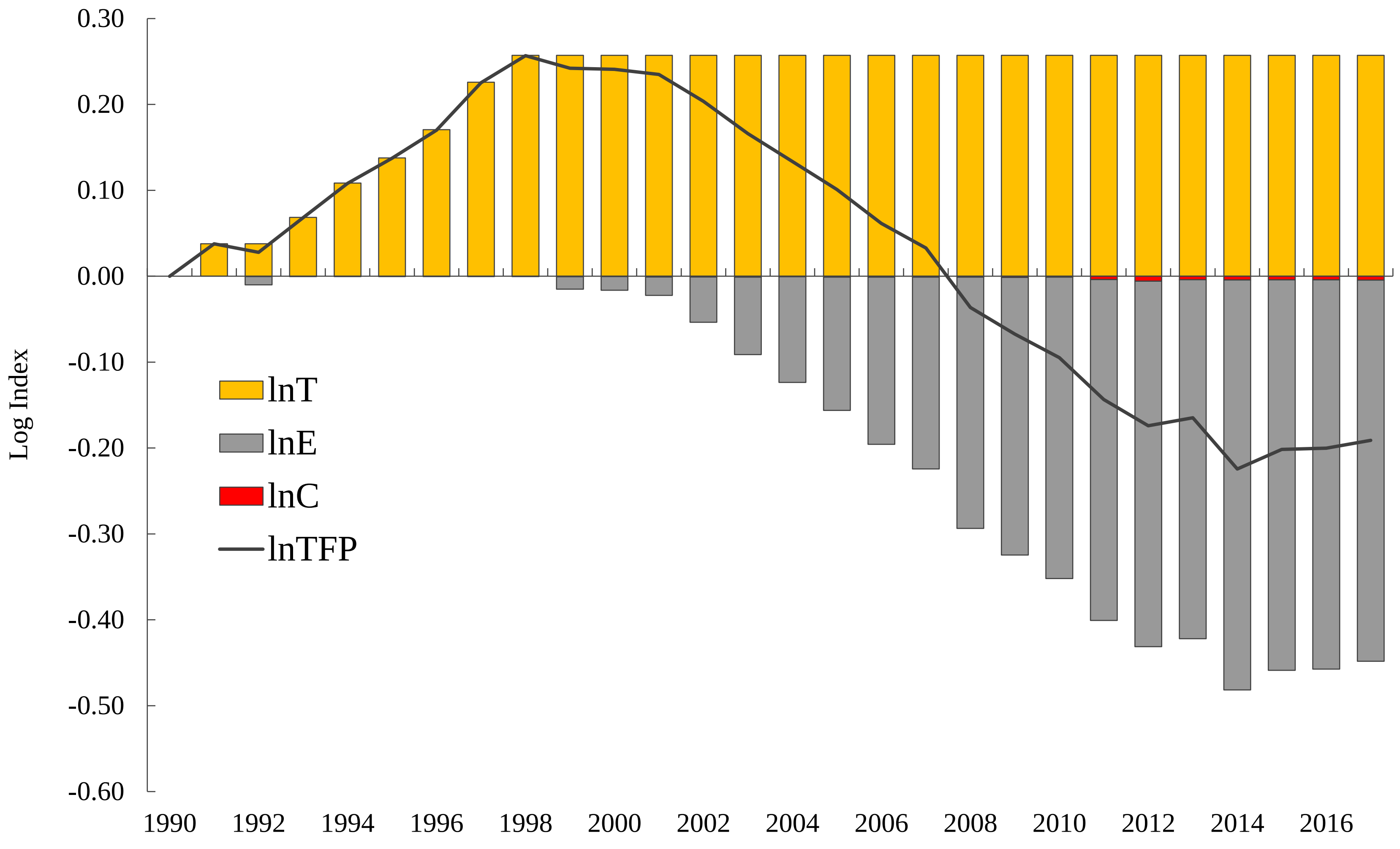
Decomposition of Mining Productivity



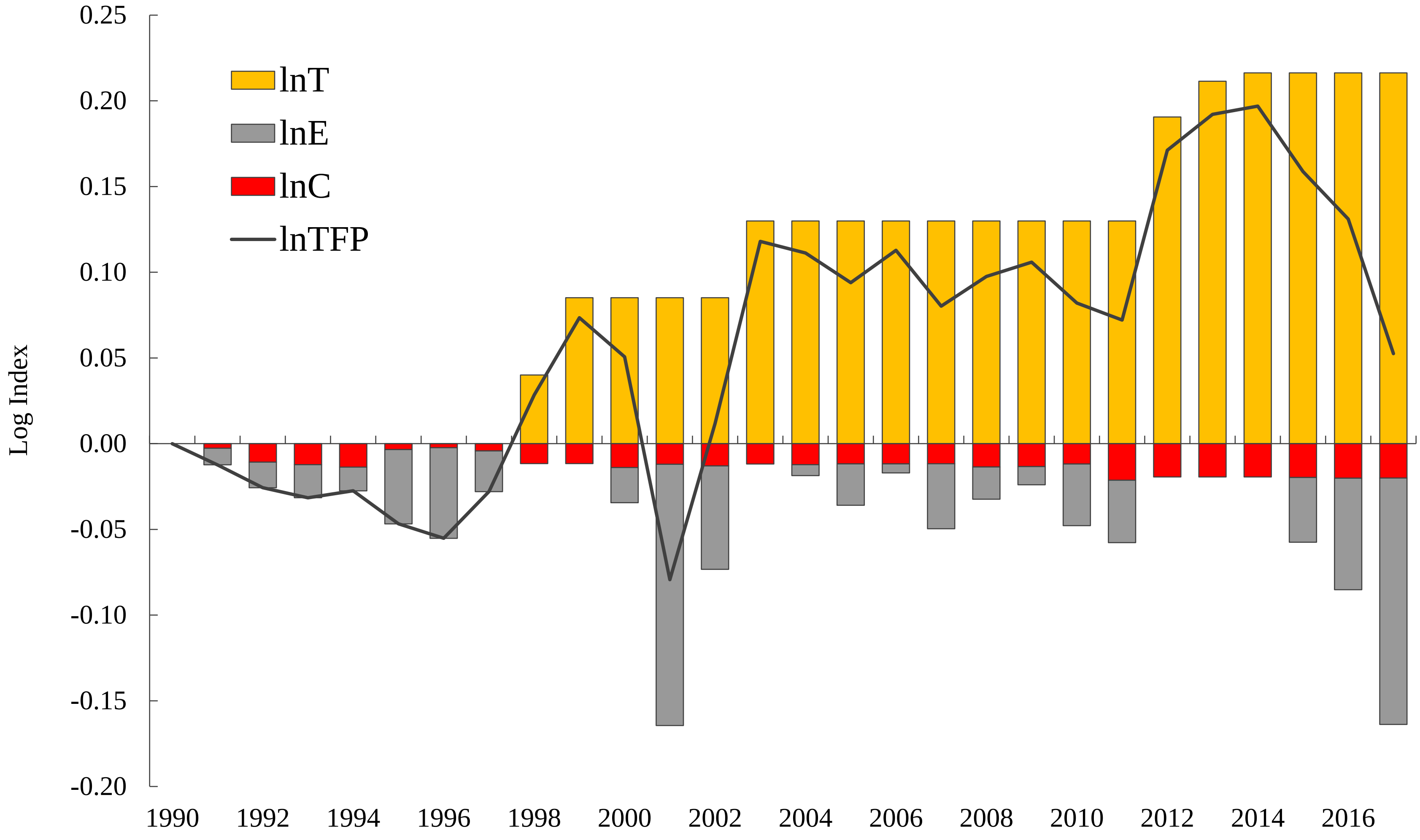
Agriculture, Fishing and Forestry



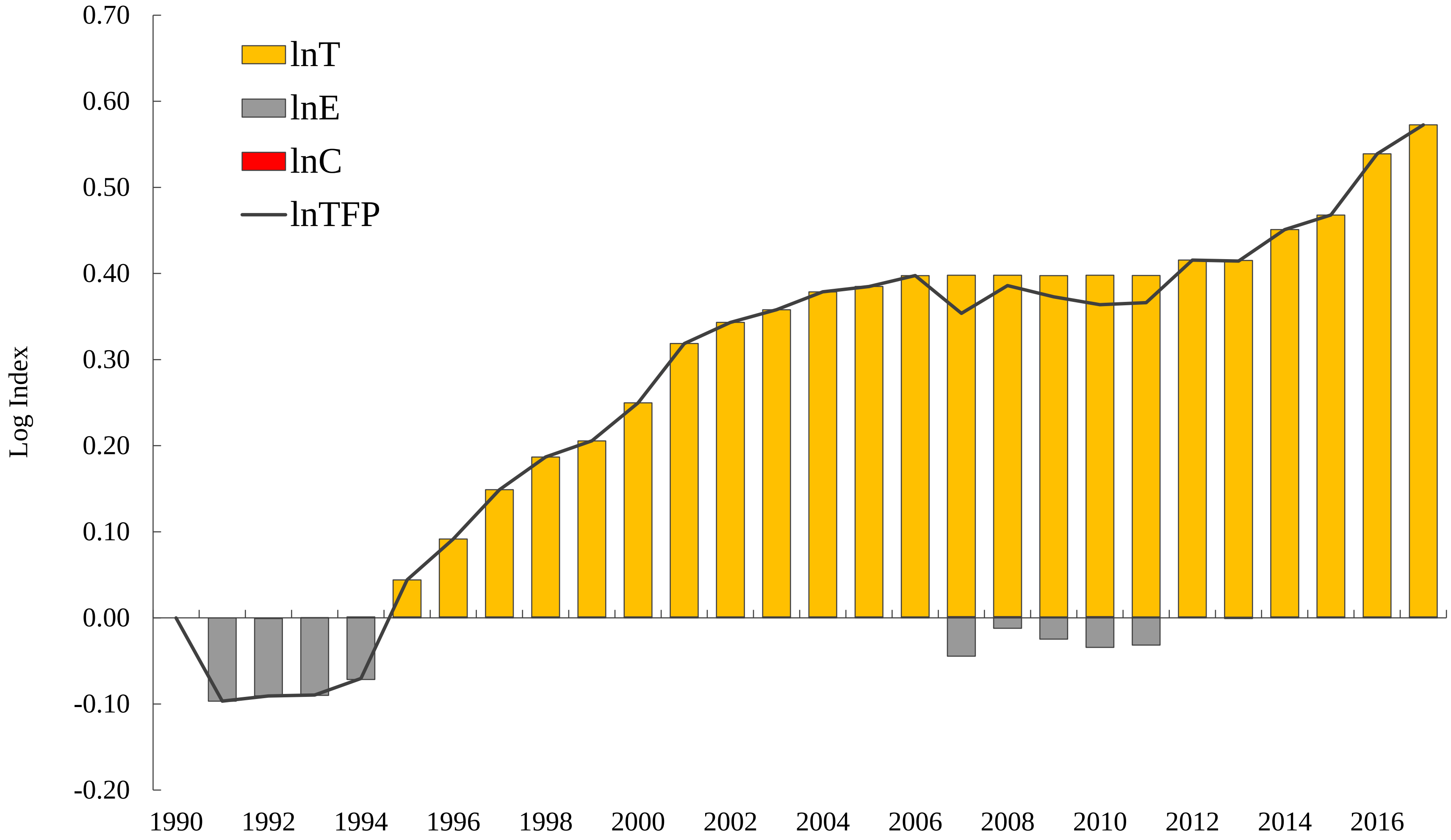
Electricity



Construction



Wholesale



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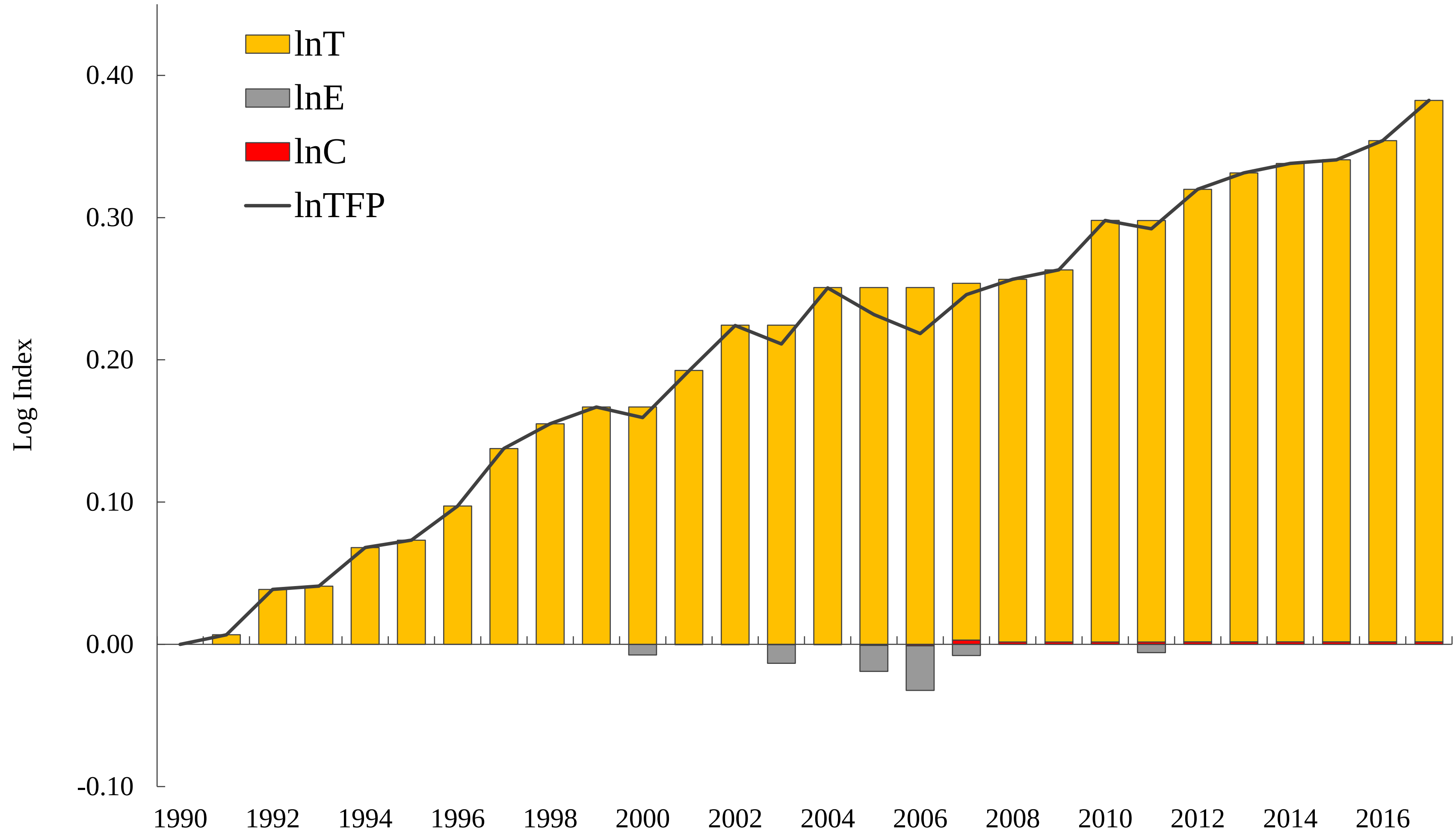
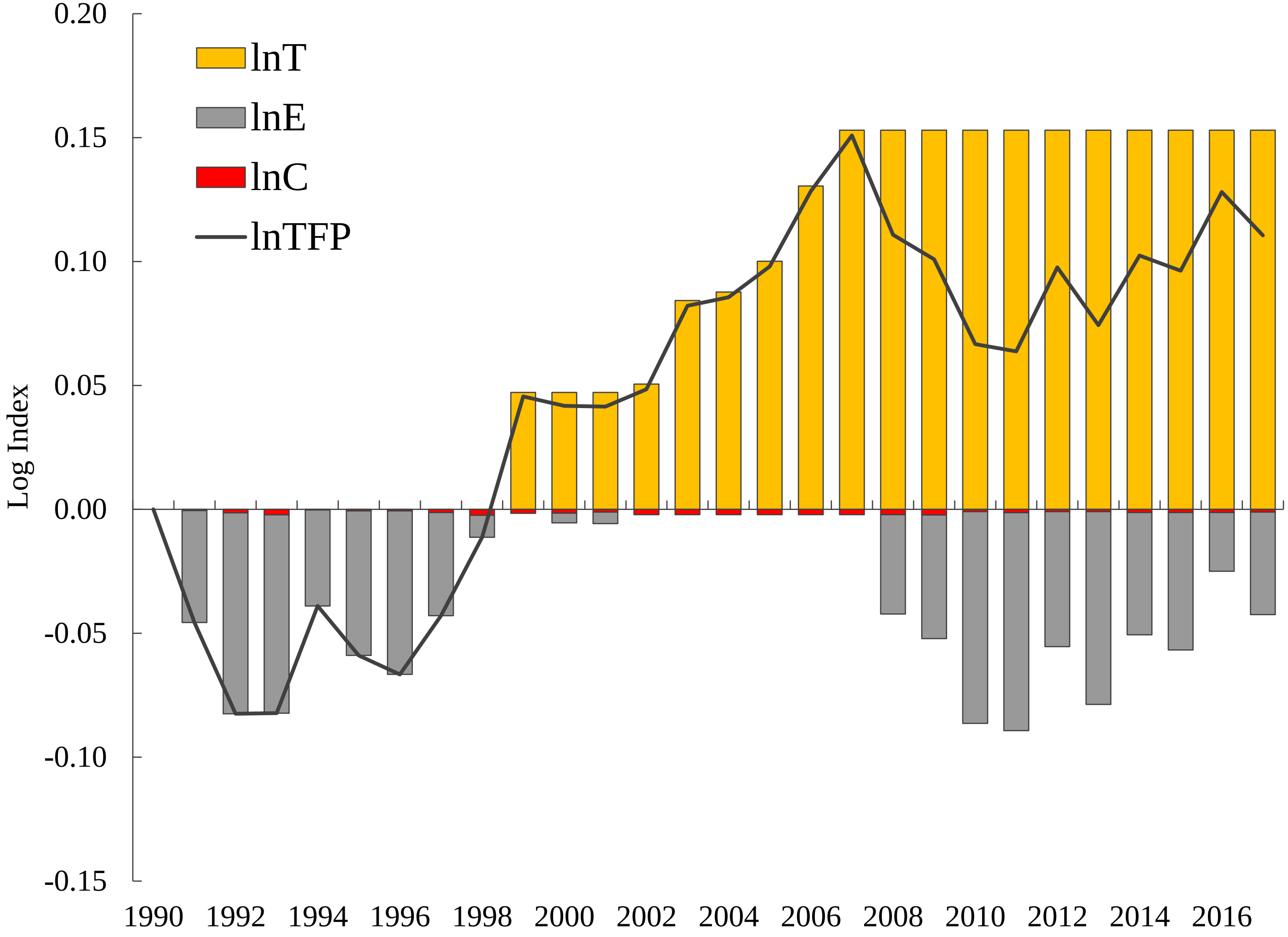
Retail

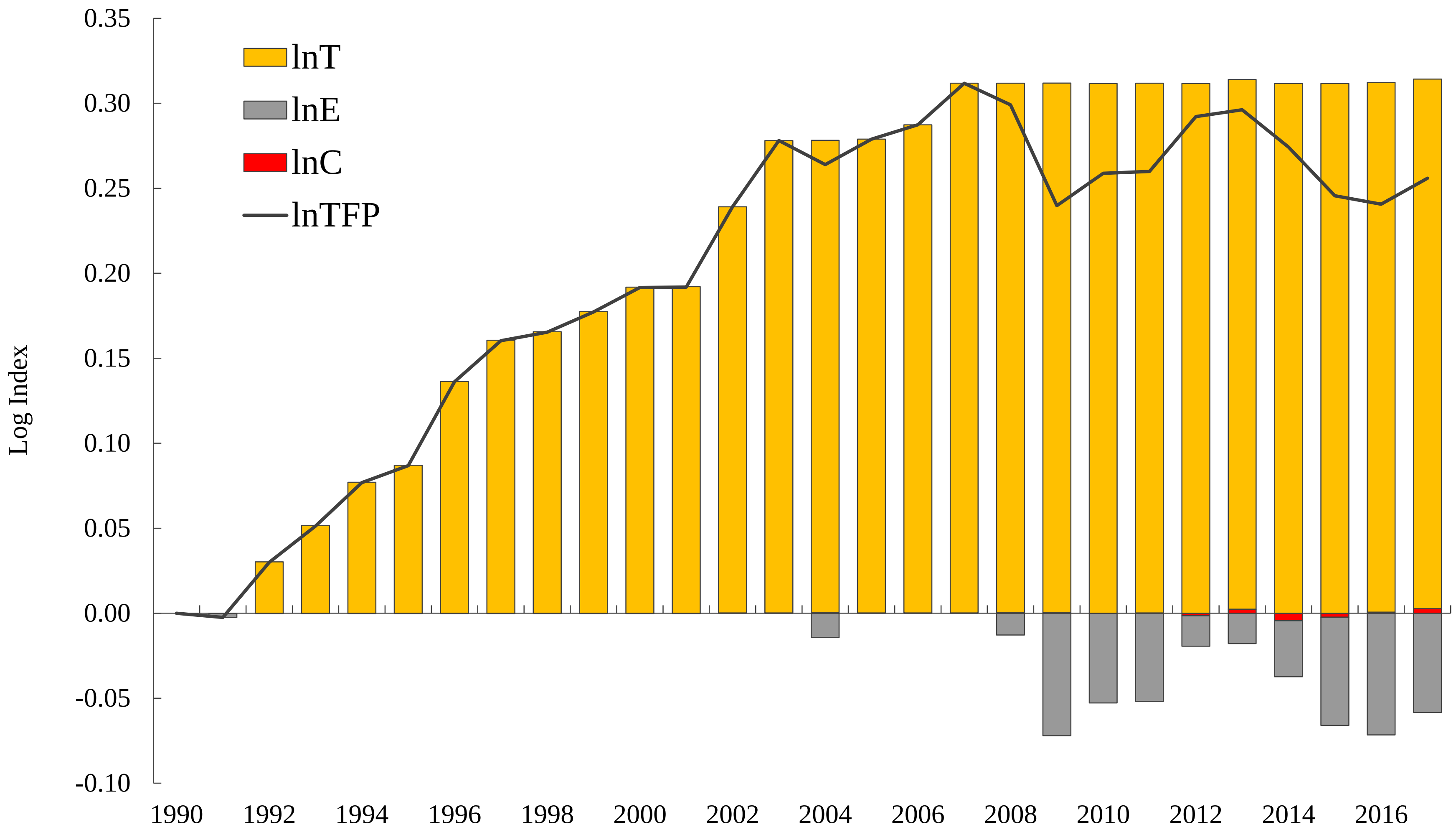


lnT
lnE
lnC
lnTFP
Log Index
0.40
0.30
0.20
0.10
0.00
-0.10
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

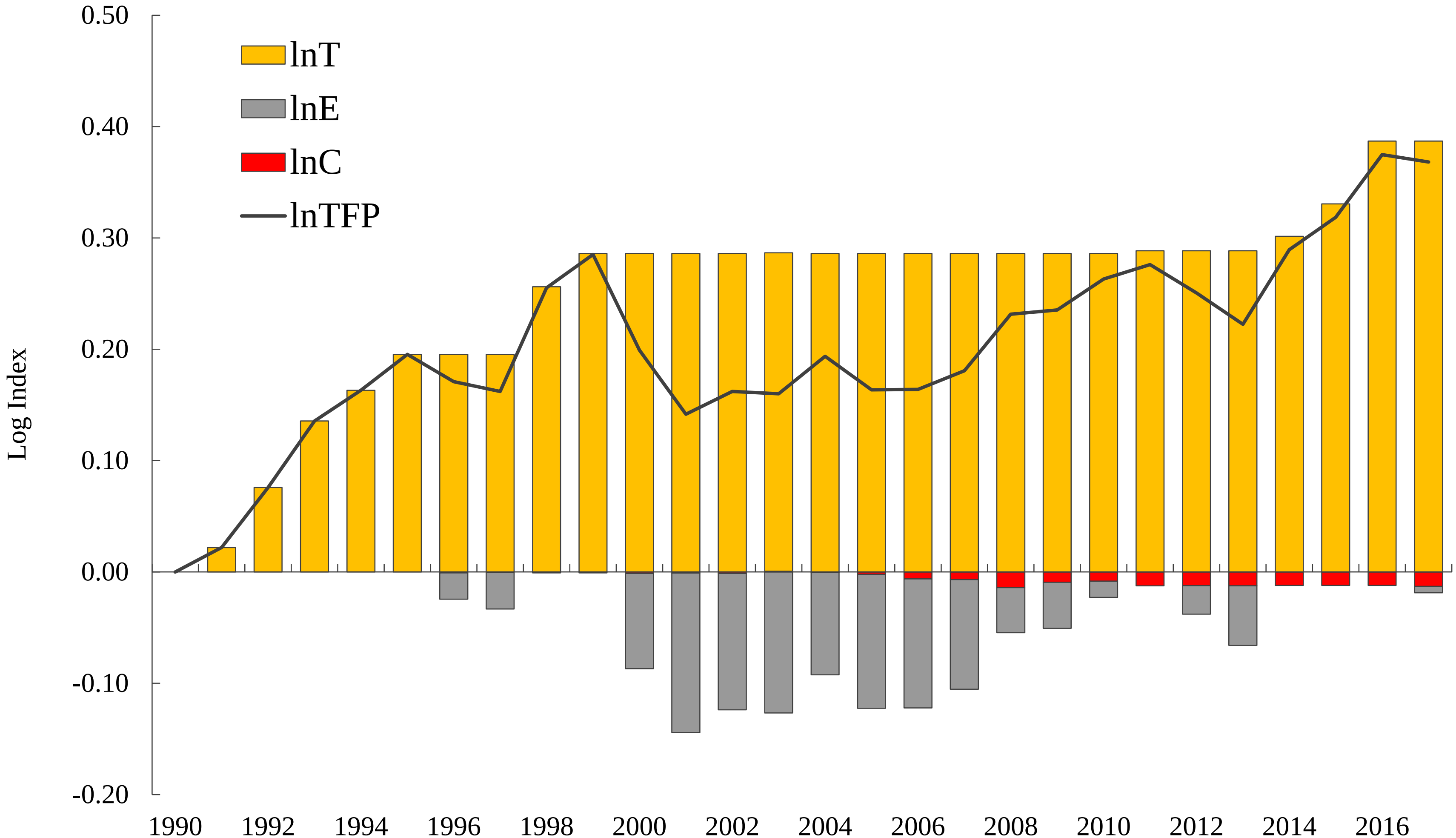
Accommodation



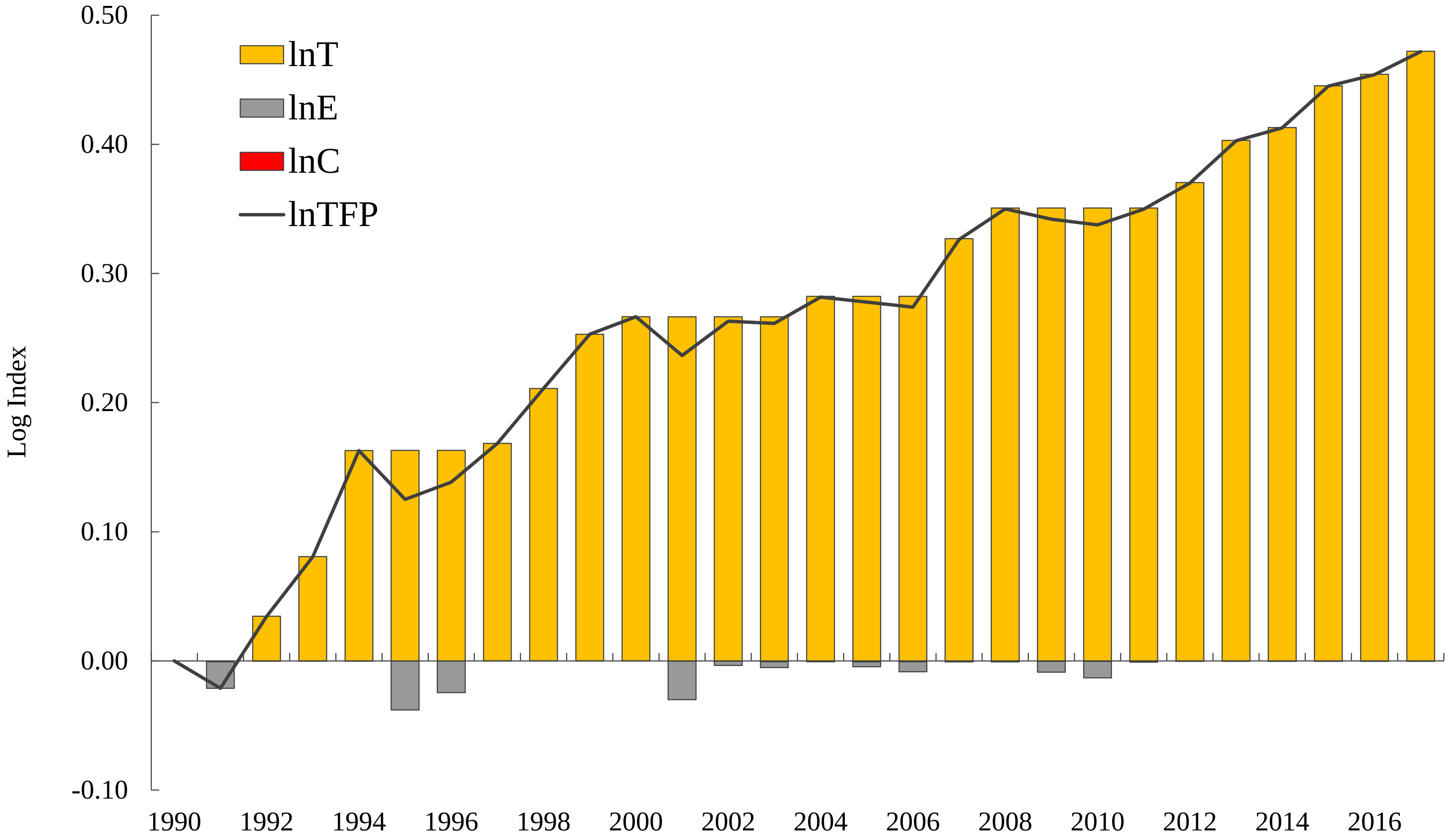
Transport


lnT
lnE
lnC
lnTFP
Log Index
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
-0.05
-0.10
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016

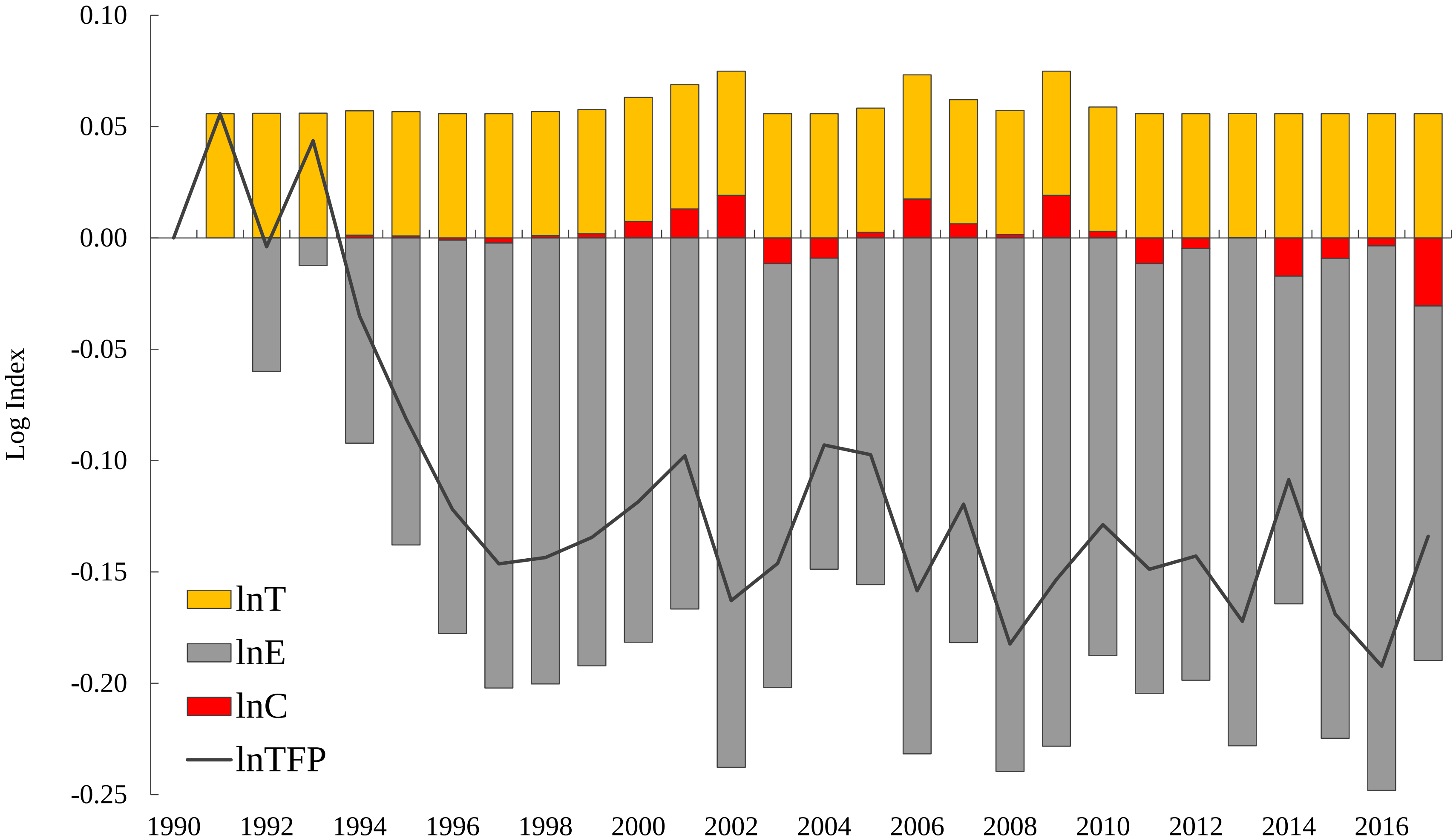
Information



Financial Services



Arts



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Thoughts on the Industry Results

- **Only 4 industries showed considerable technical progress beyond 2004:**

  (i) Agriculture, Fishing and Forestry; (ii) Financial Services;

  (iii) Retail and (iv) Wholesale

- **Some industries showed little technical progress even earlier than the 2004 peak:**

  (i) Mining (1996); (ii) Electricity (1998); (iii) Information (1999) and

  (iv) Arts (1991).

- **The amount of technical and allocative inefficiency for some industries was huge:**

  (i) Manufacturing; (ii) Mining; (iii) Electricity; (iv) Accommodation

  and (iv) Arts.

- **Some of this inefficiency is probably real and some of it probably indicates mismeasurement of inputs and outputs.**

Conclusions

- We have used a new decomposition of industry value added growth, applied to official, publically available data from the Australian Bureau of Statistics.
- The role of inefficiency proved to be very large for many industries. We think that this result is more reasonable than simply interpreting negative TFP growth as technological regress.
- Our FDH method, with bottom-up aggregation over industries, yields almost identical aggregate TFP estimates as the official statistics. Thus our new methodology will probably not greatly affect national statistical office measures of TFP growth but our interpretation of negative TFP growth being due to inefficiency highlights the important role played by macro economic stability and the avoidance of recessions.
- Our method is easily implementable by National Statistical Offices and provides policy-relevant information on growth and productivity.
- Industries that have huge amounts of inefficiency should be investigated for possible mismeasurement of the underlying inputs and outputs.