# Online Appendix: Not for Publication

Global Drug Diffusion and Innovation with the Medicines Patent Pool

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## Appendix A: Data Construction

This appendix provides more details concerning how I construct the analytical samples. I describe the process of compiling the data for diffusion and innovation analyses. In addition, I provide more information on certain generic data products generated in this process.

A.1 Drug-country-year panel of HIV drug access

The *Price and Quality Reporting Data* provide information on procurement transactions made by Global Fund-supported programs.[1] Starting from the raw data, I follow the data caveats document and drop clearly duplicated transaction records. At the country-level, I construct a listing file with all countries in the dataset and assign the appropriate International Organization for Standardization (ISO) three-digit alphabetical country code. This procedure guarantees that a country will be consistently treated regardless of the variation in spelling (e.g., "Viet Nam" vs. "Vietnam"; "DR Congo" vs. "Congo (Democratic Republic)") and facilitates data merging across different datasets. I also drop the redundant regional-level summary data (e.g., "Western Asia" and "World").

At the firm level, I unify manufacturing firm names to correct inconsistency induced by different spellings (e.g., "Cipla" vs. "Cipla Ltd." vs. "Cipla Inc."). I assign a transaction-level indicator for generic drugs if the drug is purchased from a generic manufacturer. At the drug level, I focus on generic names (international names of compounds within a drug), given that branded names vary across countries, depending partly on trademark registration. For drugs with multiple compounds, I unify the order of compounds within the drug to avoid over-counting of drug varieties; corresponding adjustments are then applied to all variables that are order-sensitive, such as milligram (mg) strength for each compound within a drug. For each drug in my database, I collect standard U.S. adult daily doses from FDA, AIDS*info*, and WHO, and I report the information in Appendix III (the medical appendix) Table A2.[2]

I calculate the percentage of generic transactions by dividing the number of transactions made with generic manufacturers for a country and a given drug in a year by the total number of

[1] Available at https://www.theglobalfund.org/en/sourcing-management/price-quality-reporting//. Data last accessed in 8/2018, when I request all available yearly data by 2017 from the online system. The data request system has been updated in 2019 and requires additional conversion from Tableau files.

[2] I focus on U.S. standard adult daily doses for two practical reasons. First, although it is ideal to collect country-specific dosing standards, it is practically impossible to collect this data across over 100 countries. Second, adult doses are more standard and comparable compared to pediatric doses that depend on age and weight. Realizing the caveats, I also use a quantity-free percentage of transaction measure.

transactions made at the same country for the same drug in the same year. I then calculate the percentage of generic quantity purchases following the same idea. Since different drug products may have different strengths (e.g., "10mg/mL", "300 mg"), I calculate the effective strength for each smallest unit – the stock keeping unit (SKU). I then calculate the total strength supplied in a transaction by multiplying strength per SKU with the number of SKUs in a pack and the number of packs. The percentage of quantity ordered is calculated as the number of patient-years supplied by generic manufacturers for a drug-country-year to the total patient-years purchases for the same drug-country-year. Finally, for product variety purchases, I count the number of unique drug-formulation (strength-dosage form)–manufacturer combinations in a country-year.

In the compound-country-year level analysis, I aggregate compound-specific information from multi-compound drugs into country-year levels. For example, I calculate the numbers of generic and total transactions related to a given compound in a country-year. I then reshape the data to the compound-country-year level and divide the two to get the percentage of generic transactions for a compound in a country-year. The same logic follows for other procedures.

A.2 Compound-year panel of HIV clinical trials

Clinical trials data are available from clinicaltrials.gov, the largest peer-reviewed clinical trials registry in the world and the most widely used by scientists. This U.S.-based trial registry accepts trial registration globally, particularly as multi-national companies typically conduct trials in multi-country clinical sites.[3] Each clinical trial has a unique identifier (i.e., an NCT number) and a set of data recorded and updated periodically.[4] Researchers can typically use Medical Subject Headings (MeSH) terms in the programming processes to pinpoint trials for specific disease conditions, but such processes are not always accurate to locate specific drugs. Therefore, I obtain compound-specific NCT numbers from AIDS*info* to identify HIV-related trials. I collect NCT numbers for all FDA-approved HIV drugs and investigational HIV drugs.

To keep a comprehensive record, I create a variable to store values for each trial based on the compound references in AIDS*info*. For trials referenced in AIDS*info* by brand names, I assign the associated generic name to unify the record. The number of new trials initiated for a compound-year is calculated based on the trial starting date reported and verified in the database.

[3] Researchers can retrieve a zipped file with all trials included in XML format or request certain trials with advanced search options. The site has been updated over time and users are recommended to check the latest XML schema and/or data request options (data last accessed: 11/2018).
[4] A descriptive webpage with data element definitions and mandatory information disclosure requirement in trials is available at: https://prsinfo.clinicaltrials.gov/definitions.html.

For each trial, I calculate the number of distinct firms collaborating in the trial. I then calculate the number of firms participating in a compound-year by computing the total number of firms collaborating in trials on a given compound in a year. This value captures the intensive margin of firms' trial participation on the compound-year level, including a firm's multiple participations across trials. For investigational trials, there are no generic names to facilitate unification, so I further collect the associated drug classes (mechanisms of action) for related aggregation.

A.3 Drug-year and compound-year panel of HIV drug product approvals

From the Drugs@FDA online database, I request "All Approvals by Month" (approvals, tentative approvals, and supplements) and append the data.[5] To pinpoint all approvals for HIV drugs, I convert the "active ingredients" variable all to lower-case and perform a text match, keeping the records if the active ingredients of a drug include any compounds used in HIV treatment. Next, I subset the most relevant approvals—original approval of a drug product produced by a firm (submission code "ORIG-1") instead of supplements to approved applications (submission code including "SUPPL"). As a final check to avoid over-inclusion, I drop a few records of drugs approved for hepatitis C treatment with antiretroviral compounds. Following the same logic, I then clean the WHO pre-qualification program—the other largest drug approval and qualification agency.[6] The list is comprehensive and relatively clean. The other steps follow the same logic and process as described above.

One must be cautions in calculating the period between the first-ever approval of a drug and its follow-on approvals, either cumulative innovation or straightforward imitation. For standalone drugs with a single compound, each compound has a unique date for its first-ever approval. For drug cocktails, I calculated a first-ever technically feasible date as the date all the underlying compounds are approved in any format. I also record the first actual approval dates for cocktails with existing compounds. These approval dates can help us understand follow-on innovation in multiple respects: approvals of new cocktails and formulations *versus* imitations.

[5] Available at: https://www.accessdata.fda.gov/scripts/cder/daf/. Note there are other ways to obtain the underlying data that involve merging across segmented files. I use this conservative data request method due to the lack of detailed instruction concerning alternatives. Last accessed: 1/20/2019.
[6] Available at https://extranet.who.int/prequal/content/prequalified-lists/medicines.

## Appendix B: Figures and Tables

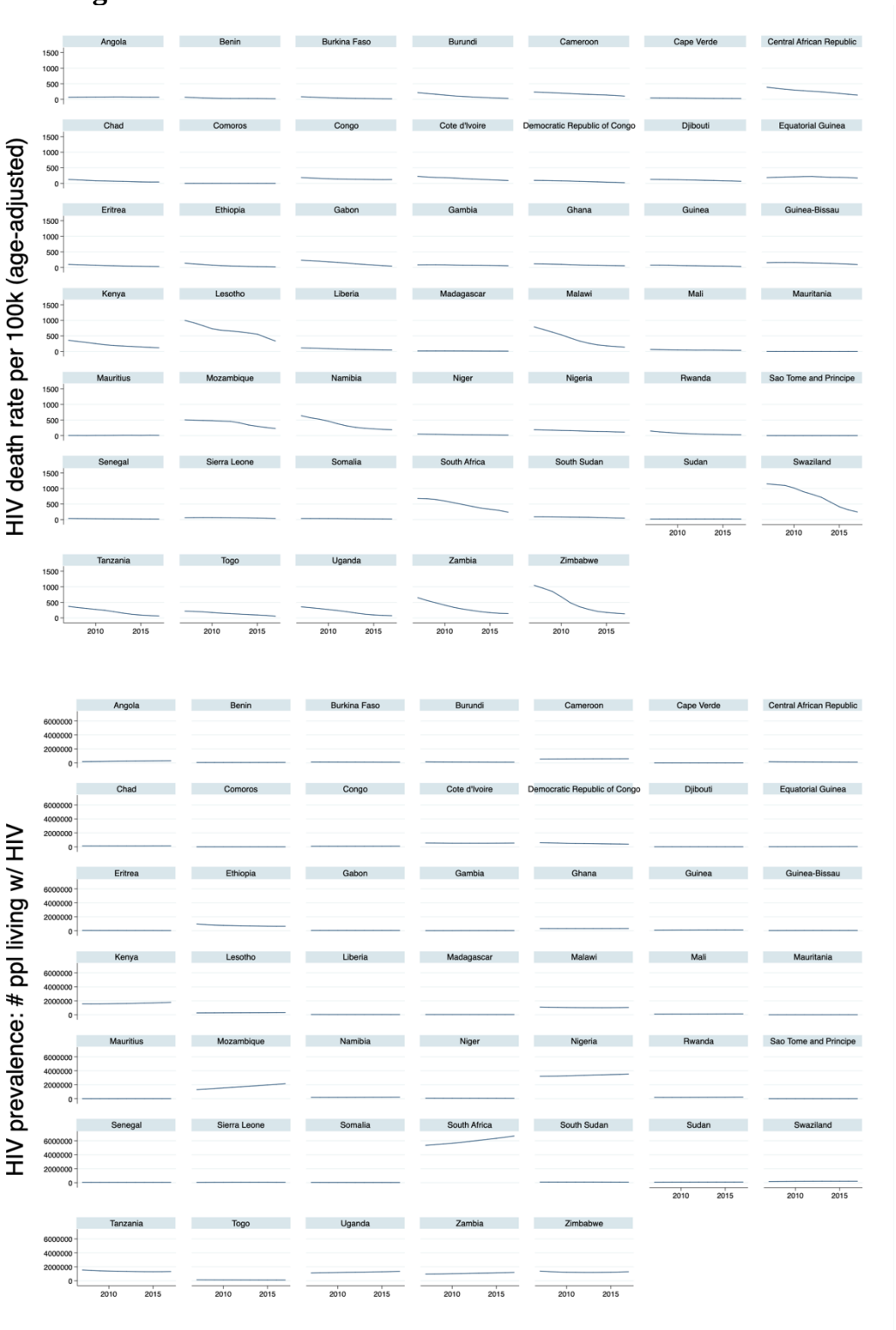



Figure B1: HIV death rate and prevalence, across MPP common territories

Notes: This figure visualizes age-adjusted HIV death rates (per 100k population) and HIV prevalence in MPP common sales territory. In particular, there are no disease-related events generating exogenous shocks to HIV/AIDS mortality during my sample period.

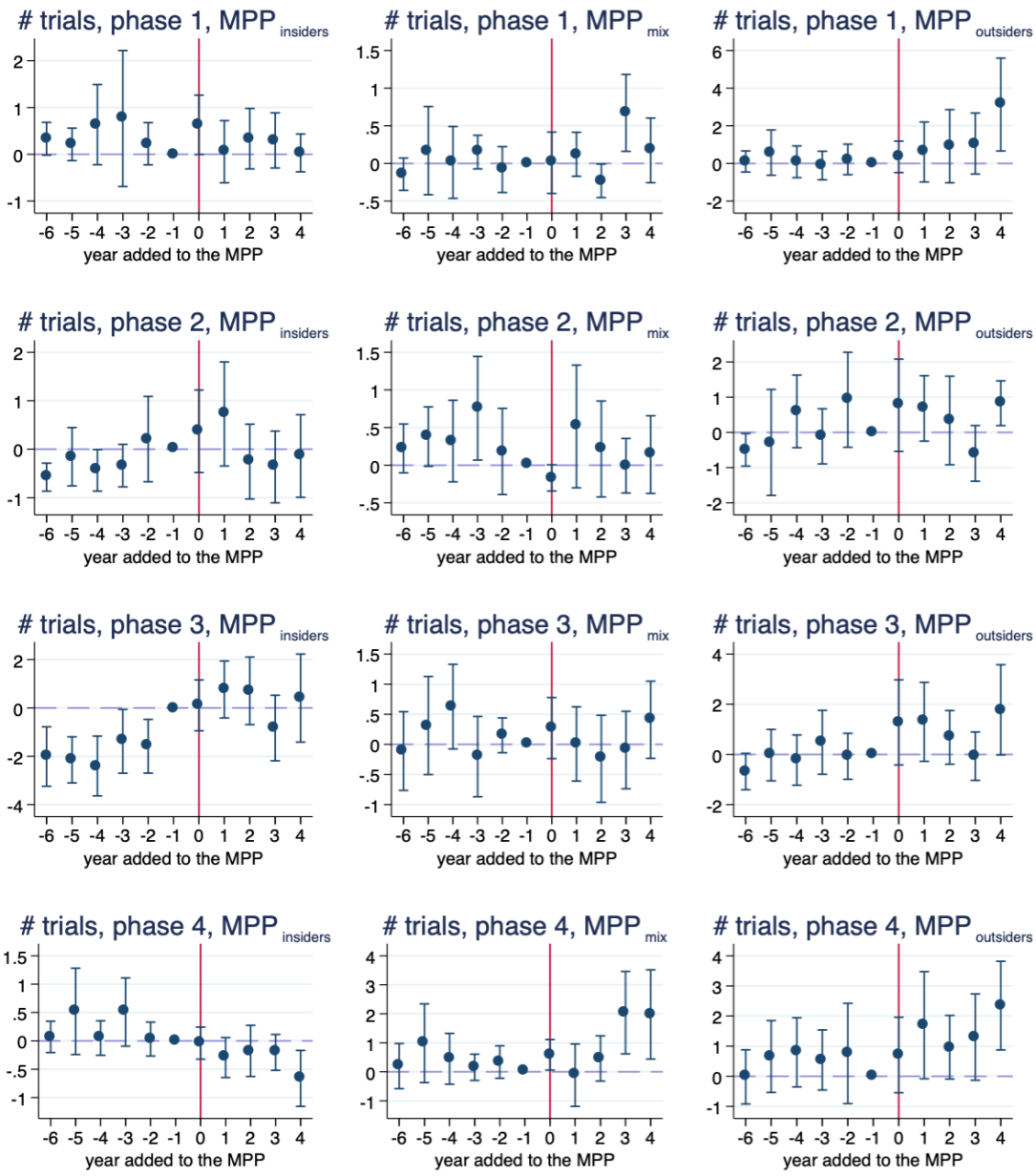



Figure B2: Event Studies for Innovation Analysis: Clinical Trials, by Firm and Phase

Notes: The figures report event-study coefficient estimates using Equation (4). The dots are point estimates of differences in outcomes between treated and control groups 6 years before and 4 years after MPP inclusion. The whiskers correspond to 95% confidence intervals.

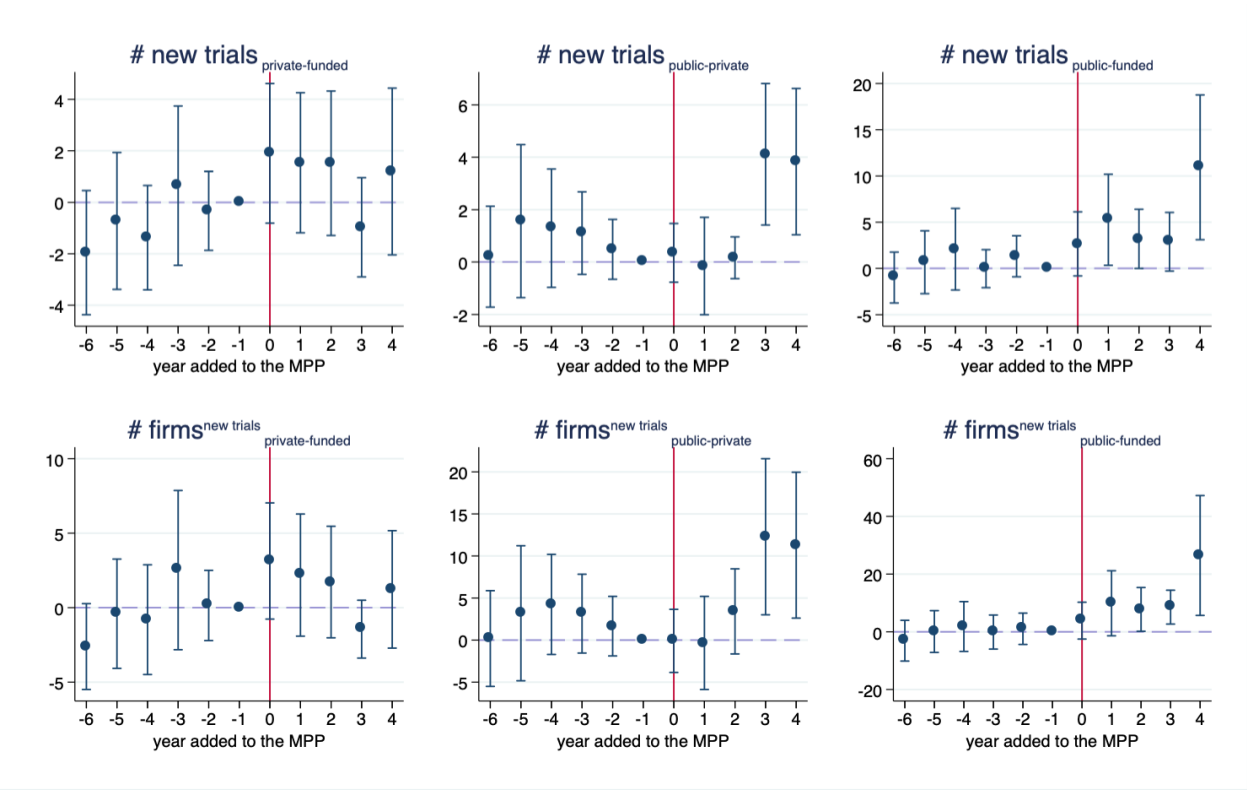



Figure B3: Event Studies for Innovation Analysis: Clinical Trials by Funding Type

Notes: These figures report event-study coefficient estimates using Equation (4). The dots are point estimates of differences in outcomes between treated and control groups 6 years before and 4 years after MPP inclusion. The whiskers correspond to 95% confidence intervals.

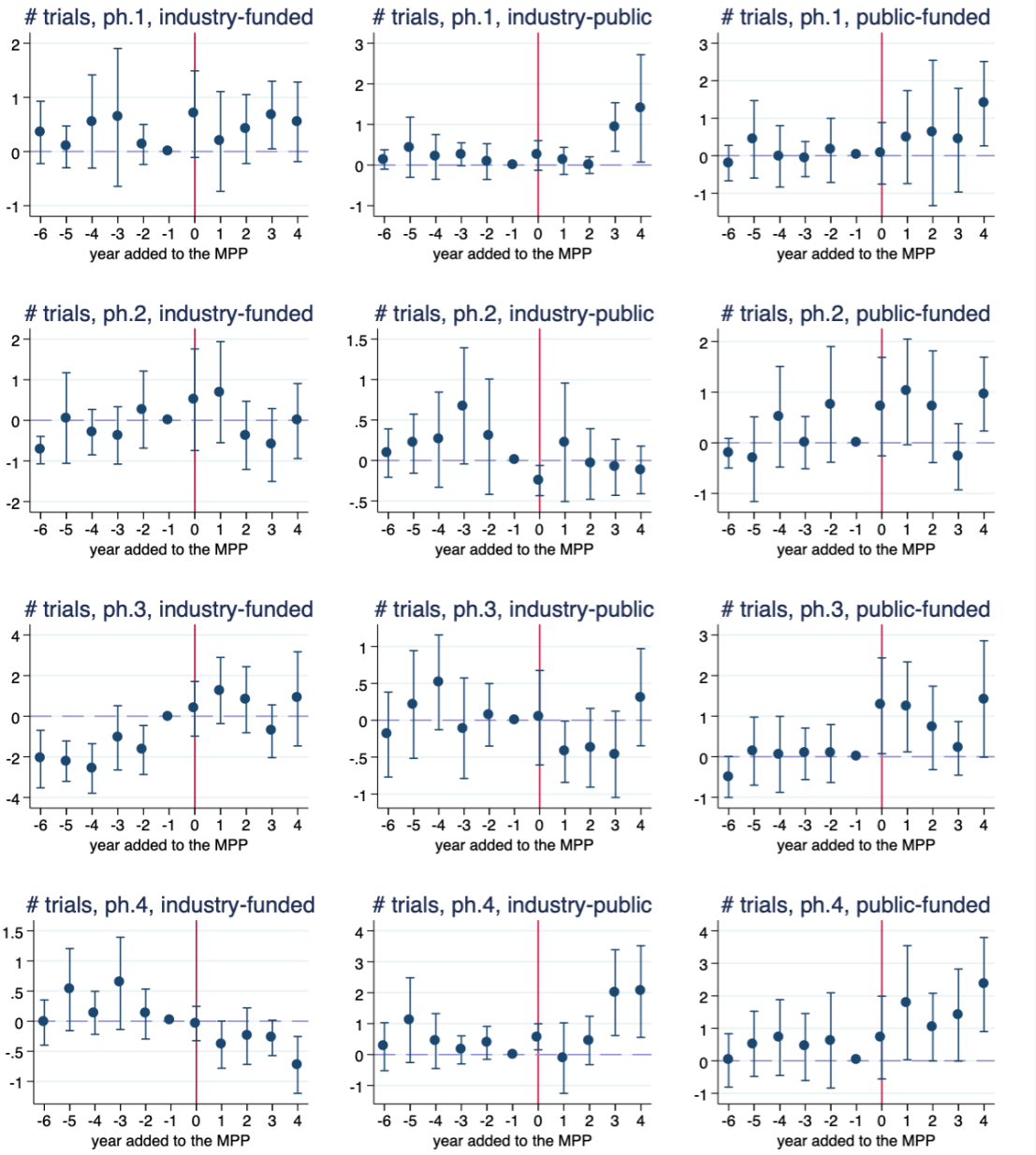
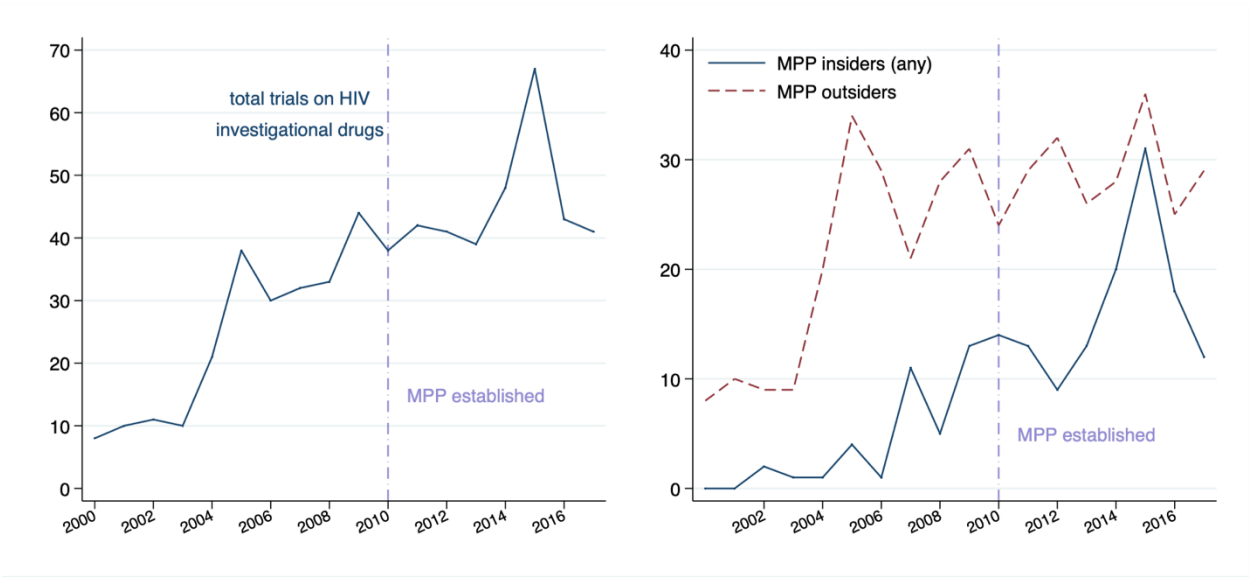
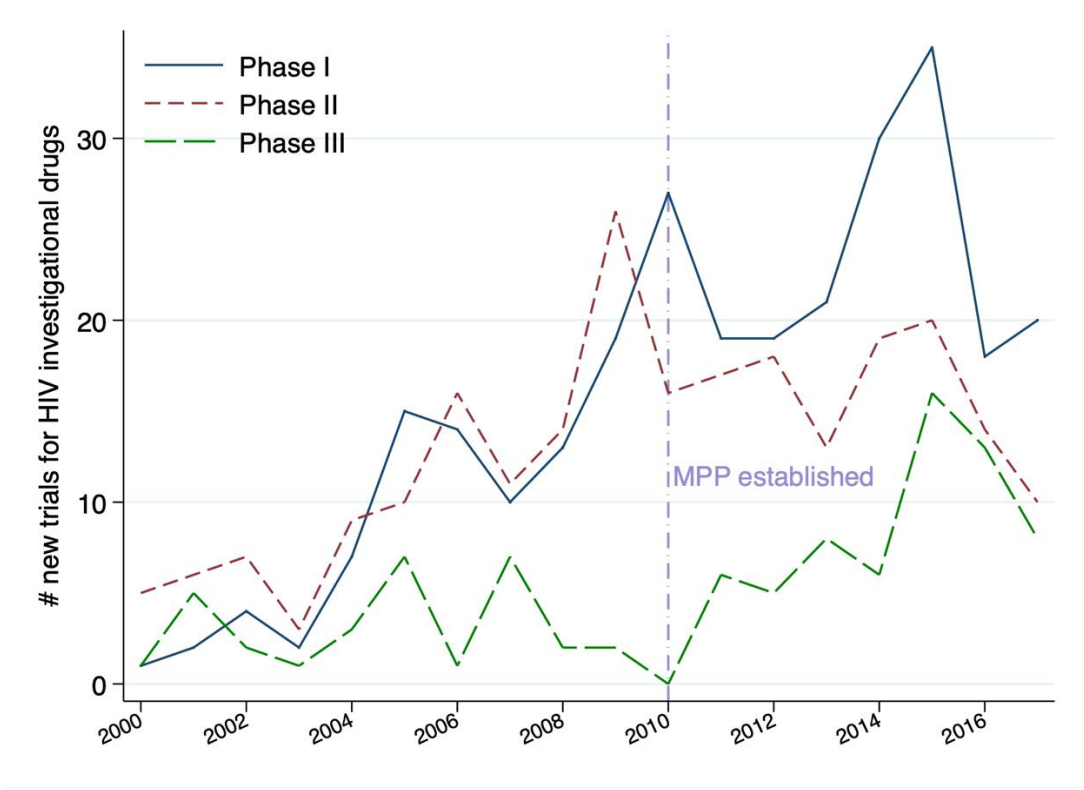



Figure B4: Event Studies for Innovation Analysis: Clinical Trials, by Funder and Phase

Notes: These figures report event-study coefficient estimates using Equation (4). The dots are point estimates of differences in outcomes between treated and control groups 6 years before and 4 years after MPP inclusion. The whiskers correspond to 95% confidence intervals.




(a) Total Trials on HIV Investigational Drugs, and across MPP-affiliation




(b) Investigational Trials by Phases (I-III)

Figure B5: Descriptive Trends: # New Trials on HIV Investigational Drugs (pipeline)

Notes: This graph depicts the trends of the number of new clinical trials initiated per year on HIV investigational drugs, i.e., new compounds that have not been approved (majority, 90%, as in phases I-III) *or* investigational use of existing drugs (beyond approved antiretrovirals) for new HIV treatment purposes. The vertical dashed line indicates the time when the MPP was established.

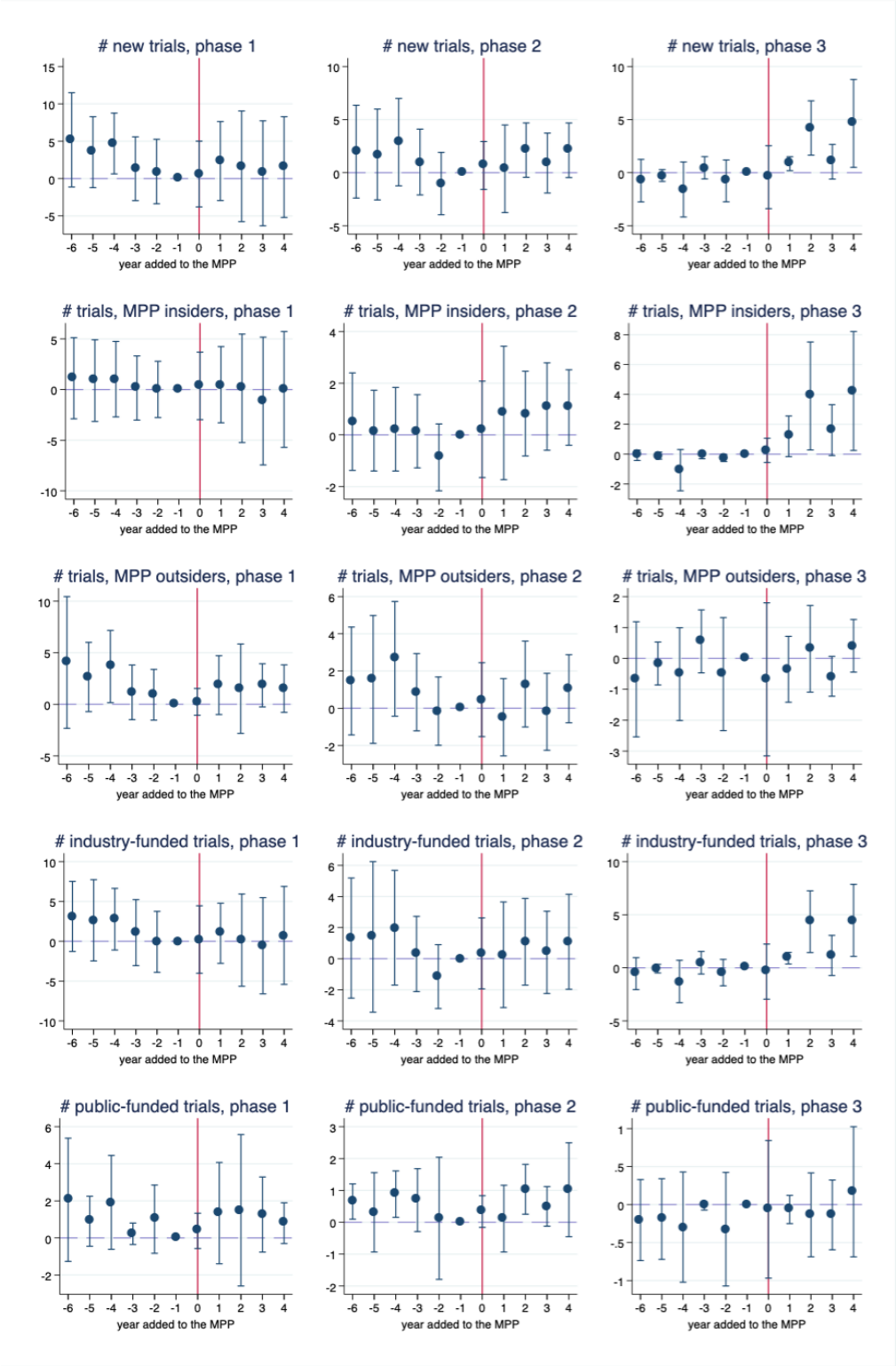



Figure B6: Event Studies: Clinical Trials for HIV Investigational Drugs, by Phase

Notes: The figures report event-study coefficient estimates at drug class-year level. The dots are point estimates of differences in outcomes between treatment and control groups 6 years before and 4 years after MPP inclusion. The whiskers correspond to 95% confidence intervals.

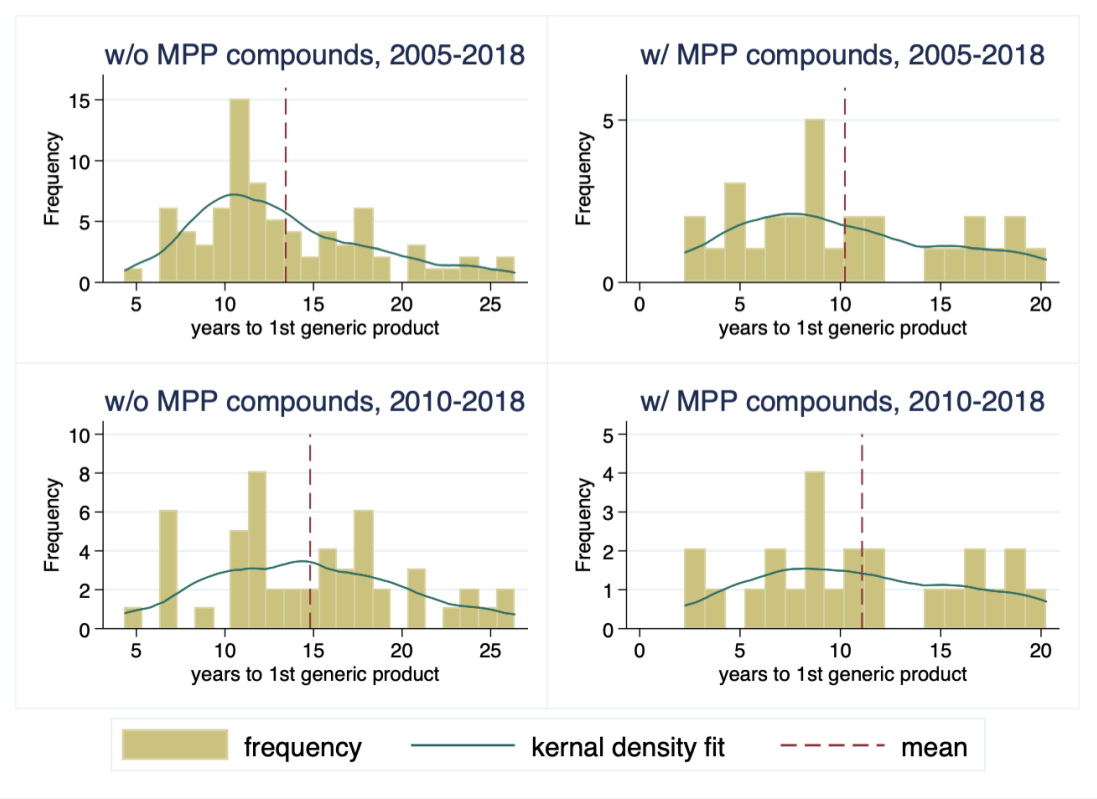
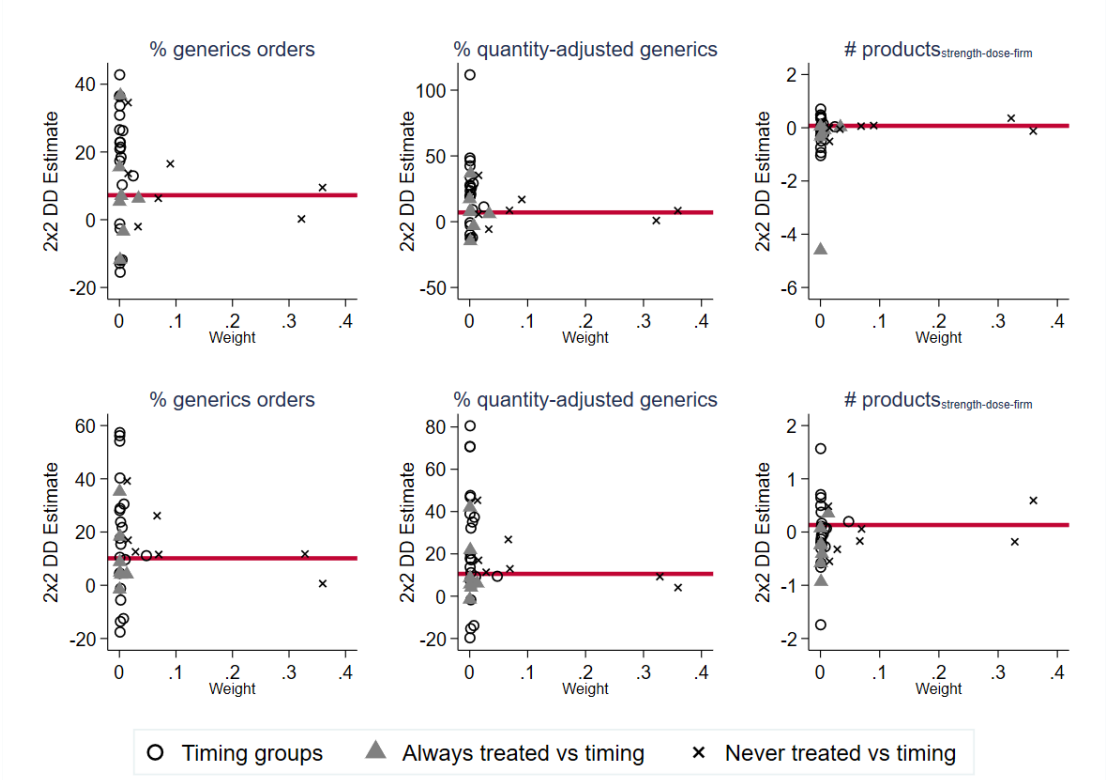
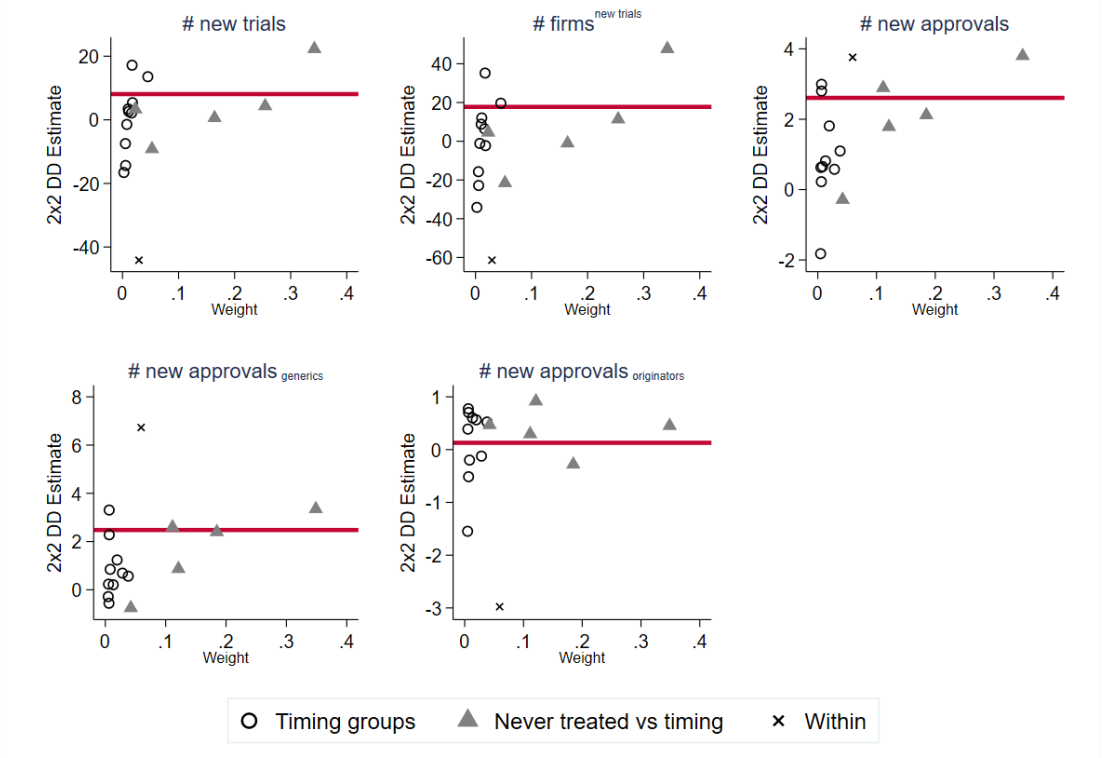



Figure B7: Histograms of Time-to-Generic by MPP Status

Notes: The figures show the association between time-to-generic and MPP status. Time-to-generic is measured as the years (continuous variable) between when all original compounds were approved and when the first generic (combination) of existing compounds is approved in a given strength-dosage form. The upper panel uses the full sample (2005-2018) and the bottom panel displays the sample where MPP has been established (2010-2018).




(a) Diffusion sample (upper: drug-country-year-level; lower: compound-country-year-level)




(b) Innovation sample: clinical trials & drug approvals

Figure B8: Bacon Decomposition for diffusion and innovation samples

Table B1: Regressing MPP Indicator on Observables

| | (1) FE only | (2) | (3) |
|---|---|---|---|
| $R^2$ (two-way s.e.) | 0.820 | 0.821 | 0.821 |
| $R^2$ (one-way s.e.) | 0.827 | 0.828 | 0.828 |
| HIV death rate | | -0.000137 | -0.000139 |
| (age-adjusted, | | (0.000228) | (0.000229) |
| per 100k pop.) | | [7.49e-05] | [7.56e-05] |
| HIV prevalence | | 4.10e-08 | 4.12e-08 |
| | | (1.20e-07) | (1.20e-07) |
| | | [3.61e-08] | [3.63e-08] |
| log(population) | | 0.193 | 0.196 |
| | | (0.420) | (0.425) |
| | | [0.153] | [0.153] |
| GDP per capita | | 7.16e-06 | 7.09e-06 |
| | | (6.02e-06) | (6.32e-06) |
| | | [5.82e-06] | [5.86e-06] |
| voice and | | 0.000692 | 0.000715 |
| accountability | | (0.00116) | (0.00126) |
| | | [0.00106] | [0.00106] |
| political stability | | 0.000450 | 0.000438 |
| and lack of | | (0.000610) | (0.000636) |
| violence | | [0.000504] | [0.000503] |
| government | | -0.000310 | -0.000305 |
| effectiveness | | (0.000790) | (0.000876) |
| | | [0.000721] | [0.000722] |
| regulatory | | 0.00126* | 0.00125 |
| quality | | (0.000740) | (0.000763) |
| | | [0.00102] | [0.00102] |
| rule of law | | -0.00105 | -0.00106 |
| | | (0.000632) | (0.000624) |
| | | [0.000965] | [0.000964] |
| control of | | 0.000653 | 0.000665 |
| corruption | | (0.000677) | (0.000713) |
| | | [0.000839] | [0.000835] |
| $patent_{dct}$ | | | 0.0139 |
| | | | (0.0791) |
| | | | [0.0360] |
| country-drug & year FEs | Y | Y | Y |
| $X_{ct}$ controls | | Y | Y |
| $X_{dct}$ controls | | | Y |
| Observations | 7,084 | 7,084 | 7,084 |

Notes: This table reports a diagnostic regression on whether the MPP inclusion decision can be predicted by changes in observed characteristics during the sample period. As shown above, none of the observables are significant predictors of when a drug-country pair is added to the MPP and is available for bundled licensing. In addition, disease rate and prevalence, population, income, and institution-related factors do not effectively increase predictive power of the MPP inclusion indicator, net of fixed effects. Robust standard errors are two-way clustered at the drug and country levels and are reported in parenthesis (). Robust standard errors clustered at the country level are reported in []. Two-way robust p-values: * $p<0.1$.

Table B2: Diffusion Analysis in Alternative Specification

| Dept. Vars. | (1) % generic orders | (2) % generic orders | (3) % generic quantities | (4) % generic quantities | (5) # products | (6) # products |
|---|---|---|---|---|---|---|
| $MPP_{dct}$ | 7.526** | 7.535** | 7.250** | 7.254** | 0.0623 | 0.0629 |
| | (3.355) | (3.347) | (3.123) | (3.122) | (0.113) | (0.113) |
| | [2.700] | [2.700] | [2.734] | [2.736] | [0.0747] | [0.0746] |
| country-drug FE | Y | Y | Y | Y | Y | Y |
| country-year FE | Y | Y | Y | Y | Y | Y |
| $X_{dct}$ control | | Y | | Y | | Y |
| LHS mean | 84.3 | 84.3 | 85.6 | 85.6 | 1.7 | 1.7 |
| Observations | 7,084 | 7,084 | 7,084 | 7,084 | 7,084 | 7,084 |

Notes: This table reports the results of estimating the MPP's causal impact on drug-country-year level generic drug diffusion with an alternative specification. All the country-year level observables are replaced with a full set of country-year level fixed effects. Fixed effects for drug-country pairs are always included. Drug-country-year level effective patent status is included in the last set of columns to demonstrate coefficient stability. Each cell reports the coefficient-of-interest from a separate regression. Robust standard errors reported in () are two-way clustered at the drug and country levels. Robust standard errors reported in [] are clustered at the country level. Two-way robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B3: Diffusion Analysis in Sample Territories

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Samples | MPP common territories | | | MPP ever-covered territories | | |
| Dept. Vars. | % generic | %Q generic | # products | % generic | %Q generic | # products |
| *Panel A: drug-country-year level analysis* | | | | | | |
| $MPP_{dct}$ | 5.011* | 5.312** | 0.115 | 7.528** | 7.280** | 0.0730 |
| | (2.851) | (2.553) | (0.148) | (2.913) | (2.761) | (0.104) |
| | [3.318] | [3.423] | [0.121] | [2.690] | [2.699] | [0.0802] |
| LHS mean | 88.65 | 89.74 | 1.77 | 85.68 | 87.00 | 1.73 |
| # obs. | 3,547 | 3,547 | 3,547 | 6,829 | 6,829 | 6,829 |
| *Panel B: compound-country-year level analysis* | | | | | | |
| $MPP_{act}$ | 8.378** | 10.06** | 0.228 | 10.54*** | 10.89*** | 0.129 |
| | (3.922) | (3.546) | (0.266) | (3.593) | (3.334) | (0.190) |
| | [3.867] | [4.084] | [0.143] | [3.064] | [3.213] | [0.111] |
| LHS mean | 84.34 | 86.33 | 2.77 | 81.29 | 83.53 | 2.57 |
| # obs. | 3,221 | 3,221 | 3,221 | 6,202 | 6,202 | 6,202 |
| FEs | Y | Y | Y | Y | Y | Y |
| $X_{ct}$ control | Y | Y | Y | Y | Y | Y |
| $X_{dct}$ control | Y | Y | Y | Y | Y | Y |

Notes: This table reports the results of estimating equation (1) in subsamples of MPP common territories (countries in every drug's territory) and the MPP ever-covered territories (eligible for at least one drug). Each cell reports the coefficient-of-interest from a separate regression. Fixed effects for drug-country pairs (Panel A), compound-country pairs (Panel B), and years are always included. The specification also controls drug-country-year level effective patent status and country-year level observables. Robust standard errors reported in () are clustered using two-way clustering at the drug and country levels. Robust standard errors reported in [] are clustered at the country level. Two-way robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B4: Diffusion Analysis in Sample Drugs

| Samples | (1) drug class in 1st pool addition | (2) drop one drug class | (3) drop U.S. not recommended | (4) drugs approved since 1996 | (5) drugs by MPP insider firms |
|---|---|---|---|---|---|
| *Panel A: % generic orders as dependent variable* | | | | | |
| $MPP_{dct}$ | 11.13*** | 7.030** | 7.415** | 6.848** | 7.304** |
| | (3.586) | (2.951) | (2.967) | (2.938) | (2.842) |
| | [3.471] | [2.773] | [2.687] | [2.705] | [2.706] |
| LHS mean | 94.80 | 82.77 | 83.92 | 83.41 | 86.64 |
| # Obs. | 4,463 | 5,828 | 6,316 | 5,786 | 6,127 |
| *Panel B: % generic quantity ordered (patient year) as dependent variable* | | | | | |
| $MPP_{dct}$ | 10.32*** | 6.520** | 7.234** | 6.620** | 7.145** |
| | (3.366) | (2.874) | (2.838) | (2.823) | (2.727) |
| | [3.335] | [2.781] | [2.693] | [2.702] | [2.709] |
| LHS mean | 95.44 | 84.11 | 85.25 | 84.64 | 88.13 |
| # Obs. | 4,463 | 5,828 | 6,316 | 5,786 | 6,127 |

Notes: This table reports the results of estimating equation (1) in subsamples with different drugs in the control groups. Each cell reports the coefficient-of-interest from a separate regression. Fixed effects for drug-country pairs and years are always included. The specification also controls drug-country-year level effective patent status and country-year level observables. Robust standard errors reported in () are two-way clustered at the drug and country levels. Robust standard errors reported in [] are clustered at the country level. Two-way robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B5: Subsample Diffusion Analysis: Ever vs Never Patented

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| Dept. Vars. | % generic orders (#) | | % generic ordered (p.p.y) | | # product-manufacturers | |
| Subsample | $Pat.$=1 | $Pat.$=0 | $Pat.$=1 | $Pat.$=0 | $Pat.$=1 | $Pat.$=0 |
| Panel A: drug-country-year subsamples | | | | | | |
| $MPP_{dct}$ | 20.65** | 4.360 | 18.03* | 4.675* | -0.0122 | 0.0887 |
| | (9.771) | (2.696) | (9.321) | (2.709) | (0.0886) | (0.126) |
| | [7.667] | [2.678] | [7.079] | [2.770] | [0.118] | [0.0924] |
| LHS mean | 83.73 | 84.54 | 84.42 | 86.12 | 1.75 | 1.70 |
| Observations | 2,029 | 5,055 | 2,029 | 5,055 | 2,029 | 5,055 |
| Panel B: compound-country-year subsamples | | | | | | |
| $MPP_{act}$ | 19.85*** | 4.601 | 17.29*** | 6.699 | -0.193 | 0.372* |
| | (3.665) | (3.735) | (3.600) | (3.962) | (0.176) | (0.198) |
| | [4.321] | [3.537] | [4.351] | [3.941] | [0.152] | [0.176] |
| LHS mean | 84.19 | 85.54 | 84.99 | 87.33 | 1.75 | 1.72 |
| Observations | 3,328 | 3,157 | 3,328 | 3,157 | 3,328 | 3,157 |
| two sets of FEs | Y | Y | Y | Y | Y | Y |
| $X_{ct}$ control | Y | Y | Y | Y | Y | Y |
| $X_{d(a)ct}$ control | Y | | Y | | Y | |

Notes: This table reports the results of subsample diffusion analyses in countries where a drug (Panel A) or compound (Panel B) is ever or never patented during the sample period. Each cell reports the coefficient-of-interest from a separate regression. The specification controls effective patent status and country-year level observables. Fixed effects for drug(compound)-country pairs and years are always included. Robust standard errors reported in () are two-way clustered at the drug/compound and country levels. Robust standard errors reported in [] are clustered at the country level. Two-way robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B6: Diffusion Analysis: Reduced-form Price and Quantity Regressions

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | Prices (Per Patient Year) | | | Quantity (Patient-Year Served) | | |
| Dept. Vars. | Overall | Generic | Branded | Overall | Generic | Branded |
| $MPP_{dct}$ | -105.8 | -86.73*** | 91.51 | 294.2 | 464.0 | -169.8** |
| | (79.15) | (28.48) | (139.9) | (2,279) | (2,270) | (77.96) |
| | [46.09] | [23.82] | [202.0] | [1,000] | [1,042] | [134.2] |
| FEs | Y | Y | Y | Y | Y | Y |
| $X_{ct}$ control | Y | Y | Y | Y | Y | Y |
| $X_{dct}$ control | Y | Y | Y | Y | Y | Y |
| LHS mean | 375.17 | 158.37 | 1696.03 | 6289.15 | 6198.92 | 90.23 |
| # Obs. | 7,084 | 6,167 | 1,351 | 7,084 | 7,084 | 7,084 |

Notes: This table reports the results of estimating equation (1) using prices and quantities as outcomes. The problems and measurement issues with direct price and quantity regressions are discussed in section 3.2 and footnotes 18-19. Each cell reports the coefficient-of-interest from a separate regression. Fixed effects for drug-country pairs and years are always included. The specification also controls drug-country-year level effective patent status and country-year level observables. The LHS mean for branded quantity is small because of the zeros exist in many units; the mean for non-zeros branded quantity is 473.12 instead. Robust standard errors reported in () are two-way clustered at the drug and country levels. Robust standard errors reported in [] are clustered at the country level. Two-way robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B7: Innovation Analysis - Clinical Trials: by Funding Types

| | (1) | (2) | (3) | (4) | (5) | (6) |
|---|---|---|---|---|---|---|
| | # new HIV trials funded by | | | # firms in new HIV trials funded by | | |
| Dept. Vars. | industry | ind.&pub. | public | industry | ind.&pub. | public |
| *Total* | | | | | | |
| $MPP_{at}$ | 2.296* | 0.898 | 4.899* | 2.750* | 3.231 | 11.77* |
| | (1.227) | (1.026) | (2.759) | (1.572) | (3.082) | (6.144) |
| LHS mean | 3.417 | 1.996 | 4.663 | 4.494 | 5.880 | 10.36 |
| *Panel A. Phase I* | | | | | | |
| $MPP_{at}$ | 0.197 | 0.313 | 0.604 | 0.251 | 0.930 | 1.133 |
| | (0.199) | (0.201) | (0.532) | (0.292) | (0.608) | (0.924) |
| LHS mean | 0.546 | 0.209 | 0.596 | 0.774 | 0.546 | 0.985 |
| *Panel B. Phase II* | | | | | | |
| $MPP_{at}$ | 0.504 | -0.244** | 0.665** | 0.556 | -0.852** | 1.416* |
| | (0.397) | (0.113) | (0.275) | (0.473) | (0.328) | (0.694) |
| LHS mean | 0.806 | 0.291 | 0.813 | 1.007 | 0.941 | 1.756 |
| *Panel C. Phase III* | | | | | | |
| $MPP_{at}$ | 2.275*** | -0.129 | 1.228*** | 2.743*** | -0.664* | 2.506* |
| | (0.721) | (0.0981) | (0.434) | (0.900) | (0.358) | (1.288) |
| LHS mean | 1.524 | 0.393 | 0.969 | 1.943 | 1.256 | 2.772 |
| *Panel D. Phase IV* | | | | | | |
| $MPP_{at}$ | -0.424** | 0.574 | 1.174 | -0.547*** | 2.352 | 2.735* |
| | (0.164) | (0.481) | (0.805) | (0.185) | (1.584) | (1.601) |
| LHS mean | 0.354 | 0.796 | 1.313 | 0.444 | 2.402 | 2.731 |

Notes: This table reports the results of estimating equation (3). The number of observations is always 540 with the balanced panel structure. Each cell reports the coefficient-of-interest from a separate regression. Industry-funded means the trial is 100% industry funded, while "ind.&pub." means the trial is private-public jointly funded. Control variables include FDA approval status, patent status, and fixed effects for compounds and years. Robust standard errors are clustered at the compound level (in parentheses). Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B8: Innovation Analysis - Clinical Trials on HIV Investigational Drugs

| Dept. Vars. | (1) # new trials | (2) # trials, MPP insiders | (3) # trials, MPP outsider | (4) # industry-funded trials | (5) # public-funded trials |
|---|---|---|---|---|---|
| *Total* | | | | | |
| $MPP_{at}$ | 4.230 | 2.959 | 1.271 | 2.871* | 1.360 |
| | (2.254) | (1.529) | (1.071) | (1.229) | (1.072) |
| LHS mean | 8.58 | 3.30 | 5.29 | 5.67 | 2.91 |
| *Panel A. Phase I* | | | | | |
| $MPP_{at}$ | -0.582 | -0.440 | -0.142 | -0.823 | 0.241 |
| | (1.305) | (0.855) | (0.762) | (0.918) | (0.605) |
| LHS mean | 3.45 | 0.81 | 2.64 | 1.95 | 1.51 |
| *Panel B. Phase II* | | | | | |
| $MPP_{at}$ | 0.553 | 0.888 | -0.335 | 0.280 | 0.273 |
| | (0.474) | (0.629) | (0.444) | (0.267) | (0.227) |
| LHS mean | 3.23 | 1.18 | 2.06 | 2.34 | 0.89 |
| *Panel C. Phase III* | | | | | |
| $MPP_{at}$ | 2.770* | 2.504* | 0.266 | 2.599** | 0.170 |
| | (1.230) | (1.097) | (0.284) | (1.051) | (0.195) |
| LHS mean | 1.98 | 1.37 | 0.60 | 1.81 | 0.17 |

Notes: This table reports the results at drug class-year level. The number of observations is always 91 with the balanced panel structure. There are seven drug classes in the analysis, of which six are drug classes with existing compounds approved and the further one captures the set of new drug classes without existing products for HIV treatment, such as gene therapy, biological antibody, etc. Each cell reports the coefficient-of-interest from a separate regression. Industry-funded means a trial is at least partly funded by industry. Control variables include FDA approval status, patent status, and fixed effects for compounds and years. Robust standard errors are clustered at the drug class level (in parentheses). Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B9: 1st Time New HIV Drug Approvals with Existing Compounds

| drug | firm | ymd | branded compound owners | # | type |
|---|---|---|---|---|---|
| *Panel A: 1st Time New Drug Approvals by Branded Firms* | | | | | |
| 3tc+zdv | ViiV | 1997.09.26 | ViiV+ViiV | 1 | cocktail |
| abc+3tc+zdv | ViiV | 2000.11.14 | ViiV+ViiV+ViiV | 1 | cocktail |
| abc+3tc | ViiV | 2004.08.02 | ViiV+ViiV | 1 | cocktail |
| ftc+tdf | Gilead | 2004.08.02 | Gilead+Gilead | 1 | cocktail |
| efv+ftc+tdf | Gilead | 2006.07.12 | BMS+Gilead+Gilead | 2 | cocktail |
| ftc+rpv+tdf | Gilead | 2011.08.10 | Gilead+Janssen+Gilead | 2 | cocktail |
| abc+dtg+3tc | ViiV | 2014.08.22 | ViiV+ViiV+ViiV | 1 | cocktail |
| cobi | Gilead | 2014.09.24 | Gilead | 1 | standalone |
| evg | Gilead | 2014.09.24 | Gilead | 1 | standalone |
| atv+cobi | BMS | 2015.01.29 | BMS+Gilead | 2 | cocktail |
| cobi+drv | Janssen | 2015.01.29 | Gilead+Janssen | 2 | cocktail |
| 3tc+ral | Merck | 2015.02.06 | ViiV+Merck | 2 | cocktail |
| ftc+rpv+taf | Gilead | 2016.03.01 | Gilead+Janssen+Gilead | 2 | cocktail |
| ftc+taf | Gilead | 2016.04.04 | Gilead+Gilead | 1 | cocktail |
| taf | Gilead | 2016.11.10 | Gilead | 1 | standalone |
| dtg+rpv | ViiV | 2017.11.21 | ViiV+Janssen | 2 | cocktail |
| cobi+drv+ftc+taf | Janssen | 2018.07.17 | Gilead+Janssen+Gilead+Gilead | 2 | cocktail |
| *Panel B: 1st Time New Drug Approvals by Generics* | | | | | |
| 3tc+nvp+zdv | Pharmacare | 2005.01.24 | ViiV+BI+ViiV | 2 | cocktail |
| 3tc+zdv+efv | Aurobindo | 2006.03.06 | ViiV+ViiV+BMS | 2 | cocktail |
| 3tc+d4t+nvp | Cipla | 2006.11.17 | ViiV+BMS+BI | 3 | cocktail |
| 3tc+d4t | Cipla | 2007.01.19 | ViiV+BMS | 2 | cocktail |
| d4t+3tc+efv | Strides | 2007.06.01 | BMS+ViiV+BMS | 2 | cocktail |
| 3tc+tdf | Hetero | 2009.11.05 | ViiV+Gilead | 2 | cocktail |
| efv+3tc+tdf | Mylan | 2010.10.25 | BMS+ViiV+Gilead | 3 | cocktail |
| 3tc+tdf+nvp | Matrix Labs | 2011.09.08 | ViiV+Gilead+BI | 3 | cocktail |
| atv+r | Matrix Labs | 2011.11.18 | BMS+AbbVie | 2 | cocktail |
| atv+r+3tc+zdv | Mylan | 2014.09.04 | BMS+AbbVie+ViiV+ViiV | 3 | cocktail |
| ftc+tdf+nvp | Mylan | 2014.09.12 | Gilead+Gilead+BI | 2 | cocktail |
| dtg+3tc+tdf | Mylan | 2017.08.02 | ViiV+ViiV+Gilead | 2 | cocktail |
| dtg+ftc+taf | Mylan | 2018.02.09 | ViiV+Gilead+Gilead | 2 | cocktail |

Notes: This table summarizes the first approvals of HIV drugs based on existing compounds, reported for originators and generics in different panels and chronologically ordered within each panel. These first-time follow-on new approvals are typically for drug cocktails, except in three cases where the originators first created new compounds approved as part of a cocktail before the new standalone compound is approved. BI stands for Boehringer Ingelheim. The column "#" counts distinct brand owners of each underlying drug. Note that first-time new generic cocktails are not reported before 2005 because of a combination of international patent enforcement in India since then and new FDA approval initiatives. This table, together with Table 1, complete the list of first-approval information for all HIV drugs by the end of 2018.

Table B10: Survival and Regression Analyses on Time-to-Generic

| | (1) | (2) | (3) | (4) |
|---|---|---|---|---|
| *Panel A: Cox Proportional Hazard Model* | | | | |
| MPP | 0.532** | 0.647** | 1.019** | 0.371 |
| | (0.222) | (0.257) | (0.397) | (0.472) |
| *Panel B: Regression Analysis* | | | | |
| MPP | -3.204*** | -3.727*** | -1.827 | -0.157 |
| | (1.117) | (1.317) | (1.102) | (1.738) |
| sample | 2005-2018 | 2010-2018 | 2005-2018 | 2010-2018 |
| year FE | | | Y | Y |
| drug class FE | | | Y | Y |
| LHS mean | 12.57 | 13.62 | 12.57 | 13.62 |
| Observations | 108 | 75 | 108 | 75 |

Notes: This table reports results of analyzing the association between time-to-generic and MPP status. Time-to-generic is measured as the years (continuous variable) between when all original compounds were approved and when the first generic (combination) of existing compounds is approved in a given strength-dosage form. The main variable of interest is an indicator variable of whether a first approved generic product has any MPP compound. Robust p-values: *** p<0.01, ** p<0.05, * p<0.1.

Table B11: Count Model Results for Innovation Analysis – Drug Approvals

| | (1) # approvals | (2) # appr.$^{generic}$ | (3) # appr.$^{branded}$ |
|---|---|---|---|
| Panel A: drug-year new approvals | | | |
| $MPP_{dt}$ | 1.014*** | 1.212*** | 0.772 |
| | (0.262) | (0.287) | (0.786) |
| LHS mean | 0.70 | 13.22 | 1.95 |
| Observations | 798 | 518 | 518 |
| Panel B: compound-year new approvals | | | |
| $MPP_{at}$ | 1.067*** | 1.115*** | 0.969** |
| | (0.227) | (0.259) | (0.477) |
| LHS mean | 2.28 | 39.95 | 4.29 |
| Observations | 378 | 266 | 336 |
| FEs | Y | Y | Y |
| controls | Y | Y | Y |

Note: This table reports innovation results in drug approvals using conditional negative binomial regressions. Fixed effects are at drug and year levels for Panel A and at compound and year levels for Panel B. I run this exercise to test whether drug approval results in Table 6 (using linear models) are robust to using count data models. The number of observations dropped in columns (2) – (3) to adjust for different drug approved by generics and branded—drugs/compounds that always have zero approvals by the corresponding firm type create no variation, and are dropped to account for different focuses in actual investment areas.

Table B12: Treatment Heterogeneity: Bacon Decomposition Results

| values/outcomes | coeff. | weight | coeff. | weight | coeff. | weight |
|---|---|---|---|---|---|---|
| *Panel A: diffusion sample* | | | | | | |
| *(drug-country-year)* | % generic orders | | % quantity-adj. generic | | # prod. (within drug-country-year) | |
| Timing Groups | 11.91 | 0.048 | 12.18 | 0.048 | 0.0001 | 0.048 |
| Always vs timing | 5.60 | 0.047 | 5.35 | 0.047 | -0.04 | 0.047 |
| Never vs Timing | 6.79 | 0.901 | 6.66 | 0.901 | 0.09 | 0.901 |
| Always vs never | 50.92 | 0.001 | 38.31 | 0.001 | -2.91 | 0.001 |
| Within | 76.23 | 0.003 | 82.28 | 0.003 | 0.10 | 0.003 |
| *(comp.-country-year)* | % generic orders | | % quantity-adj. generic | | # prod. (within comp.-country-year) | |
| Timing Groups | 11.30 | 0.088 | 12.67 | 0.088 | 0.10 | 0.088 |
| Always vs timing | 5.73 | 0.019 | 7.51 | 0.019 | 0.11 | 0.019 |
| Never vs Timing | 8.89 | 0.878 | 9.60 | 0.878 | 0.16 | 0.878 |
| Always vs never | 4.09 | 0.006 | 1.74 | 0.006 | -0.17 | 0.006 |
| Within | 25.99 | 0.009 | 18.50 | 0.009 | -1.92 | 0.009 |
| *Panel B: innovation sample* *(compound-year level)* | | | | | | |
| | # of new clinical trials | | # firms in clinical trials | | # drug product approvals | |
| Timing Groups | 6.96 | 0.13 | 11.05 | 0.13 | 1.06 | 0.13 |
| Never vs Timing | 10.08 | 0.84 | 21.56 | 0.84 | 2.78 | 0.81 |
| Within | -44.06 | 0.03 | -61.29 | 0.03 | 3.77 | 0.06 |
| | # approvals, generic | | # approvals, branded | | | |
| Timing Groups | 0.80 | 0.13 | 0.26 | 0.13 | | |
| Never vs Timing | 2.44 | 0.81 | 0.34 | 0.81 | | |
| Within | 6.74 | 0.06 | -2.97 | 0.06 | | |

Notes: The table reports Bacon decomposition (2021) results for main outcomes in the diffusion and innovation samples. The results are directly comparable to the benchmark results in Table 3 for diffusion and Tables 4 & 6 for innovation, and estimated using the same main specifications used in corresponding analyses. Figure B8 reports the corresponding visualization of Bacon decomposition results.

Table B13: Results from the Demand Estimation

| | (1) OLS | (2) Nested logit | (3) Logit |
|---|---|---|---|
| $\ln(s_{j\|g(j)})$ | 0.702*** | 0.862*** | |
| | (0.0144) | (0.0814) | |
| $p_j$ | -0.137*** | -1.946*** | -3.483*** |
| | (0.0227) | (0.243) | (0.441) |
| drug age (U.S. appr.) | 0.0119* | -0.196*** | -0.449*** |
| | (0.00637) | (0.0404) | (0.0838) |
| prod. variety | 0.345*** | -0.00503 | 0.434** |
| | (0.0335) | (0.122) | (0.179) |
| regulatory quality | 0.00194 | -0.0646*** | -0.121*** |
| | (0.00558) | (0.0208) | (0.0378) |
| rule of law | 0.0226*** | 0.0507*** | 0.0532* |
| | (0.00546) | (0.0162) | (0.0291) |
| control of corruption | -0.00783* | 0.0361** | 0.0785*** |
| | (0.00446) | (0.0148) | (0.0272) |
| Kleibergen-Paap F statistic | | 19.50 | |
| 1st stage $(s_{j\|g})$ | | 104.42 | |
| 1st stage $(p_j)$ | | 46.91 | 54.56 |
| country FE | Y | Y | Y |
| year FE | Y | Y | Y |
| $X_j$ controls | Y | Y | Y |
| Observations | 7,084 | 7,084 | 7,084 |

Note: This table presents results of estimating the nested logit demand model as in Equation (6) and compares it with OLS and a plain logit. The instruments for conditional market share and price are: (1) whether a drug is effectively patented in the country-year, (2) the number of manufacturers for the same drug in a country-year, and (3) the number of competing products, i.e., drug product-firm combinations for other drugs in the same drug class. IVs for the plain logit do not include the second instrument to avoid over-identification. Only main parameters of interests are reported for simplicity. Observable controls, $X_j$, include within-drug product variety in a country-year, number of compounds within a drug, number of years since a drug's U.S. approval, country-year level HIV prevalence and age-adjusted death rates, institutional factors (i.e., the six world governance indicators), log(population) and GDP per capita. The excluded instruments are at drug-country-year level: patent status, number of competitors and number of close competitors in the same drug class. The first-stage statistics displayed immediately under coefficients-of-interests are the Kleibergen-Paap F statistic that are robust to heteroskedasticity. The first-stage F statistics for each endogenous variable is the Sanderson-Windmeijer multivariate F test of excluded instruments. Standard errors are clustered at drug-country level. Robust p-value: *** p<0.01, ** p<0.05, * p<0.1.

Table B14: Estimations of Pricing Equations

| Dept. var: marginal cost ($) | (1) MC pricing flat MC | (2) Bertrand-Nash Oligopoly single-prod. firm | (3) Bertrand-Nash Oligopoly multi-prod. firm |
|---|---|---|---|
| $MPP_j$ | -0.642*** | -1.908*** | -1.952*** |
| | (0.112) | (0.524) | (0.539) |
| $Q_j$ | | 3.60e-07*** | 3.83e-07*** |
| | | (1.27e-07) | (1.31e-07) |
| #variety | -0.209*** | 0.445* | 0.495** |
| | (0.0616) | (0.234) | (0.244) |
| $\#firms_{dct}$ | -0.310*** | -1.584*** | -1.662*** |
| | (0.0398) | (0.480) | (0.494) |
| $Patent_{dct}$ | -0.173 | 0.210 | 0.198 |
| | (0.192) | (0.255) | (0.262) |
| year FE | Y | Y | Y |
| country FE | Y | Y | Y |
| $X_j$ controls | Y | Y | Y |
| Kleibergen-Paap rk Wald F-stat | | 16.66 | 16.66 |
| Observations | 7,084 | 7,084 | 7,084 |

Notes: This table reports the results from estimating competitive marginal cost pricing and oligopolistic pricing on the drug-country-year diffusion sample using Equations (8) and (12), respectively. Only main parameters of interests are reported for simplicity. $X_j$ is a vector of drug-country-year level controls including whether a drug is effectively patented in a country-year, number of drug products and competitors for a drug in a country-year, country-year level HIV prevalence and age-adjusted death rates, population, GDP per capita, and institutional factors. Country and year fixed effects are always included. Quantity variable is instrumented by the number of competing products in the same drug class within a market (country-year). Standard errors are clustered at drug-country level. The first-stage F-statistics reported are adjusted for heteroskedasticity clustering. Robust p-value: *** p<0.01, ** p<0.05, * p<0.1.

Table B15: Sensitivity Analysis of Demand Estimation to Market Size

| | (1) | (2) | (3) | (4) | (5) |
|---|---|---|---|---|---|
| market size measures | 10% population | 30% population | 50% population | 70% population | pop*pr. HIV $death_{15to59}$ |
| $\ln(s_{j\|g})$ | 0.862*** | 0.861*** | 0.861*** | 0.861*** | 0.863*** |
| | (0.0826) | (0.0812) | (0.0810) | (0.0809) | (0.0811) |
| $p_j$ | -1.968*** | -1.942*** | -1.938*** | -1.937*** | -1.941*** |
| | (0.247) | (0.243) | (0.242) | (0.242) | (0.243) |
| 1st stage $_{joint}$ | 19.50 | 19.50 | 19.50 | 19.50 | 19.50 |
| 1st stage ($s_{j\|g}$) | 104.42 | 104.42 | 104.42 | 104.42 | 104.42 |
| 1st stage ($p_j$) | 46.91 | 46.91 | 46.91 | 46.91 | 46.91 |
| country FE | Y | Y | Y | Y | Y |
| year FE | Y | Y | Y | Y | Y |
| $X_j$ controls | Y | Y | Y | Y | Y |
| Observations | 7,084 | 7,084 | 7,084 | 7,084 | 7,084 |

Note: This table presents results of estimating the nested logit demand model as in Equation (6), and each column demonstrates robustness of the estimation to alternative market size measures. Observable controls, $X_j$ include within drug product variety in a country-year, number of compounds within a drug, number of years since a drug's US approval, country-year level HIV prevalence and age-adjusted death rates, institutional factors (i.e., the six world governance indicators), log(population) and GDP per capita. The excluded instruments are at drug-country-year level: patent status, number of competitors and number of close competitors in the same drug class. The first-stage statistics displayed immediately under coefficients-of-interests are the Kleibergen-Paap F statistic that are robust to heteroskedasticity. The first-stage F statistics for each endogenous variable is the Sanderson-Windmeijer multivariate F test of excluded instruments. Each j denotes drug-country (dc) for simplicity in notations. Robust p-value: *** p<0.01, ** p<0.05, * p<0.1.

Table B16: Pool Operating Expenses from Financial Statement

| time period | use of the funds (raw $/SFr.) | CHF/USD (annual) | MPP costs ($ current) |
|---|---|---|---|
| 2010.7-2011.12 | $ -4,254,666 | NA | -4,254,666 |
| 2012.1-2012.12 | SFr. -4,086,052 | 0.9377 | -4,357,526 |
| 2013.1-2013.13 | SFr. -4,271,467 | 0.9269 | -4,608,336 |
| 2014.1-2014.12 | SFr. -4,332,580 | 0.9147 | -4,736,613 |
| 2015.1-2015.12 | SFr. -4,759,073 | 0.9628 | -4,942,951 |
| 2016.1-2016.12 | SFr. -4,568,395 | 0.9848 | -4,638,906 |
| 2017.1-2017.12 | SFr. -4,974,406 | 0.9842 | -5,054,263 |

Notes: The MPP operating costs are obtained from the financial statements in the "Annual Reports" from the MPP. Specifically, "use of the funds" within the "statement of changes in capital" is used to measure the costs of this pool. This calculation is similar to manually summing up the personnel and administrative costs (the two main categories of MPP expenditure). The annual foreign exchange rate of Swiss Francs to one U.S. Dollar is provided by the Federal Reserve Bank of St. Louis.

## Appendix C: Mathematical Appendix

C.1 Deriving the price substitution matrix

I derive the substitution matrix by taking partial derivatives of market share *k* w.r.t price *j*. Here, I derive the general expression for the price derivatives from the demand side. With information from the supply-side, the relevant elements from the matrix are the products owned by the same branded firm in a given market (i.e., subset products owned by the same firm).

Given that

$$\hat{s}_j = \frac{e^{\frac{\delta_j}{1-\sigma}}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma}}{\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}},\ \hat{s}_k = \frac{e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}}{\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}},\ \text{and}\ \hat{s}_{k|g} = \frac{e^{\frac{\delta_k}{1-\sigma}}}{\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}} = \frac{\hat{s}_k}{\hat{s}_g}$$

$$\frac{ds_k}{dp_j} = \frac{d}{dp_j}\left[\frac{e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}}{\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}}\right]$$

$$= \frac{\left(e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)'\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right] - e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]'}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]^2}$$

$$= \frac{\overbrace{\left(e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)'}^{\equiv A}}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} - \frac{e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\overbrace{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]'}^{\equiv B}}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]^2}$$

$$= \frac{A}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} - \hat{s}_k \times \frac{B}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]}, \quad \text{eqn. (III.1)}$$

where $A \equiv \left(e^{\frac{\delta_k}{1-\sigma}}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)' = \left(e^{\frac{\delta_k}{1-\sigma}}\right)'\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma} + e^{\frac{\delta_k}{1-\sigma}}\left(\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)'$

and $B = \left[\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]'\ if\ g(k) = g(j);\ = \left[\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]'\ if\ g(k) \neq g(j).$

In the following part, I derive the analytic forms of the price derivatives for three cases. In each case, I first derive the expressions for A and B and then plug them back into eqn. (III.1).

Simplification note: that $\left(e^{\frac{\delta_k}{1-\sigma}}\right)' = 0$ if $j \neq k$ and $\left(\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)' = 0$ if $g(j) \neq g(k)$.

Case 1: $j=k$ (diagonal elements)

$$A = \left(e^{\frac{\delta_j}{1-\sigma}}\right)' \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} + e^{\frac{\delta_j}{1-\sigma}} \left(\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma}\right)'$$

$$= -\frac{\alpha}{1-\sigma} e^{\frac{\delta_j}{1-\sigma}} \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} + e^{\frac{\delta_j}{1-\sigma}} \times \frac{\alpha\sigma}{(1-\sigma)} \times \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} \times \frac{\overbrace{e^{\frac{\delta_j}{1-\sigma}}}^{=\hat{s}_{j|g}}}{\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}}$$

$$= -\frac{\alpha}{1-\sigma} e^{\frac{\delta_j}{1-\sigma}} \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} \left(1 - \sigma\hat{s}_{j|g}\right)$$

$$= -\frac{\alpha}{1-\sigma} \hat{s}_j \left(1 - \sigma\hat{s}_{j|g}\right) \times \left[\sum_{g=0}^{G} \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]$$

$$B = \left[\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]' = (1-\sigma)\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} \left(e^{\frac{\delta_j}{1-\sigma}}\right)'$$

$$= -\alpha e^{\frac{\delta_j}{1-\sigma}} \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma} = -\alpha\hat{s}_j \times \left[\sum_{g=0}^{G} \left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]$$

Plug back to equation (III.1),

$$\frac{ds_j}{dp_j} = \frac{-\frac{\alpha}{1-\sigma}\hat{s}_j\left(1-\sigma\hat{s}_{j|g}\right) \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} - \hat{s}_j \times \frac{-\alpha\hat{s}_j \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]}$$

$$= -\frac{\alpha}{1-\sigma}\hat{s}_j\left(1-\sigma\hat{s}_{j|g}\right) - \alpha\hat{s}_j\hat{s}_j$$

$$= -\alpha\hat{s}_j\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma}\hat{s}_{j|g} + \hat{s}_j\right)$$

Case 2: $j \neq k, g(j) = g(k)$ (different alternatives within the same nest)

$$A = \overbrace{\left(e^{\frac{\delta_k}{1-\sigma}}\right)'}^{=0} \left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma} + e^{\frac{\delta_k}{1-\sigma}} \left(\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)'$$

$$= e^{\frac{\delta_k}{1-\sigma}}(-\sigma)\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma-1} e^{\frac{\delta_j}{1-\sigma}} \times \frac{-\alpha}{1-\sigma}$$

$$= \frac{\alpha\sigma}{1-\sigma} \times \underbrace{\frac{e^{\frac{\delta_k}{1-\sigma}}}{\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}}}_{\hat{s}_{k|g}} \times \underbrace{e^{\frac{\delta_j}{1-\sigma}} \times \left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}}_{\hat{s}_j \times \sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}} = \frac{\alpha\sigma}{1-\sigma}\hat{s}_{k|g}\hat{s}_j \times \sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}$$

$$B = \left[\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]' = (1-\sigma)\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\left(e^{\frac{\delta_j}{1-\sigma}}\right)'$$
$$= -\alpha\hat{s}_j \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]$$

Plug back to equation (III.1),

$$\frac{ds_k}{dp_j} = \frac{\frac{\alpha\sigma}{1-\sigma}\hat{s}_{k|g}\hat{s}_j \times \sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} - \hat{s}_k \times \frac{-\alpha\hat{s}_j \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} = \alpha\hat{s}_j\left(\frac{\sigma}{1-\sigma}\hat{s}_{k|g} + \hat{s}_k\right)$$

Case 3: $j \neq k, g(j) \neq g(k)$ (different alternatives in different nests)

$$A = \overbrace{\left(e^{\frac{\delta_k}{1-\sigma}}\right)'}^{=0}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma} + e^{\frac{\delta_k}{1-\sigma}}\overbrace{\left(\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{-\sigma}\right)'}^{=0} = 0$$

$$B = \left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]' = \left[\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]' = -\alpha\hat{s}_j \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]$$

Plug back to equation (III.1),

$$\frac{ds_k}{dp_j} = -\hat{s}_k \times \frac{-\alpha\hat{s}_j \times \left[\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}\right]}{\left[\sum_{g=0}^{G}\left(\sum_{k\in g} e^{\frac{\delta_k}{1-\sigma}}\right)^{1-\sigma}\right]} = \alpha\hat{s}_j\hat{s}_k$$

Summary: Finally, I summarize the three cases together.

$$\frac{ds_k}{dp_j} = \begin{cases} -\alpha\hat{s}_j\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma}\hat{s}_{j|g} + \hat{s}_j\right) & j = k \\ \alpha\hat{s}_j\left(\frac{\sigma}{1-\sigma}\hat{s}_{k|g} + \hat{s}_k\right) & j \neq k, g(j) = g(k) \\ \alpha\hat{s}_j\hat{s}_k & j \neq k, g(j) \neq g(k) \end{cases}$$

Notes: (1) here $\alpha$ is the absolute value of the price coefficient. (2) when calculating the $\widehat{\Delta}_{jk} = -\frac{ds_k}{dp_j}$, one also needs to put an extra condition $f_j = f_k$ in each case to index for drug ownership.

C.2 Counterfactual estimation procedures

Two counterfactual situations are evaluated: 1) without a patent pool; 2) with a fully expanded patent pool (once a compound enters, no geographic segmentation within my sample period). The goal is to use estimated demand and supply parameters to simulate counterfactual prices and quantities in each scenario (under different market structure assumptions) and compute changes in consumer and producer surpluses.

In section 6, I investigate two broad cases in the supply-side market structure: marginal cost pricing and a Bertrand-Nash game. In the first case of marginal cost pricing, one can either assume marginal cost curves to be flat or increasing in quantity. Counterfactuals regarding the case with flat marginal cost curves are fairly straightforward as counterfactual prices can be simulated by adjusting the counterfactual values of the MPP variable. In this case, consumers obtain all the social surplus. Alternatively, when assuming marginal cost increases in quantity, a shift (down) in the supply curve will also affect equilibrium quantity. Regarding this case of competitive pricing with upward sloping marginal cost curve, I simulate counterfactuals using fixed point iterations.

In the second case of a Bertrand-Nash game, I simulate counterfactual prices, quantities, and marginal costs by optimization in each country-year market. This case is then broken down to three sub-cases: single product oligopoly and multi-product oligopoly. The major difference across the three cases lies in how I define the ownership matrix. In the single product case, only the diagonal elements in the substitution matrix are relevant to a firm's pricing decision. In the multi-product case, I assign ownership based on branded-firm's drug ownership and treat cross-firm cocktails as owned by a separate firm.

In the following part, I described more details regarding how to use fixed point algorithm or optimization to solve for the equilibrium values in relevant scenarios.

Fixed point iteration: competitive pricing with upward sloping MC curve

$$\hat{q}_j = \Pr_j(\hat{p}_j) \times M = \hat{s}_j(\hat{p}_j) \times M \quad (1)$$

$$\hat{p}_j = mc_j(\hat{q}_j) = \beta MPP_j^{cf} + X_j\gamma + \eta\hat{q}_j + \omega_j \quad (2)$$

To fix ideas, I use $MPP_j^{cf} = 0, \forall j$ (counterfactual: without the MPP) to elaborate below. Note that the MPP only enters through supply side but not via the demand side. The analytical form for $\hat{s}_j$ in equation (1) is as below.[7]

$$\hat{s}_j = \frac{e^{\frac{\delta_j}{1-\sigma}}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma}}{\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}}, \text{ where } \delta_j(\hat{p}_j) = X_j\beta + \xi_j - \alpha\hat{p}_j$$

Now, obtaining *counterfactual* equilibrium price and quantity using *fixed point algorithm*:

[7] More details are available from the book by Kenneth Train (2009) "Discrete Choice Methods with Simulation."

For each market (country-year), find $(\hat{p}_j, \hat{q}_j)\ s.t.$ (1) and (2) hold. Start with a guess $p_j^0$ close to the true value with a random component, e.g., $p_j^0 = p_j(0.95 + 0.1 * uniform(1))$.

Iteration #1:

$$\hat{q}_j^1 = \hat{s}_j(\hat{p}_j) \times M$$
$$\hat{p}_j^1 = \underbrace{X_j\gamma + \omega_j}_{\widehat{p_j - \eta q_j}} + \eta\hat{q}_j^1$$

… iteration # $l + 1$:

$$\hat{q}_j^{l+1} = \hat{s}_j(\hat{p}_j) \times M$$
$$\hat{p}_j^{l+1} = X_j\gamma + \omega_j + \eta\hat{q}_j^{l+1}$$

Continue until $\left\|p_j^{l+1} - p_j^l\right\| < \varepsilon$

<u>Numerical optimization: oligopolistic pricing, with single/multi-product firms</u>

$$\hat{p}_j = argmin_{p_j} \left\| \hat{p}_j - \widehat{mc}_j - \underbrace{\widehat{\Delta}_{jk}^{-1} \times \hat{s}_j}_{\widehat{makeup_j}} \right\|^2 \quad (1)$$

$$\hat{q}_j = \Pr_j(\hat{p}_j) \times M = \hat{s}_j(\hat{p}_j) \times M \quad (2)$$

$$mc_j(\hat{q}_j) = \beta MPP_j^{cf} + X_j\gamma + \eta\hat{q}_j + \omega_j \quad (3)$$

$$\hat{s}_j = \frac{e^{\frac{\delta_j}{1-\sigma}}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{-\sigma}}{\sum_{g=0}^{G}\left(\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}\right)^{1-\sigma}}, \text{ where } \delta_j(\hat{p}_j) = X_j\beta + \xi_j - \alpha\hat{p}_j \quad (4)$$

$$\widehat{\Delta}_{jk} = \begin{cases} \alpha\hat{s}_j\left(\frac{1}{1-\sigma} - \frac{\sigma}{1-\sigma}\hat{s}_{j|g} - \hat{s}_j\right) & ,j = k \\ -\alpha\hat{s}_j\left(\frac{\sigma}{1-\sigma}\hat{s}_{k|g} + \hat{s}_k\right) & ,j \neq k, g_j = g_k, f_j = f_k \\ -\alpha\hat{s}_j\hat{s}_k & ,j \neq k, g_j \neq g_k, f_j = f_k \\ 0 & ,o.w.(i.e., f_j \neq f_k) \end{cases} \quad (5)$$

$$\hat{s}_{j|g} = \frac{e^{\frac{\delta_j}{1-\sigma}}}{\sum_{j\in g} e^{\frac{\delta_j}{1-\sigma}}}, \text{ where } \delta_j(\hat{p}_j) = X_j\beta + \xi_j - \alpha\hat{p}_j \quad (6)$$

Here, for each market, a profit maximization decision is built within (1) to ensure that the counterfactual new price is generated from the Bertrand-Nash game by minimizing the squared distance between the price and the sum of marginal cost and markup. The latter two are simultaneously updated using (2) and (3) within the fmincon minimization within (1). I impose mild conditions that prices are positive and less than twice the actual non-counterfactual prices to ensure that price search is within a realistic range.

More specifically, the algorithm starts with an initial guess of $\hat{p}_j$ for each country-year market. It then calculates the objective function using $\hat{p}_j$, relevant demand and supply parameters, and the counterfactual marginal cost. The optimal new prices (from the first-order condition) are obtained using fmincon. The quantity and marginal cost are then updated with the above equation system.

Other counterfactuals

One can also obtain counterfactual estimations of oligopoly price setting with flat marginal cost curves. These results can be obtained with flexible adaptation to the above optimization code by revising the quantity part (setting the quantity coefficients to zero) and using supply-side parameters from corresponding estimations (with a flat marginal cost assumption).

Additional notes on an alternative estimation approach

Alternatively, one can get the quantity equation (1) using a simulation approach (less efficient).

One can obtain equation (1) by simulating demand from the nested logit utility function.

$$u_{ijct} = \underbrace{X_{jct}\beta - \alpha p_{jct} + \xi_{jct}}_{\delta_{jct} = \ln(s_j) - \ln(s_0) - \sigma \ln(s_{j|g})} + \zeta_{ig(j)ct} + (1-\sigma)\varepsilon_{ijct}$$

Therefore, the utility from counterfactual prices for a given $ct$ can be expressed as below. Where the $\zeta_{ig(j)} + (1-\sigma)\varepsilon_{ij}$ cannot be simulated with the independent GEV simulator in MATLAB, it shall be simulated using the inverse CDF approach based on the nested logit CDF (Train book, p. 79, equation (4.1)).

$$u_{ij}(\hat{p}_j) = \underbrace{X_j\beta + \xi_j}_{\delta_j - \alpha p_j} + \alpha\,\hat{p}_j + \zeta_{ig(j)} + (1-\sigma)\varepsilon_{ij}$$

To simulate the utility for $N_{sim}$ =100,000 consumers across drugs in a given market (country-year), draw $N_{sim} \times J$ nested logit errors from the Generalized Extreme Value (GEV) distribution. Here $j \in \{0,1,\dots,J\}$ indicates distinct drugs within a market, including the outside option 0. For each simulated consumer $i$, (1) calculate the $u_{ijct}, \forall j$, (2) find the $j$ that maximizes utility for $i$, and (3) define the realized choices for person $i$ as $z_j(i) = 1$ if $i$ choses $j$.

With the realized choices, one can calculate $\hat{s}_j = \frac{\sum_i^{N_{sim}} z_j(i)}{N_{sim}}$ and $\hat{q}_j = M \times s_j$ for a single market. Then, repeat the process for each country-year market and save the results into a vector for (2).

C.3 Graphic representation of model fit, and additional results

To test the performance of the optimization and fixed-point algorithm, I use actual data instead of counterfactual values to test whether I can reproduce actual prices and quantities. In addition, I run the algorithm multiple times and confirm the results are not sensitive to the initial guess. The numeric precision is about 99% in all of these placebo tests. I report graphic representation below. In all cases, the placebo prices and quantities fit well with the 45-degree lines.[8]

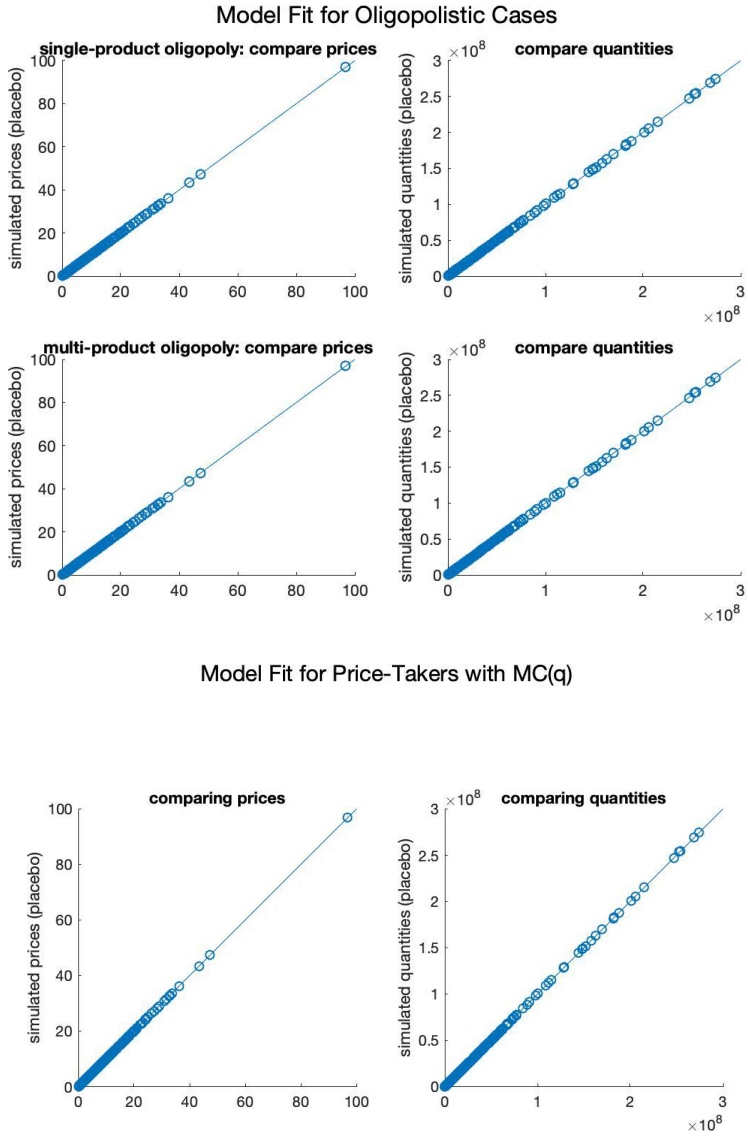



Figure C1: Graphical Demonstration of Model Fits

[8] I also produced corresponding graphs for "actual *vs.* counterfactual" and they are available upon request.

Additional results with alternative marginal cost assumptions

In the main analyses, I use flat marginal cost for competitive pricing and increasing marginal cost for oligopolistic pricing. These assumptions are good choices to capture the differences that capacity constraints matter in the two cases I study. This also provides more conservative estimates of the welfare gains from the MPP to consumers and producers.

As an additional exercise and comparison, I also produce the opponent counterfactuals: specifically, for price-taking firms with increasing marginal cost curves and oligopolistic pricing with flat marginal cost curves. From a realistic standpoint, the former case is more interesting as a transition stage of the two cases I discuss in the main text. However, it is worth noting that "price-takers with increasing marginal cost curve" is a typical case where the counterfactual producer surplus can explode. The reason is that when extrapolating the MC(q=0) point that is needed for calculating the producer surplus triangle, the MC(q) curve would generate many negative prices with small quantities that would not be observed in the data. In other words, the in-sample fit can be fine, but 0.5*beta(q)*$q^2$ provides overly large estimations for producer surplus (grey numbers), despite the still reasonable estimates of relative changes. The "oligopolistic pricing with flat MC" case uses strong assumptions that firms actively optimize and extract profit in LMIC without any capacity constraints, which contradicts reality and thus generates larger divisions in counterfactual cases. I report them below for a comparison.

Table C1: Welfare Re-Estimation: Alternative MC Assumptions

| welfare estimates ($ M) | MC pricing MC(q) | Oligopolistic Pricing (w/ flat MC) single-prod. firm | multi-prod. firm |
|---|---|---|---|
| $E(\widehat{CS_0})$ | 8,112.5 | 6,409.2 | 6,246.4 |
| $E(CS)$ | 8,747.7 | 8,747.7 | 8,747.7 |
| $E(\widehat{CS_1})$ | 8,836.3 | 8,821.1 | 8,811.5 |
| Δ$: $CS_0$ | 635.2 | 2,338.5 | 2,501.3 |
| Δ%: $CS_0$ | 7.83% | 36.49% | 40.04% |
| Δ$: $CS_1$ | 88.6 | 73.4 | 63.8 |
| Δ%: $CS_1$ | 1.01% | 0.84% | 0.73% |
| $E(\widehat{PS_0})$ | 252$B | 3,071.3 | 3,315.2 |
| $E(PS)$ | 266$B | 4,179.5 | 4,309.6 |
| $E(\widehat{PS_1})$ | 267$B | 4,271.8 | 4,392.1 |
| Δ$: $PS_0$ | 14.1$B | 1,108.2 | 994.4 |
| Δ%: $PS_0$ | 5.58% | 36.08% | 30.00% |
| Δ$: $PS_1$ | 338.4 | 92.3 | 82.5 |
| Δ%: $PS_1$ | 0.13% | 2.21% | 1.91% |

Additional graphs regarding these additional cases are available upon request.

## Appendix D: Medical Appendix

### Brief Explanation of the Background and Classes of Antiretroviral Therapy

Human immunodeficiency virus (HIV) infects the immune system's cells, resulting in the impairment or destruction of their functions. Such an infection leads to the progressive deterioration of the immune system, generating *immune deficiency*. This deficiency can be defined as the condition in which the immune system can no longer fight any infection or disease. Unlike certain other viruses, HIV does not allow the human body to disinfect itself completely. Once a patient infected with HIV, that patient will have it for life. Consequently, acquired immunodeficiency syndrome (AIDS) can develop when HIV is left untreated. This stage of infection occurs when one's immune system is badly damaged, making one vulnerable to *opportunistic infections* – infections that occur more frequently and severely among people with a weakened immune system. Such infections include tuberculosis and several cancers. Although AIDS is the final stage of HIV infection, not everyone who has HIV advances to this stage. An HIV infection can be contracted through three main routes: (1) unprotected sexual intercourse; (2) the sharing of contaminated syringes, needles, surgical equipment or other sharp instruments and transfusion of contaminated blood; (3) from a mother to her infant during pregnancy, childbirth, and breastfeeding.

People with AIDS left untreated typically survive about three years on average. Once dangerous opportunistic illnesses develop, an infected person's life expectancy without treatment falls to about one year. Although medical treatment is necessary to prevent the death of AIDS patients, no effective cure currently exists. However, with proper treatment, it is possible to control HIV. The medicine used for the treatment of HIV is antiretroviral therapy (ART). According to the WHO guidelines, standard ART consists of a combination of drugs to maximally suppress HIV and inhibit the disease's progression. In addition, this therapy prevents further transmission of HIV. As a result, huge reductions in death rates and infection rates have been documented when using a potent ART regimen, especially in the early stages of the disease. The WHO recommends that people with HIV undergo ART as soon as possible after diagnosis without restrictions of the CD4 counts (a type of immune cells greatly reduced in HIV patients). It also recommends pre-exposure prophylaxis for people at high risk of HIV infection as an additional option among other non-drug based comprehensive prevention plans.

Table D1: ART drug classes

| Drug class (abbr.) | Simple description (mechanisms of action explanations) |
|---|---|
| Nucleoside Reverse Transcriptase Inhibitors (NRTIs) | block reverse transcriptase, an enzyme HIV needs to make copies of itself. |
| Non-Nucleoside Reverse Transcriptase Inhibitors (NNRTIs) | bind to and later alter reverse transcriptase, an enzyme HIV needs to make copies of itself. |
| Protease Inhibitors (PIs) | block HIV protease, an enzyme HIV needs to make copies of itself. |
| Fusion inhibitor (FIs) | block HIV from entering the CD4 cells of the immune system, e.g., HR1. |
| Entry inhibitor (EIs) | block proteins on the CD4 cells that HIV needs to enter the cells, CCR5. |
| Integrase Inhibitors (IIs) | stop HIV from making copies of itself by blocking a key protein that allows the virus to put its DNA into the healthy cell's DNA. |
| Enhancers | help other ART work better by enhancing the blood levels. |

Notes: (1) the distinctions between FIs and EIs are not substantial, mainly on which protein the drug binds to block HIV virus from entering the CD4 cells. In many cases they are grouped together into one broader class. (2) Entry inhibitors have multiple sub-classes, e.g., CCR5 inhibitor, post-attachment inhibitor (the new compound, IBA), etc.

Table D2: Clinical Guidelines on ART Standard Dosing (U.S. adult daily doses)

| drug API code | adult daily dose | Notes |
|---|---|---|
| ABC | 600 mg | |
| ATV | 300 mg | |
| DRV; TCM | 800 mg | |
| ddI | 400 mg | 250mg/d if weight <60kg |
| DTG | 50 mg | |
| EFV | 600 mg | |
| FTC | 200 mg | |
| ENF; T20 | 180 mg | |
| ETR; ETV | 400 mg | |
| FPV | 1400 mg | |
| IDV | 1600 mg | |
| 3TC | 300 mg | |
| MVC | 600 mg | |
| NFV | 2500 mg | 2250 mg when taken 3 times/day |
| NVP | 400 mg | Phase in: 200mg in the first 14 days |
| RAL | 800 mg | |
| r; RTV | 200 mg | The avg./mode: 100-400mg/d; depends on other compounds used |
| SQV | 2000 mg | |
| d4T | 80 mg | 60mg if weight <60kg. |
| TDF | 300 mg | |
| TPV | 1000 mg | |
| ZDV; AZT | 600 mg | FDA: 600mg; WHO 250-300mg |
| ABC+3TC | 600+300 mg | |
| ABC+3TC+ZDV | 600+300+600 mg | |
| ATV+r | 300+100 mg | |
| EFV+FTC+TDF | 600+200+300 mg | |
| EFV+3TC+TDF | 600+300+300 mg | |
| EFV+3TC+ZDV | 600+300+600 mg | |
| FTC+TDF | 200+300 mg | |
| 3TC+NVP+d4T | 300+400+80 mg | if <60kg, then 300+400+60 mg |
| 3TC+NVP+ZDV | 300+400+600 mg | |
| 3TC+d4T | 300+80 mg | |
| 3TC+TDF | 300+300 mg | |
| 3TC+TDF+NVP | 300+300+400 mg | |
| 3TC+ZDV | 300+600 mg | |
| LPV+r | 800+200 mg | |

Notes: This table is used to convert active pharmaceutical ingredients (API) into standardized U.S. adult drug daily doses as a quantity-adjusted measure. Five observations in grey are dropped from the sample as they only appear in the data a handful of times. I checked drug dosing guidelines using AIDS*info* and FDA labeling, and consulted WHO guidelines for global standards. The above measures are recorded as adult daily dosing for a representative patient weighting over 60 kg (average adult weights are above 60 kg in most countries but can be smaller in low-income and developing countries). The localized doses can be smaller than the U.S. guideline in resource-limited developing countries. In the absence of country-specific clinical guidelines, I use this U.S. adult-based conversion as one outcome of interest.

## Table D3: 2017 and 2012 top selling HIV drugs and MPP status

The two tables here are used to demonstrate top-selling HIV drugs.

Table D3.1: HIV drugs among 2017 top 200 drugs by global sales

| rank 2017 | HIV drugs among top 200 drugs by global sales, 2017 | generic abbreviations | MPP status (by 12/31/2017) | sales ($M) |
|---|---|---|---|---|
| 24 | Genvoya | EVG+TAF+FTC+COBI | all in | 3,730 |
| 31 | Triumeq | ABC+DTG+3TC | out*+in+out | 3,172 |
| 32 | Truvada | FTC+TDF | all in | 3,169 |
| 72 | Prezista/Prezcobix/Rezolsta | [Prezista]: DRV; [Prezcobix/Rezolsta for US/Europe]:DRV+COBI | out$; out$+in | 1,821 |
| 74 | Tivicay | DTG | in | 1,810 |
| 75 | Atripla | EFV+FTC+TDF | out+in+in | 1,806 |
| 100 | Descovy | FTC+TAF | in | 1,300 |
| 109 | Isentress and Isentress HD | RAL | out* | 1,204 |
| 120 | Odefsey | FTC+RPV+TAF | out+in | 1,106 |
| 126 | Stribild | EVG+COBI+FTC+TDF | all in | 1,054 |
| 129 | Viread | TDF | in | 1,046 |
| 139 | Complera/Eviplera | [US/European]: RPV+FTC+TDF | out+in+in | 966 |
| 191 | Sustiva franchise (includes sales of bulk efavirenz) | EFV | out | 729 |
| 196 | Edurant/rilpivirine | RPV | out | 714 |

Table D3.2: HIV drugs among 2012 top 100 drugs by global sales

| rank 2012 | HIV drugs among top 100 drugs by global sales, 2012 | generic abbreviations | MPP status (by 12/31/2017) | sales ($M) |
|---|---|---|---|---|
| 26 | Atripla | EFV+FTC+TDF | out+in+in | 3574 |
| 29 | Truvada | FTC+TDF | all in | 3,303 |
| 67 | Sustiva franchise (includes sales of bulk efavirenz) | EFV | out | 1,527 |
| 68 | Reyataz | ATV | in | 1521 |
| 71 | Isentress | RAL | out* | 1515 |
| 76 | Prezista | DRV | out$ | 1414 |

Notes: out* means restrictive MPP licenses (pediatric-only) and treated as outside the pool for conservative estimates. out$ means the corresponding drug is not officially in the pool but have price arrangements with the MPP. The top selling drug list is obtained from Med Ad News report and has been used in previous studies. For more details regarding the source, see Duggan and Scott Morton (2006).

Reference: Duggan, M., & Scott Morton, F. M. (2006). The distortionary effects of government procurement: evidence from Medicaid prescription drug purchasing. *The Quarterly Journal of Economics*, *121*(1), 1-30.

## Appendix E: Legal Appendix

Table E1: Key MPP license contract terms
(Simple explanations of abbreviations are listed at the end of the table)

| API code | firm | eligibility for sublicenses (manufacturing) | sales scope: # countries | sales outside territory | royalty rates (in territory) | technology transfer | additional flexibilities |
|---|---|---|---|---|---|---|---|
| ABC (ped.) | ViiV | worldwide | 121 | permitted if no granted patents or non-infringing | 0% | n/a | challenge |
| ATV | BMS | worldwide | 122 | enables those not relying on BMS tech to sell if not infringe granted patents | 3%: adult forms in countries w/ patents; 0%: ped., or sub-Saharan/ India sales | provided to all sublicensees, no obligation to use | n/a |
| BIC | Gilead | China, India, South Africa | 116 | permitted if compulsory license issued | 5% of FP net sales. 0% on API/ped. formulation. | one time for Indian & South-African sub-licensees | terminate; challenge |
| COBI | Gilead | China, India, South Africa | 116 | permitted if compulsory license issued | 5% of FP net sales. 0% on API/ped. forms. | one time for Indian & South-African sub-licensees | terminate; challenge |
| DTG (adult; ped.) | ViiV | worldwide | adult: 94; ped.: 121 | permitted if no granted patents or non-infringing | 0%: all ped. & adults in 82 countries; 5%: Philippines, India, Vietnam, Moldova; 7.5%: Egypt, Indonesia, Morocco, Armenia, Ukraine, Mongolia, Tunisia; 10%: Turkmenistan | n/a | challenge |
| EVG | Gilead | China, India, South Africa | 109 | permitted if compulsory license issued | 5% of FP net sales. 0% on API/ped. sales | one time for Indian sub-licensees | terminate; challenge |
| FTC | Gilead | China, India, South Africa, & licensed on TDF, TAF, COBI, EVG, even if terminated | 116 | possible if not infringe any granted patents | 0%; there may be royalties on other components of any specific combination | n/a | licensees terminated TDF can still benefit from no-sue on tdf/ftc, taf/ftc, & tdf/ftc/efv |
| LPV/r (adult; ped.) | AbbVie | worldwide | adult: all 54 African; ped.: 102 | permitted if not infringe granted patents | 0% | n/a | challenge |
| RAL (ped.) | MSD | worldwide | 92 | permitted if not infringe granted patents | 0% | n/a | challenge |
| TAF | Gilead | China, India, South Africa | 116 | permitted if compulsory license issued | 5% of FP net sales. 0% on API/ped. sales | one time for Indian sub-licensees | terminate; challenge |
| TDF | Gilead | China, India, South Africa | 116 | permitted if compulsory license issued | 3-5% of FP net sales. 0% on API/ped. sales. | one time for Indian & South-African sub-licensees | terminate |

Notes: (1) common information omitted in the table: all of these licenses allow flexible compound combinations, all waive data exclusivity, all agree patents pooled include all pending and granted patents, and all agree to let WHO or a stringent regulatory authority (SRA), such as U.S. FDA, to help with quality-assurance. (2) A typical example for sales outside of territory when non-infringing is in the presence of compulsory license. (3) the sublicensing territory defines the manufacturing territory and the sales scope defined the countries available for sales using MPP licenses. (4) The "countries" defined in the sale scope (geographic territory) are economies/countries as in the World Bank/United Nations definition, but not necessarily a sovereign state (e.g., certain commonwealths are treated as an independent "country" in measures of economics/development). (5) API = Active Pharmaceutical Ingredient (i.e., compound, for small molecule drugs). FP = finished products. (6) Contracts regarding "manufacturing" in the MPP typically do not distinguish between API vs. FP manufacturers. (7) In the last column, "challenge" = allow patent challenges; "terminate" = allow termination of licensing agreements.

Source: The Medicines Patent Pool official website product page (https://medicinespatentpool.org/what-we-do/global-licence-overview/licences-in-the-mpp/), collected from each compound's key features and detailed/corrected a few incidences with raw information from the MPP (sub-)licensing contracts. Last updated: December 31, 2018.

## Panel E2: Drug-Territory Coverage Final Panel (by end of 2018)

| Country names | code | ldc | atv | bic | cobi | dtg | evg | ftc | lpv/r | taf | tdf |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Afghanistan | AFG | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Algeria | DZA | 0 | 2017 | | | | | | 2015 | | |
| Angola | AGO | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Anguilla | AIA | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Antigua and Barbuda | ATG | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Armenia | ARM | 0 | 2013 | 2017 | 2011 | 2016 | 2011 | 2011 | | 2014 | 2011 |
| Aruba | ABW | 0 | | 2017 | 2011 | | | 2011 | | 2014 | 2011 |
| Azerbaijan | AZE | 0 | 2013 | | | | | | | | |
| Bahamas | BHS | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Bangladesh | BGD | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Barbados | BRB | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Belarus | BLR | 0 | 2013 | 2017 | 2017 | | | 2017 | | 2017 | 2017 |
| Belize | BLZ | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Benin | BEN | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Bhutan | BTN | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Bolivia | BOL | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Botswana | BWA | 0 | 2013 | 2017 | 2017 | 2014 | 2017 | 2011 | 2015 | 2014 | 2011 |
| British Virgin Islands | VGB | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Burkina Faso | BFA | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Burundi | BDI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Cambodia | KHM | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Cameroon | CMR | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Cape Verde | CPV | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Central African Republic | CAF | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Chad | TCD | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Comoros | COM | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Cook Islands | COK | 0 | 2017 | | | | | | | | |
| Costa Rica | CRI | 0 | 2013 | | | | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Côte d'Ivoire | CIV | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Cuba | CUB | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Dem. Republic of the Congo | COD | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Djibouti | DJI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Dominica | DMA | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Dominican Republic | DOM | 0 | 2013 | 2017 | 2011 | | | 2011 | | 2014 | 2011 |
| Ecuador | ECU | 0 | 2013 | 2017 | 2017 | | 2017 | 2011 | | 2014 | 2011 |
| Egypt | EGY | 0 | 2017 | | | 2014 | | | 2015 | | |
| El Salvador | SLV | 0 | 2013 | 2017 | 2017 | 2014 | 2017 | 2011 | | 2014 | 2011 |
| Equatorial Guinea | GNQ | 0 | 2017 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Eritrea | ERI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Ethiopia | ETH | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Fiji | FJI | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Gabon | GAB | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Gambia | GMB | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Georgia | GEO | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Ghana | GHA | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Grenada | GRD | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Guatemala | GTM | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Guinea | GIN | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Guinea-Bissau | GNB | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Guyana | GUY | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Haiti | HTI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Honduras | HND | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| India | IND | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Indonesia | IDN | 0 | 2017 | 2017 | 2017 | 2014 | 2017 | 2011 | | 2014 | 2011 |
| Iraq | IRQ | 0 | 2013 | | | | | | | | |
| Jamaica | JAM | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Kazakhstan | KAZ | 0 | 2013 | 2017 | 2017 | | 2017 | 2011 | | 2014 | 2011 |
| Kenya | KEN | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Kiribati | KIR | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Korea Dem. Republic | PRK | 0 | 2013 | | | 2014 | | | | | |
| Kosovo | XKX | 0 | | | | 2014 | | | | | |
| Kyrgyzstan | KGZ | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Lao PDR | LAO | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Lebanon | LBN | 0 | | | | | | | | | |
| Lesotho | LSO | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Liberia | LBR | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Libya | LBY | 0 | 2013 | | | | | | 2015 | | |
| Madagascar | MDG | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Malawi | MWI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Malaysia | MYS | 0 | 2017 | 2017 | 2017 | | | 2017 | | 2017 | 2017 |
| Maldives | MDV | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Mali | MLI | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Marshall Islands | MHL | 0 | 2013 | | | | | | | | |
| Mauritania | MRT | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Mauritius | MUS | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Micronesia | FSM | 0 | 2013 | | | 2014 | | | | | |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moldova | MDA | 0 | 2013 | 2017 | 2011 | 2016 | 2011 | 2011 | | 2014 | 2011 |
| Mongolia | MNG | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Montserrat | MSR | 0 | | 2017 | 2011 | | | 2011 | | 2014 | 2011 |
| Morocco | MAR | 0 | 2017 | | | 2016 | | | 2015 | | |
| Mozambique | MOZ | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Myanmar | MMR | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Namibia | NAM | 0 | 2013 | 2017 | 2017 | 2014 | 2017 | 2011 | 2015 | 2014 | 2011 |
| Nauru | NRU | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Nepal | NPL | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Nicaragua | NIC | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Niger | NER | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Nigeria | NGA | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Niue | NIU | 0 | 2017 | | | | | | | | |
| Pakistan | PAK | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Palau | PLW | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Palestine | PSE | 0 | 2013 | | | 2014 | | | | | |
| Panama | PAN | 0 | 2013 | | | | | | | | |
| Papua New Guinea | PNG | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Philippines | PHL | 0 | 2017 | 2017 | 2017 | 2014 | | 2017 | | 2017 | 2017 |
| Republic of the Congo | COG | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Rwanda | RWA | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Samoa | WSM | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Sao Tome and Principe | STP | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Senegal | SEN | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Seychelles | SYC | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Sierra Leone | SLE | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Solomon Islands | SLB | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Somalia | SOM | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| South Africa | ZAF | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| South Sudan | SSD | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Sri Lanka | LKA | 0 | 2013 | 2017 | 2017 | 2014 | 2017 | 2011 | | 2014 | 2011 |
| St Lucia | LCA | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| St. Kitts and Nevis | KNA | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| St. Vincent & the Grenadines | VCT | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Sudan | SDN | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Suriname | SUR | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Swaziland | SWZ | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Syrian Arab Republic | SYR | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Tajikistan | TJK | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Tanzania | TZA | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Thailand | THA | 0 | | 2017 | 2017 | | 2017 | 2011 | | 2014 | 2011 |
| Timor-Leste | TLS | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Togo | TGO | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Tonga | TON | 0 | 2013 | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Trinidad and Tobago | TTO | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |
| Tunisia | TUN | 0 | 2017 | | | 2014 | | | 2015 | | |
| Turkmenistan | TKM | 0 | 2013 | 2017 | 2017 | 2014 | 2017 | 2011 | | 2014 | 2011 |
| Turks and Caicos Islands | TCA | 0 | | 2017 | 2011 | | 2011 | 2011 | | 2014 | 2011 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Tuvalu | TUV | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Uganda | UGA | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Ukraine | UKR | 0 | 2017 | 2017 | 2017 | 2016 | | 2017 | | 2017 | 2017 |
| Uzbekistan | UZB | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Vanuatu | VUT | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Vietnam | VNM | 0 | 2017 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Yemen | YEM | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | | 2014 | 2011 |
| Zambia | ZMB | 1 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |
| Zimbabwe | ZWE | 0 | 2013 | 2017 | 2011 | 2014 | 2011 | 2011 | 2015 | 2014 | 2011 |

Notes: The above table include the complete licensing territories for adult formulations specified in MPP contracts by end of 2018. Among all the countries that ever covered in the MPP territory, only three are not developing countries by the World Bank 2018 classifications: Belarus, Moldova, and Ukraine. The country code reported in the table and used in the analysis is the ISO three-digit alphabetical code that uniquely identify a country. Given the multiple ways of country name spellings and historical country name changes (e.g., most recently in Apr. 2018, Swaziland to eSwatini), the most rigorous way is to merge any country-involved data set using country codes instead of country names.

## List of the 103 countries (and code) covered in the Global Fund data in the Diffusion Analysis:

Afghanistan (AFG), Albania (ALB), Angola (AGO), Armenia (ARM), Azerbaijan (AZE), Bangladesh (BGD), Belarus (BLR), Belize (BLZ), Benin (BEN), Bhutan (BTN), Bolivia (Plurinational State) (BOL), Bulgaria (BGR), Burkina Faso (BFA), Burundi (BDI), Cambodia (KHM), Cameroon (CMR), Cape Verde (CPV), Central African Republic (CAF), Chad (TCD), China (CHN), Colombia (COL), Comoros (COM), Congo (COG), Congo (Democratic Republic) (COD), Croatia (HRV), Cuba (CUB), CÃ´te d'Ivoire (CIV), Djibouti (DJI), Dominican Republic (DOM), Ecuador (ECU), Egypt (EGY), El Salvador (SLV), Equatorial Guinea (GNQ), Eritrea (ERI), Ethiopia (ETH), Gabon (GAB), Gambia (GMB), Georgia (GEO), Ghana (GHA), Guatemala (GTM), Guinea (GIN), Guinea-Bissau (GNB), Guyana (GUY), Haiti (HTI), Honduras (HND), India (IND), Indonesia (IDN), Iran (Islamic Republic) (IRN), Jamaica (JAM), Jordan (JOR), Kazakhstan (KAZ), Kenya (KEN), Kyrgyzstan (KGZ), Lao (Peoples Democratic Republic) (LAO), Lesotho (LSO), Liberia (LBR), Macedonia (Former Yugoslav Republic) (MKD), Madagascar (MDG), Malawi (MWI), Mali (MLI), Mauritania (MRT), Mauritius (MUS), Moldova (MDA), Mongolia (MNG), Morocco (MAR), Mozambique (MOZ), Myanmar (MMR), Namibia (NAM), Nepal (NPL), Nicaragua (NIC), Niger (NER), Nigeria (NGA), Pakistan (PAK), Palestine (PSE), Papua New Guinea (PNG), Paraguay (PRY), Peru (PER), Philippines (PHL), Russian Federation (RUS), Rwanda (RWA), Sao Tome and Principe (STP), Senegal (SEN), Sierra Leone (SLE), Somalia (SOM), South Africa (ZAF), South Sudan (SSD), Sri Lanka (LKA), Sudan (SDN), Suriname (SUR), Swaziland (SWZ), Tajikistan (TJK), Tanzania (United Republic) (TZA), Thailand (THA), Timor-Leste (TLS), Togo (TGO), Tunisia (TUN), Uganda (UGA), Ukraine (UKR), Uzbekistan (UZB), Viet Nam (VNM), Yemen (YEM), Zambia (ZMB), Zimbabwe (ZWE)

## Appendix F: Case Studies on R&D

To supplement the innovation results, I provide a few qualitative cases on new generic drugs that have stemmed from the MPP and firms' decisions or reactions during the process. Although ex ante unclear, new products created by MPP generic licensees can benefit branded firms by offering a higher market value in developing countries outside the MPP territories. For example, the new single-pill once-daily cocktail TLD was first approved by a generic firm in 2018 and recommended by the WHO as a starting therapy for treatment naïve patients in the same year. This WHO recommendation can potentially increase branded sales in other middle-income countries that are not covered by the pool.

Branded firms are not active in developing pediatric formulations, partly because most pregnant women in the U.S. are tested for HIV. Mother-to-children transmission can then be prevented by suppressing the viral load during pregnancy with HIV drugs. The lack of a pediatric version mainly affects developing countries and low-income populations in developed countries. Under such a circumstance, pooled licensing can induce socially beneficial innovation by allowing generic firms to develop localized solutions. For example, the first pediatric granules formulation for lopinavir/ritonavir (LPV/r) was developed by generic firms with MPP licenses and gained FDA approvals in 2018. If needed, branded firms can be granted back low-cost non-exclusive licenses for patents on this new formulation.

Once participating in the pool, branded firms may adjust R&D strategies accordingly. The case of Gilead's pool participation and R&D decisions illustrate this point. Gilead joined the MPP in July 2011 and contributed several approved drugs, including tenofovir disoproxil fumarate (i.e., TDF, a prodrug of tenofovir).[9] Gilead then started phase II trials of tenofovir alafenamide fumarate (i.e., TAF, a prodrug of TDF) in December 2011, collected primary results in October 2012, and started phase III trials in December 2012. The phase III trials on a TAF cocktail were completed with main results in 2014, and TAF was licensed to the MPP in the same year, before the 2015 FDA approval. It is worth noting that the earliest clinical trial of TAF was completed in 2003. Although a firm's phase III trial decision can be affected by many factors, the timeline suggests that Gilead is at least not reducing R&D after MPP participation.[10]

In addition, discussions with practitioners suggest that drug access programs can benefit branded firms by improving corporate image. This change can increase employee retention and attract institutional investors (e.g., pension funds) who would invest in firms that actively make a social impact. Generic licensing via the MPP can be a cost-effective way to reach these goals.

[9] Prodrug is an inactive compound that can be metabolized into a pharmacologically active form within the body. In many cases, prodrug can improve the absorption of a drug with lower dose and side-effects.
[10] Furthermore, Gilead started phases II/III trials on tenofovir-based microbicides in 2012, while the phase I trials were finished in 2008. Those trials are joint with partners in the public sector from South Africa. Because microbicides belong to a new drug class that is more valuable to developing countries, Gilead's decision may reflect a combination of factors, among which can be its engagement with the MPP.

## Appendix G: Historical Patent Pools

Notes: First, I summarize key features of some historical patent pools surveyed in Serafino (2007), the most comprehensive survey that describes the details of many historical patent pools. Second, I tabulate findings in empirical studies regarding a few patent pools and their historical context. Finally, I elaborate some features in the pool design, industry contexts, and measures that can reconcile the differences in theoretical and empirical studies, and I further explain how these features can partly explain my finding.

Table G1: Brief summary of key features of patent pools

I. Early pools associated with monopolies and cartels (1856-1919)

| pool names (year, industry) | purpose | management | royalties/ licensing terms | economic consequences/other notes |
|---|---|---|---|---|
| [1] Sewing Machine Combination (1856, sewing machine) | to avoid litigation between patent-holders and to maintain high prices. | 3 manufacturers started the pool, E. Howe (who holds vital patents and a firm) also joined later. | $15 per machine produced by the licensees. Of that, $5 to Howe, $3 to a legal fund, and the $7 divided equally among the four members. | (1) mass-production of sewing machines. Annual production growed 5-fold within 5 years. (2) home-use sewing machines were made possible with all patented technologies. (3) price was reduced by 50% the day the last pooled patent expired. |
| [2] National Harrow Company (1890, harrows) | defuse litigation between patent-holders; enable price-fixing between manufacturers | formed as a patent-administrating holding company among 6 firms controlling 90% of the U.S. market in spring tooth harrow production. | $1 per harrow sold; firms need to adhere to pool-set uniform price schedules (e.g., min prices & max sales quotas). | (1) one firm sold below the set prices and was sued by the others in the pool. (2) the 1902 Supreme Court held in favor of the pool in response to the price-cutting firms' allegation of Sherman Act violation. |
| [3] United Shoe Machinery Company (1899, shoes) | to control the American shoe market with thousands of interrelated patents. | resulted from a merge of three companies. | NA | In Dec. 1947, the United States sued United Shoe for violating the Sherman Act for their monopoly levied by thousands of interrelated patents. The Supreme Court ruled against United Shoe in 1954. |
| [4] Association of Licensed Automobile Manufacturers (ALAM) (1903, automobiles) | to manage patents on automobiles, started with a single patent that covered petroleum-burning engine in a car. Other patents were added to the pool later. | the Electric Vehicle Company (EVC) formed the pool w/ other firms. Firms wanted to sublicense had to prove prior experience in automobile manufacturing (i.e., admit infringement), thus excluded all new entrants. | 1.25% royalty rate on all cars produced. 2/5 of that went to the EVC, 1/5 to the inventor, and 2/5 to the ALAM treasury to handle legal expenses. | H. Ford was rejected for sublicensing, entered production regardless, and sued by the pool in 1903. The patent was upheld by a district court in 1909 but overturned by the court of appeals in 1911. The industry was convinced that patent war was self-destructive, and firms set up a cross-licensing system for most patents in 1915. |
| [5] Motion Picture Patents Company (MPPC) (1908, motion pictures) | to form a cartel to bring suit against independent filmmakers | T. Edison owned most patents and entered into a trust with all the major film firms, patent-holders, and the biggest raw film supplier. | MPPC use one license clause to compel licensors not to use motion picture machines from competitors. | The Supreme Court cancelled all MPPC patents in 1915 after cancelling their patents on raw film in 1915, and the court further found the MPPC in violation of the Sherman Act in 1917 and disbanded the MPPC. |

| | | | | |
|---|---|---|---|---|
| [6] Association of Sanitary Enameled Ware Manufacturers (Standard Sanitary) (1909, enamelware) | to form a cartel to fix prices and exclude other manufacturers from the market | formed by firms with key patents and controlled 85% of the market. A committee of 5 firms administers the license & resale agreements. (e.g., prohibit sales to those dealing with non-pool firms; unify trademark.) | $5 per day per furnace; provided for the return of 80% of royalties, assuming that licensees obey the contract. (and, penalize price schedule violations; preferential prices to certain firms) | The Supreme Court ended the pool in 1916 because it included anticompetitive provisions and ended a period where patent pools were free from scrutiny under U.S. antitrust laws. |
| [7] Standard Oil Cracking Pool (1911, oil cracking) | to (1) create a monopoly and to (2) restrain interstate commerce by controlling gasoline supply produced by cracking. | 4 patent holders (firms) and 46 licensees in 79 contracts. All 4 firms were released from past infringement liability and obtained the rights to use one another's patents in their own processes. | Royalties were divided among the 4 firms on a fixed share. Each firm was entitled to sub-license all the patents, and to share in a fixed percentage of all the royalties. | The pool licensed over 70 refiners. The 1931 Supreme Court ruled that pools were not necessarily anticompetitive, were sometimes necessary to reduce litigation, and could set suitable royalty rates as long as not excluding interested firms. |
| [8] Davenport folding beds (1916, folding beds) | to form a cartel | The Seng Company entered into an exclusive licensing arrangement in 1916 with patent holders (Pullman co.: 13 patents, another firm: 7 patents, and two independent inventors: one patent each) and gained the right to manufacture and sell products in the pool. | 33% royalties to the Pullman co.; the rest were allotted by a formula in the pooling agreement. The Seng Co. paid a fixed share into the pool. | NA |
| [9] Glass Container Association of America (Hartford-Empire) (1919, glass container) | to assign production quotas, fix prices, compile all essential patents, and exclude new competitors | managed by a 7-member board with outside input from Hartford-Empire to ensure production quotas and price-fixing. The 7 firms were later consolidated with Hartford-Empire in the pool agreement. | NA | Hartford-Empire controlled over 600 patents (used in producing 94% of the U.S.-made glass products), when a district court ruled in 1942 that the pool violated the Sherman Act. The decision was upheld by the Supreme Court in 1945. The court did not disband the pool but allowed it to use a revised, uniform royalty regime. |
| [10] National Lead Co. (1920, titanium-based pigments) | National Lead Co. and other producers settled their patent claims with a set of cross-licensing agreement; to fix prices by limiting global competition. | Major firms: In 1920, National Lead and a Norwegian firm started a cross-licensing agreement. In Jan 1933, National Lead and DuPont used a similar licensing agreement restricting competition. | Under the cross-licensing terms, firms retained rights to one another's patents, within exclusive regions. | In 1947, DuPont and National Lead controlled 90% of the U.S. market, when the court ruled that the division of market by territory violated the Sherman Act. The contracts involving present and future patents as well as know-hows contributed to a patent thicket and created entry barriers to the domestic market. |

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| [11] New Wrinkle (1937, wrinkle finish products) | 3 firms jointly incorporated a company (New Wrinkle, Inc.) to license their competing patents, i.e., to fix prices and to reduce litigation. | The pool was the licensing agent but did not produce any products covered by its patents. | 5-cent per gallon product sold or used by licensees; allowed for reduced royalties to all licensees if any subsequent license granted lower royalty rates; fix min prices. | In 1952, the Supreme Court ruled that the purpose and result of the pool (to fix prices) violated the Sherman Act. |
| [12] Line Material Co. (1938, dropout fuse cutouts – electronic devices) | 2 firms owned patents with necessary claims of the technology formed a pool to fix prices. | One firm was the exclusive licensor, and both firms were allowed to make and sell devices using both patents. | royalty-free cross-licensing; divided royalties and expenses between the two firms; and set a price schedule for sublicensees. | In 1948, the Supreme Court ruled that the price-fixing cross-licensing arrangement violated the Sherman Act and disbanded the pool. |
| [13] Singer '401' (1956, zigzag sewing machines) | formed by Singer (the sole U.S. firm) and its Italian and Swiss competitors to bar Japanese firms from the U.S. market. | used a series of inter-related cross-licensing agreements between Singer (American), Vigorelli (Italian), and Gegauf (Swiss). | Royalty-free for cross-licenses between the three firms. The firms agreed to broaden the scope of the patent claims. | The Singer sued the largest domestic importer of Japanese machines and 2 other distributors. In 1959, Singer sought to ban all imported machines from Europe and Japan, claiming foreign competition harmed domestic firms. The Supreme Court held in 1963 that Singer violated the Sherman Act. |

## II. Pools created in response to U.S. government policy objectives

| pool names (year, industry) | purpose | management | royalties/ licensing terms | other notes |
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| [14] Manufacturers Aircraft Association (1917, aircraft) | The U.S. is entering WWI and recommended a patent pool (and threats to acquire the patents). Prior to 1917, the aircraft industry was stagnated due to the high royalty and extensive patent litigation brought by Glenn Curtiss and the Wright brothers. | The pool started with 11 aircraft manufacturers and expanded to include every important aircraft manufacturer supplying the U.S. government. | $200 per plane ($1,000 per plane on a Wright Brothers patent prior to the pool); lower to $100 per plane one year after the pool. | Allowed patent addition to the pool. Patent divided into two groups and only one of them earn ongoing royalties (determined by arbitration). The pool contributed to the growth of the U.S. aircraft industry during WWI. |
| [15] Radio Corporation of America (RCA) (1919, radio) | The RCA was recommended by government and formed post WWI to end foreign control over the U.S. radio industry, with buyouts by GE and pool patents from several firms. | AT&T and Westinghouse were joint owners and added their patents into the pool. RCA cross-licensed with GE and became the exclusive vendor. The RCA highlighted the American interests control the majority of stock, director had to be U.S. citizen, and limited foreign stock holding to be less than 20%. | NA | In 1932, the Justice Department sued GE, AT&T, and Westinghouse to sell their interests; RCA became an independent company, retained the patents and full ownership of National Broadcasting Company. |

III. More recent pools that address standardization (1995-current)

| pool names (year, industry) | purpose | management | royalties/ licensing terms | other notes |
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| [16] MPEG-2 Patent Portfolio (1997, video compression technology) | to offer "one-stop shopping" for licenses necessary to produce MPEG-2 products. | managed by MPEG LA to provide nondiscriminatory access to essential MPEG-2 patents owned by many patent holders. New licensors and essential patents are added periodically. | fair, reasonable, & non-discriminatory (FRAND); most favorable royalty rates (no one gets more favorable rates); grant-back (future essential patents held by licensors are licensed back into the pool automatically, w/o raising royalty rates). | global utility of the technology and the standardization of widely used consumer and professional devices using MPEG-2. |
| [17] Bluetooth Special Interest Group (SIG) (1997, bluetooth) | to establish a standard and to allow easy access to the technology | 5 firms formed the SIG as a privately held, not-for-profit trade association. The SIG does not make or sell products but owns the trademarks and standardization documents, markets and licenses to over 7,000 member firms. | SIG licenses to member companies on a royalty-free basis. Firms must be members of the SIG to utilize resources from the pool. | The pool announced in 2005 plans to add technologies such as Wi-Fi in combination with Bluetooth to improve interconnectivity. |
| [18] OpenCable Applications Platform (OCAP) (1997, cable TV applications, standards) | to allow "one-stop shopping" for licenses related to OCAP. (The OCAP is based on the DVB's MHP standards) | On behalf of OCAP, the pool is administered by Via Licensing Corporation, an independent subsidiary of Dolby Lab that specializes in IP law and licensing. | consumer devices: $1.5 per device; service providers: $0.3 per subscriber per year, or a one-time, 5-year license, $1.5 per subscriber. | NA |
| [19] DVD3C (1998, DVD, data storage) | to provide "one-stop shopping" for licenses essential to DVD products. (All read-only discs are considered DVD-ROM discs.) | Sony and Philips organized the pool after a 10-firm negotiation failed to build a pool with all major patent holders. Pioneer and LG later joined the pool. Philips acts as the licensor. | Royalty allocations determined by a formula.Grant-back provision requires all licensors to include their new essential patents into the pool. | NA |
| [20] G.729 Audio Data Compression (1998, data compression algorithm) | to provide a one-stop-shop for all IPR licenses, to spur the global adoption and success of key technologies, and to improve the quality of communications. | The privately-owned firm Sipro Lab was made the exclusive licensing agent for the pool since 1998. Sipro made "one-stop shopping" agreement with 4 members in the pool and 2 firms outside the pool. | available upon request from Sipro. In 2005, the licensing policy was changed to only offer licenses to end-product manufacturers and excludes generic manufacturers. | NA |
| [21] MPEG-4 (1998, standards for data compression) | to provide "one-stop shopping" for patents essential to the manufacture of MPEG-4 products. | by MPEG LA. A group of experts determines whether patents are "essential" to the MPEG-4 standard, i.e. (whether a product would necessarily infringe upon one or more patents in the pool) | $0 up for the first 50,000 units sold per year; after that, $0.25 per unit with a cap of $1 million per firm per year ($3 million cap on enterprises). Rates do not change upon new patents' inclusion and not rise over 25% for similar license grants. | Include grant-back clauses; each patent is included in the pool for 5 years and can be renewed as long as the patent is deemed useful. |

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| [22] IEEE 1394/FireWire (1999, digital standards - digital interface) | to provide "one-stop shopping" for patents essential to the manufacture of IEEE 1394-compatible products and systems. | The pool is administrated by MPEG LA, an independent licensing administrator not affiliates with any patent owner (gets administrative fees from collected royalties). | FRAND, worldwide coverage and include all essential patents from licensors. $0.25 per product with pooled patents. "most favorable royalty rates" ensures no licensee gets favorable royalty rates. | NA |
| [23] 3G Patent Platform Partnership (1999, digital standards) | to allow for FRAND access to patents for implementing the W-CDMA 3GPP standard. | The pool is a group of 19 telecommunications firms ("platform companies"). Membership is open to all interested/involved parties. | Licensees can choose between joint license or standard license agreements. Members provide all funding for the platform. | Several hundred (out of several thousands) of patents owned by over 100 firms are essential to 3G. |
| [24] DVD6C (1999, DVD) | See DVD3C. | formed in 1999 between 6 firms. Toshiba Corporation acts as the licensor in this agreement. | 4% of the net selling price of the product or $4.00 per product, whichever is higher; 4% of the net selling price of the DVD decoders or $1.00 per product, whichever is higher. Grant-back clause exists. | The Department of Justice cleared the pool in the U.S. In 2000, the European Commission also approved the patent pool. |
| [25] Multimedia Home Platform (DVB-MHP) (2004, digital standards) | to protect patent-holders by "covenant not to sue" clause and to promote the manufacture of MHP-based products. | European Telecommunications Standards Institute (ETSI, a France-based NPO), licenses essential patents to the MHP specifications. 655 members from 59 countries (beyond Europe) participate and fund the pool. | €1000 for the test suite; upon passing tests, the implementation costs €10,000 and an annual royalty fee to the DVB Project. The DVB MHP license is royalty-free so far as the licensee does not bring an infringement claim against another implementer. | NA |
| [26] AVC/H.264 (2005, digital compression) | to provide "one-stop shopping" for patents essential to the manufacture of H.264 products. | administrated by MPEG LA. | royalties assessed by units sold per year; with a max annual royalty cap; royalty-free for up to 100,000 units per year. | terms are similar to those for MPEG-2 & -4 |
| [27] Open Invention Network (OIN) for Linux Software (2005, Linux) | to foster R&D in Linux w/o worries on IP issues, to spur complementary products creation, and to foster innovation. | formed in 2005 as an LLC to promote and protect Linux software. Initial investors included IBM, Sony, NEC, Philips, Novell, and Red Hat. | royalty-free, but licensees shall refrain from asserting their own patents against the Linux. | NA |
| [28] UHF RFID Consortium (2005, radio) | to benefit the industry and patent holders by providing the market with a cost-effective way to obtain licenses to essential patents. | In 2006, the UHF RFID consortium made Via Licensing the administer of the pool. | an independent, third-party decides essentiality for submitted patents and calls for any additional patents. A single FRAND license will be made available to all interested parties. | NA |

IV. Recent Pools (and proposals for pools) involving biomedical and agricultural technologies (by 2007)

| pool names (year, industry) | purpose | management | royalties/ licensing terms | other notes |
|---|---|---|---|---|
| [29] Pillar Point Partners (1992, Laser Eye Surgery) | to fix prices and eliminate competition between the only two firms with FDA approval to market laser eye surgery equipment in the U.S. | Summit and VISX created a new firm, Pillar Point Partners (PPP), to pool and license their patents. | $250 per-use royalty shared by the 2 firms according to a pre-set formula. Each firm was prohibited from licensing its own products w/o the consent of the other. | In 1998, the FTC alleged the pool anticompetitive and ordered the two firms to dissolve the pool, to use royalty-free, non-exclusive license for each other, and to prohibit coordination in licensing decisions. |
| [30] Golden Rice Pool (2000, rice) | to provide access to the patents needed to grow, distribute, and use Golden Rice (genetically engineered strain of rice to combat vitamin-A deficiency). | Syngenta manages the license with its own proprietary technology (invented by two professors) and four other firms. Syngenta also helps with licensing to agriculture centers of developing countries. | The licenses are royalty-free to any farmer earning less than $10,000 annually. The inventors also have the right to grant sub-licenses for the same purpose | Only 12 out of the over 70 Golden Rice patents in the U.S. are related to developing countries. All 12 of them are waived by the rightholders. |
| [31] AvGFP (2001, Green Florescent Protein) | to clear a patent thicket that restricted commercial use of green florescent protein (GFP), which allows researchers to visualize cellular proteins w/o chemical dyes. | In 2001, four firms and Columbia Univ. pooled patents related to GFP. GE Healthcare acts as the exclusive licensing agent. | rights covered by U.S., European, and Japanese patents on AvGFP mutations. NPOs can use the license for free so far as not serving any for-profit entities. | The license restricts use of R&D into human therapeutics. |
| [32] Public Intellectual Property Resource for Agriculture (PIPRA) (2001, agriculture) | to make agricultural tech more available for the development and distribution of subsistence crops in developing countries and to promote the management of IP such that biotech products are freely available for research and humanitarian projects. | a collaboration among 39 NPOs in 10 countries. No membership fee to join but members have to be NPOs working in the agricultural field and agree to the terms in a Memorandum of Understanding. | free. The pool is funded by the Rockefeller and McKnight Foundations, and is based on the UC Davis campus. | By 2007, PIPRA members are still working on the details of the initiative and business model. |
| [33] stART Licensing, Inc. (2005, animal reproductive technology) | Formed by two firms (Geron and Exeter) as a new firm to manage and license combined patent portfolio on animal reproductive technologies (including cloning), and thus to generate revenues via licensing programs. | Geron and Exeter hold 49.9% and 50.1% of the firm. Geron receives cash and milestone payments. Exeter provides the start-up capital and management services. | Profits from stART, Inc. will be distributed to the two firms proportionate to equity interests. | Geron faced three patent interferences, but the USPTO invalidated each of these competing cloning patents, and thus increased the value of the stART portfolio. |

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| [34] The SARS IP Working Group (proposed 2005, medicine) | to avoid delays and complications in the development of a SARS vaccine, and to make SARS vaccines and treatments available in case of a pandemic. | The WHO SARS Consultation Group created the IP Working Group. NPOs in the U.S., Canada, and Hong Kong involved. | NA | [noted 6/2019]: Did not establish as the SARS epidemic subsided. |
| [35] Essential Medical Inventions Licensing Agency (EMILA) (proposed 2006, med.) | to manage patent pools or licensing programs that increase generic competition and access to patented medical products and vaccines in developing countries. | Will be a Swiss NPO with global members. Members will elect an executive board and will have several expert committees. | royalty to the pool using the WHO/ UNDP Tiered Royalty Method. Divide royalties among patent holders based on expert advice or arbitration. | [noted 6/2019]: not established yet. |
| [36] Medicines Patent Pool (2010, med.; proposed in 2006) | increase access to and facilitate the development of life-saving medicines for low- and middle-income countries. | Funded by UNITAID, a global health initiative. | 0% for pediatric formulations; typically, 0-5% for adult products; may expand to use tiered pricing. | initially target HIV drugs, expanded to include Hep. C and TB and is currently working on further expansion to include certain cancer and diabetes. |

**Sources:**

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