Inequality and Demand-Driven Innovations: Evidence from International Patent Applications

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Introduction

- Income and wealth inequality have been rising in many developed countries (Piketty, 2014)
- At the same time, productivity growth has slowed down
  - Gordon (2016) attributes it to decreasing returns to innovation
- Research question: How does inequality affect the incentives to innovate by affecting the demand for new goods?
- Motivating stylized fact: richer households purchase a larger variety of goods than poorer ones (Jackson, 1984; Falkinger and Zweimüller, 1996)
  - Also holds for selected “innovative goods” more here
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Overview

• **This paper**: Model with non-homothetic preferences (based on Föllmi and Zweimüller, 2016) in which richer households purchase a larger variety of goods than poorer ones.

• **Market size effect**: how many households purchase a new good?

• **Price effect**: how high is the willingness to pay of a household for a new good?

• **Main results**:
  • Inequality is more likely to encourage innovation when the size of the population is large (for a given total income).
  • Inequality is more likely to discourage innovation when innovations become more incremental (easily substitutable).

• Extend model to study **patent subsequent filings in multiple countries** and show that they depend in the same qualitative way on inequality in the destination countries as innovation depends on inequality in the basic model.
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Empirical Analysis

- **Challenge**: In a globalized economy, incentives to innovate not only depend on local market conditions and local inequality, but also on foreign demand.

- **Empirical strategy**: Using data from PATSTAT, we analyze how **patent flows** towards a country depend on inequality in this country
  - Innovator with registered priority filing likely only files for subsequent patent protection in a country if corresponding market profitable enough to justify paying fixed costs of subsequent filing.

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Related Literature

Theory of demand-induced innovations:

- Föllmi and Zweimüller (2006, 2016): market size and price effects
  - inconclusive about effect of inequality on innovation; no theory about conditions under which market size or price effects dominate

Empirical studies:

- Jaravel (2017); Beerli, Weiss, Zilibotti and Zweimüller (2014)
- Aghion et al. (forthcoming): effect of innovation on inequality
- Several papers about relation between inequality and growth
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The effect of inequality on innovation

Proposition 1
An increase in inequality is more likely to increase the number of innovations $N$ (and less likely to decrease $N$) the larger the size of the population $L$ the smaller total income $Y$ is.

Intuition: Free entry condition: $(\text{Price-marginal cost})(\text{market size})=F$
- When $L$ increases, a firm charging a given price needs to sell to a lower fraction of households in order to break even
- When innovations become more incremental due to a rise in $Y$, innovators have to charge lower prices and need to sell to more households in order to break even.
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International Context

- There are many countries and two types of fixed costs:
  - **Inventing** a good costs $R$ (in any country)
  - Obtaining **patent protection** in country $s$ and transferring a technology to country $s$ costs $F_s$.

**Proposition 2**

The aggregate patent flow $Q_{ikl}$ is more likely to increase (and less likely to decrease) in the level of inequality $I_l$ in country $l$ the larger the population size $L_l$ and the lower total income $Y_l$ is.
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- Patents with priority years 1980-2014 (about 4 Mio.), covering 52 patent offices (EU27 + OECD + BRICS)
- Priority and subsequent filings comprise PCT, Paris Convention, and regional applications at the EPO and were extracted from Patstat (Rassenfosse et al., 2013)
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Explanatory Variables

- **Inequality**: GINI pre- and post-tax (SWIID; Solt 2016), top-10%, -5%, and -1% income shares (WID; Piketty et al.)
- Measures of population and real GDP from IMF and WDI
- Measure of patent protection: Ginarte-Park-Index (latest version available until 2010), linear interpolation to obtain yearly data (original data: 5-year intervals)
- **Further controls**: Distance, common language, relative economic size of a country, relative trade openness
- Missing value imputation
Estimation

Theoretically induced hypotheses

- Positive interaction of inequality with population size (in destination)
- Negative interaction of inequality and GDP (in destination)

Econometric Specification

- Quasi-Poisson model
- Fixed effects for origin $k$, destination $l$, time $t$, and industry $i$

Model details here
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Econometric Specification

- Quasi-Poisson model
- Fixed effects for origin $k$, destination $l$, time $t$, and industry $i$
Aggregate International Priority and Subsequent Filings from 1980–2013
Average Inequality over Time

Gini post-tax

Gini pre-tax

Top-10% income-share

Top-5% income-share

Top-1% income-share

Legend:
- country-average
- high-income countries (World-Bank)
- low- and high-middle income countries (World-Bank)
- fitted values (local polynomial regression)
- 95%-two-sided CIs
- average EU-28
Average GDP and Population over Time

- **GDP p.c. (thousands; real PPP)**
  - country-average
  - high-income countries (World-Bank)
  - low- and high-middle income countries (World-Bank)
  - fitted values (local polynomial regression)
  - 95%-two-sided CIs
  - average EU-28

- **GDP (billions; real PPP)**

- **Population (millions)**
## Results: Country-Pair-Year Aggregate Data

<table>
<thead>
<tr>
<th>Inequality measure:</th>
<th>Gini post-tax</th>
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<th>Top-10% income-share</th>
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</tr>
</thead>
<tbody>
<tr>
<td>log(POP_{lt})*INEQUALITY_{lt}</td>
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<td>4.56***/***</td>
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<td>-7.86**/</td>
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<td>3.26***/***</td>
<td>2.91***/***</td>
<td>2.31***/***</td>
</tr>
</tbody>
</table>

Note: Estimation sample covers 46,069 country-pair-year observations. The dependent variable is aggregate patent-flows from country $k$ to country $l$ in year $t$. Estimation results derived from Quasipoisson regression with unconditional fixed-effects for origins, destinations, and years.

[(1)/(2)] inference based on (1) clustering on country-pair and on (2) three-way-clustering on origins, destinations, and years. ***, **, * indicate significance at 0.01, 0.05, and 0.1, respectively.
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<td>(\log(POP_{lt}))*INEquality_{lt} (\uparrow) (\downarrow)</td>
<td>5.86***/***</td>
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<td>7.24***/***</td>
<td>9.34***/**</td>
<td>12.34***/**</td>
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<td>-10.12***/***</td>
<td>-9.39***/**</td>
<td>-11.42***/**</td>
<td>-14.17***/**</td>
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<td>INEquality_{lt} (\uparrow) (\downarrow)</td>
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<td>40.02***/***</td>
<td>44.76***/**</td>
<td>52.70***/**</td>
<td>60.14***/**</td>
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<td>-8.36***/***</td>
<td>-7.64***/**</td>
<td>-7.26***/**</td>
<td>-6.42***/**</td>
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<td>(\log(GDP_{lt})) (\uparrow) (\downarrow)</td>
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<td>5.80***/**</td>
<td>4.66***/**</td>
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<td>9.48***/***</td>
<td>9.86***/**</td>
<td>9.68***/**</td>
<td>9.29***/**</td>
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<tr>
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<td>-0.43/*</td>
<td>-0.47/*</td>
<td>-0.49/*</td>
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<td>GP-INDEX_{lt} (\uparrow) (\downarrow)</td>
<td>0.27***/***</td>
<td>0.24/***</td>
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<tr>
<td>(\text{log}(\text{PO}P_{it})) (*\text{INEQUALITY}_{it})</td>
<td>3.66***/**</td>
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<td>1.97***/</td>
<td>3.06***/</td>
<td>3.88***/</td>
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<td>(\text{log}(\text{GDP}<em>{it})) (*\text{INEQUALITY}</em>{it})</td>
<td>-4.79***/***</td>
<td>-7.11***/***</td>
<td>-4.50***/</td>
<td>-5.72***/</td>
<td>-6.76***/</td>
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<tr>
<td>(\text{INEQUALITY}_{it})</td>
<td>15.29***/**</td>
<td>30.55***/***</td>
<td>28.00***/***</td>
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<td>8.96***/***</td>
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<td>( \log(GDP_{it}) \text{INEQUALITY}_{it} )</td>
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<td>-9.42***/***</td>
<td>-8.60***/***</td>
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<tr>
<td>( \text{GP-INDEX}_{lt} )</td>
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<tr>
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<tr>
<td>(\log(POP_{it}))*INEQUALITY_{it})</td>
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<td>1.90***/\</td>
<td>2.92***/\</td>
<td>3.72***/\</td>
</tr>
<tr>
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<td>-5.16***/\</td>
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<tr>
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<td>26.44***/***</td>
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<td>32.77***/\</td>
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<tr>
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<td>-3.74***/\</td>
<td>-3.50***/***</td>
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<tr>
<td>(\log(GDP_{it}))</td>
<td>3.27***/***</td>
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<td>2.76***/\</td>
<td>2.50***/\</td>
<td>2.02***/\</td>
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Note: Estimation sample covers 1,913,365 observations. The dependent variable is aggregate patent-flows in sector \(i\) from country \(k\) to country \(l\) in year \(t\). Sectors are measured by SITC Rev.2 2-digit codes. Estimation results derived from Quasipoisson regression with unconditional fixed-effects for sectors, origins, destinations, and years. Inference based on (1) clustering on sector and on (2) four-way-clustering on sectors, origins, destinations, and years. ***, **, and * indicate significance at 0.01, 0.05, and 0.1, respectively.
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<td>8.90***/***</td>
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<td>(\text{RELSIZ}_{klt})</td>
<td>8.09***/***</td>
<td>9.14***/***</td>
<td>9.52***/***</td>
<td>9.44***/***</td>
<td>9.01***/***</td>
</tr>
<tr>
<td>(\text{RELTRADEOPEN}_{klt})</td>
<td>-0.49***/</td>
<td>-0.39***/</td>
<td>-0.38***/</td>
<td>-0.40***/</td>
<td>-0.41***/</td>
</tr>
<tr>
<td>(\text{COMLANG}_{kl})</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
<td>0.01</td>
</tr>
<tr>
<td>(\log(DIST_{kl}))</td>
<td>0.19***/ ***</td>
<td>0.19***/ ***</td>
<td>0.19***/ ***</td>
<td>0.19***/ ***</td>
<td>0.19***/ ***</td>
</tr>
<tr>
<td>(\text{GP-INDEX}_{lt})</td>
<td>0.23***/ **</td>
<td>0.22***/</td>
<td>0.18***/</td>
<td>0.19***/</td>
<td>0.20***/</td>
</tr>
</tbody>
</table>

Note: Estimation sample covers 1,913,365 observations. The dependent variable is aggregate patent-flows in sector \(i\) from country \(k\) to country \(l\) in year \(t\). Sectors are measured by SITC Rev.2 2-digit codes. Estimation results derived from Quasipoisson regression with unconditional fixed-effects for sectors, origins, destinations, and years. \(^{(1)}/(2)\) inference based on (1) clustering on sector and on (2) four-way-clustering on sectors, origins, destinations, and years. ***, **, and * indicate significance at 0.01, 0.05, and 0.1, respectively.
Conclusions

- Model and empirical results indicate that inequality is more likely beneficial for innovation the larger the population, and the less substitutable the marginal innovation is (more likely for low GDP)

- **Implications:** (1) Secular stagnation (running out of valuable innovations) makes it more likely that inequality is bad for innovation, (2) population growth has the opposite effect, and (3) how a redistribution of income or wealth affects innovation depends on the relative importance of both effects (in addition to direct incentive effects)
Differences in consumption pattern

Innovative Goods Variety by Expenditure Group, 2012

Data from US consumer expenditure survey (CEX, INTR). 61 out of over 600 goods were classified as “innovative” (e.g. computers, digital audio players, new cars...). The number of “innovative” goods is defined as the number of these selected goods of which a household has purchased at least one unit in 2012.
Model Setup (closed economy)

- **Utility** of household $i$:

$$U_i = f(C_i) + G_i$$

- $C_i = \int_{j=0}^{N} c_{ij} dj$: variety of **innovative goods** consumed ($N$: measure of invented innovative goods).

- **Assumptions**: $c_{ij} \in \{0; 1\}$; $\frac{\partial f(C)}{\partial C} > 0$; $\frac{\partial^2 f(C)}{\partial C^2} < 0$; and $\frac{\partial f(C)}{\partial C}\bigg|_{C=0} = 1$

- $G_i$: quantity of **non-innovative goods** consumed

- **Production**:
  - Producing one unit of an innovative (non-innovative) good requires $c$ ($\Omega > c$ ) units of labor
  - Inventing an innovative good requires $F$ units of labor
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- Inventing an innovative good requires $F$ units of labor
Market Structure and Distribution

- Innovations are granted patents; technologies for non-innovative goods are in public domain.
- Labor markets are competitive; free entry into R&D.
- Timing: $t = 0$: innovation; $t = 1$: production and consumption
- Total labor endowment (in efficiency units): $Y$; Size of population: $L$
- Labor endowment of household $i$: $y_i = \theta_i \frac{Y}{L}$
  - $\theta_i$ distributed with density $g(\theta)$ (cumulative density $G(\theta)$).
Equilibrium

- Innovative good $j$ sold at price $p(j)$ and non-innovative goods at price $\Omega$.
- Households purchase all goods where the prices lie below their willingness to pay.
- $p(j) < \Omega$ holds in equilibrium and only households of type $\theta_i > \hat{\theta}$ that are rich enough to purchase all innovative goods also purchase non-innovative goods.
- As non-innovative goods are substitutes to innovative goods, innovators are constrained in their price setting power.
  - Results are similar in an extended model with non-innovative basic need goods.
Solving the Model

• **Profits** of firm selling at price $p(\theta)$ to all households with $\theta_i > \theta$:

$$\pi(\theta) = (p(\theta) - c) L(1 - G(\theta))$$

• **Free entry** ($\pi(\theta) = F$) implies: $p(\theta) = c + \frac{F}{L(1 - G(\theta))}$

• For the threshold $\hat{\theta}$, above which households start purchasing non-innovative goods, $p(\hat{\theta}) = z(\hat{\theta}) = \Omega \frac{\partial f(C(\hat{\theta}))}{\partial C(\hat{\theta})}$ and $C(\hat{\theta}) = N$ must hold. This gives the free entry condition:

$$\left(\Omega \frac{\partial f(N)}{\partial N} - c\right)L(1 - G(\hat{\theta})) = F \quad (1)$$

• From the budget constraint of household $\hat{\theta}$

$$(y(\hat{\theta}) = \hat{\theta} \frac{Y}{L} = \int_{j=0}^{N} p_j \, dj),$$

we can derive:

$$N = C(\hat{\theta}) = \frac{Y}{L} \int_{s=0}^{\hat{\theta}} \frac{1}{p(s)} \, ds = \frac{Y}{L} \int_{s=0}^{\hat{\theta}} \frac{L(1 - G(s))}{cL(1 - G(s)) + F} \, ds \quad (2)$$
Econometric Specification

- **Aim** is to estimate a conditional expectation for the aggregate variable

\[ \mathbb{E}(Q_{jkl} | c_{jkl} \in C_{jkl}) = g(\eta_{jkl}) \] with

\[ \eta_{jkl} = \delta_j + \delta_k + \delta_l + \delta_t + z_{jkl}^T \gamma + x_{lt}^T \beta \] where

- \( Q_{jkl} \) are aggregated filings with SITC codes \( j \) subsuming single filings \( i \) and summing over all \( ikl \) constellations for each fixed \( klt \) with \( i \in j \)
- \( \delta_k, \delta_l, \delta_j, \delta_t \) are fixed effects
- \( x_{lt} \) containing the variables of interest, namely Inequality*log(POP), Inequality*log(GDP)
- \( z_{jkl} \) containing further control variables

- Robust estimation with Quasi-Poisson model (QMLE results apply, even if conditional distribution of the dependent variable is misspecified)
Robustness of Results

- Using one-dimensional FE estimators for the Poisson model (independence over time!) with a FE for country pairs for the aggregate analysis, and a FE for each combination of origin-destination-sector yields qualitatively and quantitatively highly similar results.

- Results robust when using linear regression of log(depvar) or other glm estimators

- Robust to including further bilateral characteristics, measures of FDI, gross national savings, ...