Skill-Biased Technical Change and the Cost of Higher Education

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Motivation

The cost of a college degree is a major issue.

- Obama initiatives

In this paper we ask:

- What causes the cost of college to rise?
  - Our answer: Skill- and sector-biased technological change.
The cost of a college degree is a major issue.

- Obama initiatives

In this paper we ask:

- What causes the cost of college to rise?
  - Our answer: Skill- and sector-biased technological change.
- How do higher costs affect educational attainment?
  - Our answer: For our model—and many like it—not much
### Employees per Student

<table>
<thead>
<tr>
<th></th>
<th>1976</th>
<th>1999</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>0.185</td>
<td>0.209</td>
<td>0.186</td>
</tr>
<tr>
<td>Professional staff</td>
<td>0.102</td>
<td>0.134</td>
<td>0.132</td>
</tr>
<tr>
<td>Administrative</td>
<td>0.012</td>
<td>0.014</td>
<td>0.015</td>
</tr>
<tr>
<td>Faculty</td>
<td>0.060</td>
<td>0.067</td>
<td>0.062</td>
</tr>
<tr>
<td>Graduate assistants</td>
<td>0.010</td>
<td>0.009</td>
<td>0.009</td>
</tr>
<tr>
<td>Other professionals</td>
<td>0.020</td>
<td>0.043</td>
<td>0.046</td>
</tr>
<tr>
<td>Non-professional staff</td>
<td>0.084</td>
<td>0.075</td>
<td>0.054</td>
</tr>
</tbody>
</table>

**Note:** All quantities in FTE terms.

**Source:** U.S. Department of Education.

- Providing a college education appears to require a fixed number of workers.
## Education & General Capital

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Capital</th>
<th>Equipment</th>
<th>Structures</th>
<th>Total Capital</th>
</tr>
</thead>
<tbody>
<tr>
<td>1959-60</td>
<td>31.08</td>
<td>4.18</td>
<td>29.08</td>
<td>33.26</td>
</tr>
<tr>
<td>1969-70</td>
<td>30.74</td>
<td>4.39</td>
<td>30.32</td>
<td>34.71</td>
</tr>
<tr>
<td>1975-76</td>
<td>31.48</td>
<td>4.90</td>
<td>32.56</td>
<td>37.47</td>
</tr>
<tr>
<td>1980-81</td>
<td>32.43</td>
<td>5.38</td>
<td>33.21</td>
<td>38.59</td>
</tr>
<tr>
<td>1985-86</td>
<td>31.11</td>
<td>6.28</td>
<td>30.47</td>
<td>36.76</td>
</tr>
<tr>
<td>1990-91</td>
<td>30.88</td>
<td>7.27</td>
<td>29.80</td>
<td>37.07</td>
</tr>
</tbody>
</table>

Note: All quantities in 1,000s of $2005 per FTE.

Source: U.S. Dept. of Education, and authors’ calculations.

- Higher education appears to be getting more capital intensive at only a modest rate.
Why Has the Cost of College Risen?

- “Service sector disease” (Baumol and Bowen, 1966; Baumol, 1967)
- Inefficiency (Bowen, 1980; Harris and Goldrick-Rob, 2010; Martin and Hill, 2013)
- “Arms races” (Hoxby, 1997; Ehrenberg, 2002)
- Our contribution: quantitative, general equilibrium analysis.
Literature Review

- Why Has the Cost of College Risen?
  - “Service sector disease” (Baumol and Bowen, 1966; Baumol, 1967)
  - Inefficiency (Bowen, 1980; Harris and Goldrick-Rob, 2010; Martin and Hill, 2013)
  - “Arms races” (Hoxby, 1997; Ehrenberg, 2002)
  - Our contribution: quantitative, general equilibrium analysis.

- General equilibrium models of human capital accumulation
  - Akyol and Athreya (2005) and Abbot et al. (2013): risky returns, financial aid, etc.
  - Our contribution: endogenize cost of higher education.
How We Proceed

- Wade through the data
- Construct and calibrate a model for the period 1961-2009, matching
  - GDP
  - educational attainment
  - the college earnings premium
  - college costs
  - capital usage in higher education
- Assess the fit and perform some experiments
“Cost” Data (Digest of Education Statistics)

- Distinguish between
  - expenditures (costs)
  - sticker price tuition
  - net tuition

- Expenditures
  - Education and general expenses per FTE
  - Excludes auxiliary enterprises (e.g., dorms), interest payments, and institutional grant aid, includes everything else.
Distinguish between

- expenditures (costs)
- sticker price tuition
- net tuition

Expenditures

- Education and general expenses per FTE
- Excludes auxiliary enterprises (e.g., dorms), interest payments, and institutional grant aid, includes everything else.

Sticker price tuition

- Revenues from tuition and fees per FTE

Net tuition

- Sticker price tuition less grant aid (College Board)
The trend looks similar among: public and private institutions; 2-year and 4-year institutions.

Model fit to data for “4-year” institutions.
Since 1935, the educational attainment of 30-year-olds, however measured, has more than doubled.
College Premium (Bachelors+/High School Ratios)

Earnings

Wages


Earnings

Wages
The Model

- Two sectors: goods; and higher education.

- Goods production

\[ Y_t = A_t K_t^\alpha L_t^{1-\alpha}, \]
\[ L_t \equiv [\omega_t W_t^{1-\zeta} + (1 - \omega_t) B_t^{1-\zeta}]^{1/(1-\zeta)}, \]
\[ K_t : \text{capital}, \]
\[ L_t : \text{composite labor}, \]
\[ W_t : \text{white-collar skill}, \]
\[ B_t : \text{blue-collar skill}. \]

- Skill-neutral \( (A_t) \) and skill-biased \( (\omega_t) \) technical change.
Goods Production

\[ Y_t = A_t K_t^\alpha L_t^{1-\alpha}, \]
\[ L_t \equiv [\omega_t W_t^{1-\xi} + (1 - \omega_t) B_t^{1-\xi}]^{1/(1-\xi)}. \]

- Small open economy with exogenous \( r_t \)
- Competitive, price-taking firms ⇒

\[ r_t + \delta = \alpha \frac{Y_t}{K_t}, \]
\[ w_t^B = (1 - \alpha)(1 - \omega_t) \frac{Y_t}{L_t} \left( \frac{B_t}{L_t} \right)^{-\xi}, \]
\[ w_t^W = (1 - \alpha) \omega_t \frac{Y_t}{L_t} \left( \frac{W_t}{L_t} \right)^{-\xi}. \]
The quantity of skilled labor, $W_t^E$, and capital, $K_t^E$, needed to educate a worker is determined endogenously.

The cost of educating a college student for one year is

$$c_t = \min W_t^E w_t^W + K_t^E (r_t + \delta),$$

s.t.

$$1 = z\left(\kappa (W_t^E)^{1-v} + (1 - \kappa)(K_t^E)^{1-v}\right)^{1/(1-v)},$$

There is capital-labor substitutability

- Estimate IES $(1/v)$ from data.
Workers

- Live 57 years: ages 18-74.
- Endowed with ability level $h$ at age 18: $\ln(h) \sim \mathcal{N}(\mu, \sigma^2)$.
- Can spend first 4 years getting a college degree $\Rightarrow$ become a white-collar worker.
- White-collar skill $= \gamma(h) = \gamma_1(h - \gamma_2)^3$.
  - Shape draws on Heckman, et al. (1998).
- Blue-collar skill $= h$. 
Live 57 years: ages 18-74.
Endowed with ability level $h$ at age 18: $\ln(h) \sim \mathcal{N}(\mu, \sigma^2)$.
Can spend first 4 years getting a college degree $\Rightarrow$ become a white-collar worker.
White-collar skill $= \gamma(h) = \gamma_1(h - \gamma_2)^3$.
Shape draws on Heckman, et al. (1998).
Blue-collar skill $= h$.
At time $t$, age-$a$ workers with ability level $h$ earn

$$y_{h,a,t}^{B} = h \cdot \varepsilon_{a,t}^{B} \cdot w_{t}^{B},$$
$$y_{h,a,t}^{W} = \gamma(h) \cdot \varepsilon_{a,t}^{W} \cdot w_{t}^{W}.$$

$(\varepsilon_{a,t}^{B}, \varepsilon_{a,t}^{W})$ are education-, time- and age-dependent efficiency levels.
Workers receive utility from their consumption streams

\[
\sum_{a=0}^{a_{\text{max}}-1} \beta^a \frac{1}{1-\phi} x_{a,b+a}^{1-\phi},
\]

Blue-collar workers face draft risk:

- incur the expected psychic cost \( \Delta(i_b) = \Delta_1 i_b + \Delta_2 i_b^2 \), where \( i_b \) = induction probability for a man in cohort \( b \).
Enrollment Decision

- Workers receive utility from their consumption streams
  \[
  \sum_{a=0}^{a_{\text{max}}-1} \beta^a \frac{1}{1-\varphi} x_{a,b+a}^{1-\varphi}.
  \]

- Blue-collar workers face draft risk:
  - incur the expected psychic cost \( \Delta(i_b) = \Delta_1 i_b + \Delta_2 i_b^2 \), where \( i_b = \) induction probability for a man in cohort \( b \).

- Student pays \( d_t \cdot c_t \); remainder funded through lump-sum taxes.

- Becoming a white-collar worker requires 4 years of college
  - College students work part-time, can borrow only the fraction \( \chi_1 \) of future earnings,

- Education decision characterized by ability threshold \( h_b^* \).

- The enrollment of cohort \( b \) is \( e_b = 1 - F(h_b^*) \).
Open economy

Population evolves exogenously: at time $t$, the number of age-$a$ workers is $N_{a,t}$.

The education level of people born before time 0 is taken as given.

Find the transition path to the long-run balanced growth path.

- Two-stage estimation
Table 3. Parameters Found without Using the Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Values/Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>${N_{a,t}}$ Demographics</td>
<td>Census Bureau</td>
</tr>
<tr>
<td>${\varepsilon^B_{a,t}, \varepsilon^W_{a,t}}$ Life-cycle efficiency profiles</td>
<td>CPS</td>
</tr>
<tr>
<td>${d_t}$ Net tuition copay rate</td>
<td>Dept. of Education</td>
</tr>
<tr>
<td>${e_b}_{b&lt;1943}$ Education, older cohorts</td>
<td>CPS</td>
</tr>
<tr>
<td>${i_b}$ Military induction risk</td>
<td>Card and Lemieux (2000)</td>
</tr>
<tr>
<td>$\delta$ Capital depreciation rate</td>
<td>0.05, standard</td>
</tr>
<tr>
<td>$\beta$ Discount factor</td>
<td>0.97, standard</td>
</tr>
<tr>
<td>$\alpha$ Capital share in production</td>
<td>0.3, standard</td>
</tr>
<tr>
<td>$\varphi$ 1/(coefficient of RRA)</td>
<td>2, standard</td>
</tr>
<tr>
<td>$\tau$ Income tax rate</td>
<td>0.2 $\approx$ average $G/Y$</td>
</tr>
<tr>
<td>$\zeta$ 1/(skill substitutability)</td>
<td>0.7, Heckman et al. (1998a)</td>
</tr>
<tr>
<td>$\chi_0$ Fraction of time students spend working</td>
<td>0.5</td>
</tr>
<tr>
<td>${r_t}$ real interest rates</td>
<td>National accounts,</td>
</tr>
<tr>
<td>$g_A$ TFP growth rate</td>
<td>0.75%, Jorgenson and Yip (2001)</td>
</tr>
<tr>
<td>$A_{1960}$ Logged initial TFP level</td>
<td>1, normalization</td>
</tr>
</tbody>
</table>
### Parameters Estimated inside the Model

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Baseline</th>
<th>No Borrowing Constraint</th>
<th>No Induction Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma_1$</td>
<td>skill prod. func., cubic weight</td>
<td>0.0052</td>
<td>0.0052</td>
</tr>
<tr>
<td>$\gamma_2$</td>
<td>cubic shifter in skill prod. func.</td>
<td>7.278</td>
<td>7.237</td>
</tr>
<tr>
<td>$\mu$</td>
<td>mean of log ability</td>
<td>3.399</td>
<td>3.397</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>standard deviation of log ability</td>
<td>0.1676</td>
<td>0.1696</td>
</tr>
<tr>
<td>$\iota_0$</td>
<td>evolution of $\omega$, intercept</td>
<td>$-2.530$</td>
<td>$-2.595$</td>
</tr>
<tr>
<td>$\iota_1$</td>
<td>evolution of $\omega$, trend</td>
<td>0.0960</td>
<td>0.0999</td>
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<tr>
<td>$\iota_2$</td>
<td>upper bound on $\omega$</td>
<td>0.4728</td>
<td>0.4648</td>
</tr>
<tr>
<td>$\iota_3$</td>
<td>shift parameter for $\omega$</td>
<td>0.1535</td>
<td>0.1557</td>
</tr>
<tr>
<td>$\upsilon$</td>
<td>1/IES, education prod. function</td>
<td>3.551</td>
<td>3.557</td>
</tr>
<tr>
<td>$\kappa$</td>
<td>input weight, education prod.</td>
<td>$9.78 \times 10^{-8}$</td>
<td>$9.57 \times 10^{-8}$</td>
</tr>
<tr>
<td>$z$</td>
<td>education productivity level</td>
<td>$-9.969$</td>
<td>$-9.970$</td>
</tr>
<tr>
<td>$\chi_1$</td>
<td>borrowing constraint</td>
<td>0.0782</td>
<td>1</td>
</tr>
<tr>
<td>Parameters</td>
<td>Baseline</td>
<td>No Borrowing Constraint</td>
<td>No Induction Cost</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>----------</td>
<td>-------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>$\Delta_1$ induction cost, linear term</td>
<td>0.0017</td>
<td>0.0017</td>
<td>0</td>
</tr>
<tr>
<td>$\Delta_2$ induction cost, quadratic term</td>
<td>$-0.0111$</td>
<td>$-0.0113$</td>
<td>0</td>
</tr>
<tr>
<td>GMM criterion</td>
<td>0.6012</td>
<td>0.6014</td>
<td>0.7090</td>
</tr>
</tbody>
</table>
Model Fit

star: data; dotted line: model

mean earnings ratio
enrollment at age 18
real output in log ($2005)
cost per student in log ($2005)
real K in college in log ($2005)
Table 5. Effects of parameter changes

<table>
<thead>
<tr>
<th></th>
<th>$y$ (1)</th>
<th>$c$ (2)</th>
<th>$c/y$ (3)</th>
<th>MER (4)</th>
<th>$e$ (5)</th>
<th>$w^W / w^B$ (6)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961 values: full model</td>
<td>29.0</td>
<td>9.80</td>
<td>0.338</td>
<td>2.17</td>
<td>0.201</td>
<td>1.00</td>
</tr>
<tr>
<td>2010 values: full model</td>
<td>64.9</td>
<td>26.93</td>
<td>0.415</td>
<td>2.44</td>
<td>0.346</td>
<td>2.51</td>
</tr>
<tr>
<td>Skill weight ($\omega_t$)</td>
<td>70.8</td>
<td>22.47</td>
<td>0.317</td>
<td>1.89</td>
<td>0.089</td>
<td>1.60</td>
</tr>
<tr>
<td>TFP ($A_t$)</td>
<td>37.9</td>
<td>16.89</td>
<td>0.445</td>
<td>2.48</td>
<td>0.349</td>
<td>2.53</td>
</tr>
<tr>
<td>Co-pay rate ($d_t$)</td>
<td>64.9</td>
<td>26.94</td>
<td>0.415</td>
<td>2.44</td>
<td>0.348</td>
<td>2.51</td>
</tr>
<tr>
<td>Earnings ($\varepsilon_{a,t}^B, \varepsilon_{a,t}^W$)</td>
<td>65.6</td>
<td>24.29</td>
<td>0.370</td>
<td>2.38</td>
<td>0.361</td>
<td>2.03</td>
</tr>
<tr>
<td>Population ($N_{a,t}$)</td>
<td>64.4</td>
<td>26.93</td>
<td>0.418</td>
<td>2.43</td>
<td>0.344</td>
<td>2.51</td>
</tr>
<tr>
<td>Interest rate ($r_{a,t}$)</td>
<td>60.8</td>
<td>25.53</td>
<td>0.420</td>
<td>2.45</td>
<td>0.343</td>
<td>2.52</td>
</tr>
</tbody>
</table>

Note:

$y$: GDP per capita, thousands of $2005$
$c$: College expenditures per student, thousands of $2005$
MER: Mean earnings ratio
$e$: fraction of 18-year-olds enrolled in (and completing) college
$w^W / w^B$: Skill premium = relative wages, normalized by 1961 value.
Higher costs and enrollment

Figure: Enrollment when college expenditures are fixed at 1961 values

- Partial equilibrium effects bigger than general equilibrium effects.
- All effects are modest.
Tuition Elasticities

- Increase the co-pay rate by 10 percentage points over the years 1961-64.
- Enrollment is not sensitive to price ($d$): partial equilibrium elasticity: $\epsilon_d = 0.073$.
- Consistent with time series evidence:
  - Large increase in college premium, smaller increase in enrollment.
  - Estimated borrowing constraint is loose.
- Athreya and Eberly (2013): partial equilibrium elasticity of 0.089.
- Studies from Micro-level policy interventions also suggest modest elasticities.
  - Dynarski (2003) finds that an additional $1,000 in aid (2000 dollars) increased the probability of attendance by 3.6 percentage points: back-of-the-envelope calculations suggest that $\epsilon_d = 0.140$.
  - Dynarski argues this is a typical finding.
Conclusions

- We construct a model with skill- and sector-biased technological change.
- Our model is able to match observed changes in
  - GDP
  - educational attainment
  - college earnings premium
  - college costs
  - higher education capital usage
- Our model finds that the long-run responses to tuition changes are small.
  - Consistent with micro literature and historical trends.
Since WWII, expenditures per student and net tuition have grown at the same rate as per capita GDP.

Sticker price tuition has grown faster than GDP.
Sticker Price Tuition Relative to GDP

Fraction of per worker GDP


Private Private, Non-Profit Private, For-Profit
Public Public, 4-year Public, 2-year
Equilibrium Defined

An equilibrium consists of sequences of: capital and labor inputs \( \{ K_t, W_t, B_t, K^E_t, W^E_t \} \), wage rates \( \{ w^B_t, w^W_t \} \), costs \( \{ c_t \} \), and skill thresholds \( \{ h^*_t \} \) such that:

- Given \( \{ r_t, w^B_t, w^W_t, c_t \} \), \( \{ h^*_t \} \) is optimal.
- The price of each factor equals its marginal product.
- Colleges earn no profits.
- All labor markets clear:

\[
W_t = \sum_{a > 3} N_{a,t} \varepsilon^W_{a,t} \int_{h > h^*_{t-a}} \gamma(h) \, dF(h) - E^W \sum_{a \leq 3} N_{a,t} e_{t-a},
\]

\[
B_t = \sum_a N_{a,t} \varepsilon^B_{a,t} \int_{h < h^*_{t-a}} h \, dF(h).
\]
Extending Carneiro and Lee (2011), find profiles by estimating

\[
\ln(\tilde{y}_{a,t}^B) = \xi_0^B + \xi_1^B a + \xi_2^B a^2 + \xi_3^B a^3 + \xi_4^B t \cdot a + \xi_5^B t \cdot a^2 + \xi_6^B t_2 \cdot a + \xi_7^B t_2 + \xi_1^B e_b + \xi_2^B e_b^2 + \xi_3^B e_b^3 + \xi_4^B e_b^4 + \sum_u \lambda_u^B \cdot 1\{t = u\} + \eta_{a,t}^B,
\]

where \( t_2 = \max\{t - 1990, 0\} \). Terms on first line are our estimate of \( \{\xi_{a,t}^B\} \).
Estimation Procedure

- Let $x_{mt}$ denote an observation of type $m$, $m \in \{\text{educational attainment, GDP, earnings premium, college costs, college capital usage}\}$, in year $t$, $t \in \{1961, \ldots, 2009\}$.
- Each $x_{mt}$ is a time series realization.
- The model-predicted value of $x_{mt}$ is $f_{mt}(\theta)$, where $\theta$ is the parameter vector we wish to estimate.
- Our estimate of the population value of $\theta$, $\hat{\theta}$, solves

$$
\min_{\theta} \sum_{t=1}^{T} \sum_{m=1}^{M} \left( \frac{f_{mt}(\theta)}{x_{mt}} - 1 \right)^{2}.
$$

- Assume the ratio $f_{mt}(\theta)/x_{mt}$ is stationary and ergodic.
- Asymptotic properties of $\hat{\theta}$ follow standard GMM arguments.
Alternative Theories

- Our model fits the data very well. Might there be alternative explanations?
Alternative Theories

- Our model fits the data very well. Might there be alternative explanations?

- Inefficiency
  - Between 1959 and 2009, E&G costs rose 165%: that would be a big increase in inefficiency.
  - Evidence of competition: importance of rankings; increase in enrollment.
Our model fits the data very well. Might there be alternative explanations?

Inefficiency

- Between 1959 and 2009, E&G costs rose 165%: that would be a big increase in inefficiency.
- Evidence of competition: importance of rankings; increase in enrollment.

Alternative services such as research and student support

- Disentangling costs is problematic.
- Between 1959 and 2009, E&G costs rose 165%, instructional costs rose 156%.
- Between 1980 and 2009, E&G costs rose 85% at 4-year schools, 53% at community colleges.
Alternative Theories (cont.)

“Arms wars”

- Probably occurring in private non-profit sector.
- Private non-profits are just a fraction of the industry.
- Growth of for-profit sector has restrained average costs.

### Education & General Costs Relative to GDP

<table>
<thead>
<tr>
<th>Year</th>
<th>Private</th>
<th>Private, Non-Profit</th>
<th>Private, For-Profit</th>
<th>Public</th>
<th>Public, 4-year</th>
<th>Public, 2-year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1975</td>
<td>10%</td>
<td></td>
<td></td>
<td>15%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1980</td>
<td>15%</td>
<td></td>
<td></td>
<td>20%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>20%</td>
<td></td>
<td></td>
<td>25%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>25%</td>
<td></td>
<td></td>
<td>30%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1995</td>
<td>30%</td>
<td></td>
<td></td>
<td>35%</td>
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<tr>
<td>2000</td>
<td>35%</td>
<td></td>
<td></td>
<td>40%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2005</td>
<td>40%</td>
<td></td>
<td></td>
<td>45%</td>
<td></td>
<td></td>
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<tr>
<td>2010</td>
<td>45%</td>
<td></td>
<td></td>
<td>50%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2015</td>
<td>50%</td>
<td></td>
<td></td>
<td>55%</td>
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</tr>
</tbody>
</table>

Jones and Yang

Higher Education Costs

Nov. 23 2014
Increased value added (Bowlus and Robinson, 2012)

- Increased spending has increased student learning
- Can explain increased college premium
- Not inconsistent with service sector disease
Increased value added (Bowlus and Robinson, 2012)

- Increased spending has increased student learning
- Can explain increased college premium
- Not inconsistent with service sector disease
- External evidence of increased value added is scarce:
  - lower hours of study (Babcock and Marks, 2010)
  - grade inflation (Babcock, 2010)
  - poor outcomes (Arum and Roksa, 2011)