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InSTePP International Innovation Accounts: Research and Development Spending, version 3.5

(Food and Agricultural R&D Series)

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Dedication

For Robert Evenson and Willis Peterson. Each in his unique way was a true gentlemen. They were steadfast and accomplished-friends from rural Minnesota, who both earned their undergraduate and (agricultural economics) master's degrees from the University of Minnesota before heading off to study under Zvi Griliches, then at the University of Chicago. In separate but intersecting careers, Bob and Will went on to become pioneers in the creation and policy-relevant use of R&D investment and institutional data. This work stands firmly and directly on their broad shoulders, and that of their shared mentor, Zvi.

Acknowledgments

This version of the InSTePP R&D series is the culmination of the work of many people over many decades. The earliest version of the U.S. public food and agricultural R&D series took shape at the University of Minnesota just as spreadsheet programs became available in the early 1980s (who remembers Lotus 123 and Quattro Pro?). Michelle Hallaway was an early adopter, and with her eye to data detail, care, and dogged persistence, the long-run U.S. public food and agricultural R&D series came to life. The mid-1980s saw the birth of the global public food and agricultural R&D companion to the U.S. series, under the deft senior management support of Howard Elliott, then Deputy Director General of ISNAR (the International Service for National Agricultural Research), The Hague. Han Roseboom was pivotal to the development of the first comprehensive version of these data that were unveiled in 1989 (Pardey and Roseboom 1989). The surveys and compilation of data on developing-country public food and agricultural R&D are on-going, and are now ably led by Nienke Beintema at IFPRI (International Food Policy Research Institute), Washington, D.C.

Version 3.5 of the InSTePP U.S. and global food and agricultural R&D series is an outgrowth, significant extension and update of these prior efforts by us and others. During their construction over the past five years we contacted many individuals working in many agencies throughout the world. The more than 60 respondents listed throughout this report does not do adequate justice to the work they have done to make these series possible. They all helped immeasurably in data discovery and access, which in many instances required above-and-beyond-efforts to find, check, correct and make available otherwise inaccessible information. This has been a collective effort, and we sincerely thank each and every one of them.

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InSTePP International Innovation Accounts: Research and Development Spending, version 3.5

(Food and Agricultural R&D Series)

InSTePP's International Innovation Accounts (IIA) consist of a growing body of data on the inputs and outputs to innovation processes generally, with an emphasis on innovation indicators for the life sciences (health, and, especially, food and agriculture). The collection currently includes worldwide data on the investments in and spending on research and development (R&D) overall, and food and agricultural R&D in particular, for both the public and private sectors; worldwide patent count and patent family data pertaining to genetics and genomics innovations in the life sciences; worldwide data on plant varietal rights; and indicators of the uptake and use of agricultural innovations, with an emphasis on genetic (crop varietal) innovations in agriculture. The IIA holdings complement InSTePP's Agricultural Production and Productivity Accounts that measure and assess various agricultural input, output and productivity indicators for the United States and other countries and regions of the world.

In this document we provide details of the data sources and methods of estimation used to develop version 3.5 of the food and agricultural R&D spending component of InSTePP's International Innovation Accounts. With this version, InSTePP's previous estimates of country and worldwide spending on food and agricultural R&D performed by the public sector have been completely revised, updated, and pushed back in time. This series now includes data for 158 countries for half a century, spanning the years 1960 to 2011.[1] The state and national level estimates of public food and agricultural R&D spending in the United States have also been updated, and now cover the entire 20th century and more; specifically the period 1889 to 2013.

All of the rest of the data documented here are entirely new. They include expenditure estimates of privately performed food and agriculturally related R&D in the United States for the period 1950-2011. These U.S. aggregate R&D spending estimates are segmented into three sectors—specifically agriculture and chemicals; machinery; and food processing, beverages and tobacco—and were developed from firm-specific data encompassing 408 different firms. While InSTePP has maintained a global, publicly-performed food and agricultural R&D expenditure series for some time, version 3.5 represents an update (series now ending in 2011, previously 2009) and revision of the Center's first set of expenditure estimates of privately-performed R&D oriented towards food and agriculture that were released in the version 3.0 series. In addition to the new long-run U.S. estimates, InSTePP has developed country, regional and global estimates of business expenditures on food and agricultural R&D for the period 1980-2011.

All these R&D data have been developed to support studies undertaken by InSTePP Fellows and their collaborators. The findings from these studies, along with extractions from these R&D data collections are made available to third parties by way of InSTePP's website at www.instepp.umn.edu. Not all of

[1] The 158 countries include 28 countries in Eastern Europe and the Former Soviet Union for which the estimates are less complete (and for some countries in this group less reliable) and are held as a set of "satellite accounts." The core "global" collection of public food and agricultural R&D time-series data consists of estimates for 130 countries.

InSTePP's R&D data can be shared via the site for intellectual property and other reasons. The data that can be shared are posted to the site as they become available. This document is intended to make third-party use of these shared data as informed as possible, while also serving as a comprehensive description of the R&D data sources and methods of construction for the InSTePP-related reports that draw on these series.

1. Statistical and Measurement Preliminaries[2]

In compiling InSTePP's R&D data we strove to use science indicator norms that conformed to those laid out in the *Fracasti Manual* (OECD 2002). The goal was to provide a reasonable basis for making broad international comparisons over time by standardizing the institutional and research scope and the treatment of the data as much as possible.

Much of the food and agricultural R&D expenditure data were collected or compiled in current local currency units before first deflating to the base period (2009) using country-specific implicit gross domestic product (GDP) deflators taken primarily from the *UN National Accounts Main Aggregates* database (United Nations 2014a, 2014c)[3]. R&D spending estimates, now in constant (real) local currency units, were then converted to base-period 2009 international dollars using purchasing power parity conversion factors from the *World Development Indicators* (World Bank 2014). Pardey, Roseboom and Craig (1992) provide some analytical support for using this "deflate-first-then-convert" method when dealing with pre-aggregated agricultural R&D expenditure data; the primary downside of this method is that the resulting estimates are sensitive to the choice of deflator and converter used (see also Pardey and Beintema 2001, Box 2 and Pardey et al. 2015).[4] We strove to report estimates on a by-performer basis, meaning that whenever possible, the expenditures were designated according to the type of agency performing the research (i.e., public versus private) and, ostensibly, where in the world the research was performed.

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[2] See also (Pardey and Roseboom 1989, chapter 2).

[3] In forming all previous versions of these R&D spending estimates (specifically the global public food and agricultural R&D component) we drew mainly on implicit GDP deflators taken from the World Bank Development Indicators (WDI) database to convert R&D spending estimates expressed in nominal local currency units into inflation-adjusted, base-year prices. For this version of the InSTePP Accounts we opted instead to use the UN National Accounts series as the primary source of implicit GDP deflators. The UN report a more complete series of country specific deflators for the period since 1970 (compared with World Bank sources, which for some years were missing deflators for over 80 of the countries that were available in the UN series). Moreover, for those countries where the two sources had overlapping data, there was little if any difference in the reported rates of inflation. In addition, the construction of the UN series is exceptionally well documented regards data sources and the methods used to deal with missing primary data (see UN 2014b). For years prior to 1970, we backcast the UN series using the annual rates of change in the implicit GDP deflators reported in World Bank (2014) and IMF (2014).

[4] One glaring example of the measurement implications of the choice of a convertor is examined by Feenstra et al. (2012) regarding the reported (and problematic) 40 percent mark down of China's 2005 purchasing power parity that occurred between the 2007 version of the World Bank's *World Development Indicators* and the 2008 version. This type of measurement problem is in addition to (but illustrative of) the problems implicitly introduced by using deflators and convertors pertaining to an all-encompassing basket of goods and services inherent in value aggregates such as gross domestic product, versus the use of deflators and convertors that pertain to the goods and services used for agricultural research as discussed and examined by Pardey, Roseboom and Craig (1992). See also World Bank (2013).

The notion of "public R&D" used in this compilation comprises R&D performed by the government (at all levels, e.g., federal, state and local), higher education, and private non-profit sectors. "Business or private R&D" is taken to be research performed by private-for-profit firms in the business enterprise sector as well as public enterprises (e.g., state-owned companies or public corporations) ostensibly operating as private enterprises engaged in the production and sale of goods and services. What constitutes "food and agricultural R&D" versus other R&D is sometimes problematic, especially as many of the innovations that affect food and agriculture (e.g., innovations in the basic genetic and genomics sciences, informatics, communications and so on) stem from research done in or initially targeted to other sectors. Citing OECD statistical guidelines (specifically an earlier edition of the *Frascati Manual,* OECD 1981), Pardey and Roseboom (1989, p. 6) noted that:

> "…two approaches to classification are possible:
>
> (1) according to the *purpose* of an R&D program or project;
>
> (2) according to the general *content* of the R&D program or project.[5]
>
> For example, a research project to improve the fuel efficiency of farm machinery could be placed under 'agriculture' if classified by purpose, but 'energy' if classified by R&D content."

This compilation opted for the by-purpose approach.

OECD (2002) and many national statistical systems report R&D spending for four performing sub-sectors: business enterprise, government, higher education, and private non-profit. Some agencies (including the OECD) also categorize R&D activities by field-of-science and by socio-economic objective (OECD 2002, pp. 67 and 85-87). R&D of direct relevance to food and agricultural R&D includes the "agricultural science" component of the field-of-science schema, and the "agricultural production and technology" component of the socio-economic objective classification. The field-of-science and the socio-economic objective approaches to classifying R&D data differ in ways that have potentially important measurement consequences. Notably, the field-of-science classification is oriented to the (disciplinary) "nature of R&D" (e.g., agronomy, mechanical engineering, or genetics), whereas the socio-economic objective classification pertains to the "purpose of the R&D" (e.g., biological pest control, chemical fertilizers, mechanization of agriculture). In keeping with our objective of reporting R&D by purpose, when appropriate we used the available agricultural R&D data reported by socio-economic objective wherever possible, resorting to field-of-science type data only when socio-economic objective figures were unavailable.

Nomenclature

Adopting OECD (2002) norms, the InSTePP International Innovation Accounts uses GERD to delineate gross (i.e., total public and private) domestic expenditure on research and development and BERD to delineate gross domestic business expenditures on R&D. In the same spirit we use PERD to refer to domestic public expenditures on R&D. Adapting this nomenclature further, we use agGERD when referring to gross domestic expenditures on food and agricultural R&D and, similarly, agBERD and

[5] The same purpose versus content distinction is referenced in OECD (2002, p. 143)

agPERD to refer to the business and public expenditure component respectively of GERD that pertains to the food and agriculture sectors.

Food, Beverage and Tobacco Processing R&D

Research related to food, beverage and tobacco processing R&D represents another measurement and analytical challenge that affects both the agPERD and agBERD series. There are economic, policy, and practical measurement elements in play here. As economies develop, an increasing share of the value added in food and agriculture typically derives from the food sector as an increasing amount of food is processed, transported, and consumed away from home. Tracking the commensurate changes in the mix of public and private R&D oriented to these changing economic circumstances has analytical and policy value, not least as the mix of agPERD and agBERD is likely to change in different ways given the different economic incentives for innovation in food versus agricultural production (Pardey and Beddow 2013).

Different sources have different aspirations or guidelines for the way they handle food, beverage and tobacco processing R&D. The OECD (2002, p. 67) field-of-science approach does not include food processing R&D as part of its "agricultural sciences" category, opting instead to include the "science and technology of food production" as part of its "engineering and technology" field-of-science.[6] OECD's recommended treatment of food processing R&D in their socio-economic objective classification is somewhat more complicated and opaque. OECD (2002, p. 145-146) recommend the following:

> "6. Agricultural production and technology
> 508. This SEO [socio-economic objective] covers all research on the promotion of agriculture, forestry, fisheries and foodstuff production. It includes: research on chemical fertilisers, biocides, biological pest control and the mechanisation of agriculture; research on the impact of agricultural and forestry activities on the environment; *research in the field of developing food productivity and technology. It does not include* [italics added]*:*
>
> –Research on the reduction of pollution (SEO 3).
> –Research into the development of rural areas, the construction and planning of buildings, the improvement of rural rest and recreation amenities and agricultural water supply (SEO 2).
> –Research on energy measures (SEO 5).
> –*Research for the food industry (SEO 7).* [italics added]
>
> 7. Industrial production and technology
> 509. This SEO covers research on the improvement of industrial production and technology. It includes research on industrial products and their manufacturing processes, *except where they form an integral part of the pursuit of other objectives (e.g. defence, space, energy, agriculture)* [italics added]."

A practical interpretation of this guideline is that most if not all research related to food processing would be included as part of "agricultural R&D" when reported on a "by-purpose" or socio-economic-objective basis. In the past, UNESCO (1984, p. 64) explicitly included "R&D on the processing of food and beverages, their storage, and distribution" in their concept of "agricultural R&D," and apparently

[6] See also OECD (2007).

still does given that UNESCO R&D data have increasingly standardized on *Frascati Manual* norms beginning in the mid- to late-1990s (OECD 2002, p. 195f.). The ASTI (nd, p.7) series seeks to exclude research conducted by the "…agrochemical industry, agricultural machinery, and the food processing industry off farm…" while including research related to "… on-farm storage and processing of agricultural products, commonly referred to as postharvest or food-processing research" in its "agricultural" R&D series.[7]

For practical as well as policy and analytical reasons, the agPERD and agBERD InSTePP series sought to include (on- and off-farm) research related to food, beverage and tobacco processing research in its food and agricultural R&D series. The methodology used to construct InSTePP's agBERD series overtly includes food, beverage and tobacco processing R&D. The agPERD series also strives to include food processing research in its scope of research, such that both the public and private series constitute a comparable and comprehensive compilation of food and agricultural R&D. The (pre-aggregated) nature of most of the available agPERD data means there is less measurement control over the scope of these series, but certainly some (and likely) many of the available public (food and) agricultural R&D totals include research related to food processing (and likely much of it carried out under the guise of research performed as part of the nutrition sciences). For example, this is so for the public food and agricultural R&D data available for the United States (see USDA-NIFA (2013) where food processing R&D is classified under the Knowledge Area Topic V, which is the category "Food and non-Food Products: Development, Processing, Quality, and Delivery"), the compilation reported by Keogh and Potard (2011) for Australia, and South Africa (Liebenberg 2015), for example.[8]

2. Global Public Domestic Expenditure on Food and Agricultural R&D (agPERD) Series, 1960-2011

This version of InSTePP's global domestic public expenditure on food and agricultural R&D (agPERD) series includes estimates for 158 countries spanning the period 1960-2011. They represent a revised version of the series that was previously discussed in Pardey and Alston (2011), Pardey, Alston and Chan-Kang (2013a and b) and Pardey and Beddow (2013).

The global agPERD series consists of three related parts. One part includes data for 37 high-income countries. The primary data sources for these countries are, in general, the most reliable, complete and comparable. Combining these high-income country estimates with data for an additional 93 middle- and low-income countries (excluding Eastern Europe and Former Soviet Union countries) constitutes the "core" of the public food and agricultural R&D spending series. The primary data for these middle- and

[7] In the initial incarnation of the ASTI series, the intent was to exclude "…, where possible, research applied directly at the postharvest stage, while including research that is applied at the preharvest stage but which has an impact at the postharvest stage (Pardey and Roseboom 1989, p. 7)."

[8] The research scope of the InSTePP food and agricultural R&D series (or any such R&D series for that matter) should be borne in mind when using these data in conjunction with other economic variables, such as sectoral GDP estimates. For instance, the ISIC rev. 3.1 classification includes food processing as part of manufacturing (ISIC codes 10, 11 and 12, U.N. Statistics Division 2008, p. 86f.) as does the U.S. Bureau of Economic Analysis by way of its NAICS classification of economic value added (codes 311 and 312, USBC 2012). Similar issues arise in relation to the scope of "agriculture." Following the OECD's (2002, p.145) socio-economic objective schema, the InSTePP series includes crop, livestock *and* forestry related R&D, and so in this respect is consistent in terms of sectoral coverage with the agGDP measures reported by World Bank (2014).

low-income countries are also of reasonable standard, although for some regions of the world (notably Latin America and the Middle East and North Africa) and for some countries they are less comprehensive (and less reliable) than the rich-country sources. The third component consists of a satellite series of estimates developed for 28 Eastern European and Former Soviet Union countries. The primary data for individual countries in this group are much less complete, especially during the era of the Soviet Union (i.e., prior to 1991), and sometimes inconsistent, with different sources sometimes reporting substantially different R&D spending estimates for the same country-year. Nonetheless, considerable effort was made to develop a plausible set of estimates for these countries that are consistent in conception and construction with the estimates made for the other countries of the world.

High-Income Countries

The Pardey and Roseboom (1989) estimates of public food and agricultural R&D spending by OECD countries (including the high-income countries therein) relied heavily on data from national sources. Updating that series, most subsequent compilations (e.g., Beintema et al. 2012, Beintema and Stads 2008, and Wang et al. 2012) relied almost exclusively or entirely on data from OECD sources for the high-income countries. In constructing this version of the InSTePP series, we turned once again to national sources as the preferred primary source, using other sources and methods (including OECD data) to construct estimates for these rich countries only when data from national sources were unavailable. In compiling the public sector data, our objective was to develop a series spanning at least 50 years, beginning in 1960. In so doing, we drew on the Pardey and Roseboom (1989) compilation—or more particularly, the data sources cited therein—for the earlier years in this new series, but for this earlier period we opted to use new, better and additional (national) data whenever possible.

Table 1 summarizes the sources-cum-methods we used to develop the public food and agricultural R&D spending series for the high-income countries for each decade since 1960 and for the entire sample period. The left-hand side of the table indicates the share of observations from each source for each decade and overall; the right-hand side of the table shows the shares of R&D spending by source. The notes to Table 1 provide some detail about the types of sources we drew from and the estimation methods we used when directly observed data were not available.

[Table 1: *Summary of agPERD Data Sources and Estimation Methods for High-Income Countries, 1960-2011*]

Around one-fifth of the 1,924 (52 years x 37 countries) public food and agricultural R&D estimates were obtained directly from various national sources, the details of which are reported in the upper section of Table 2. However, many of these estimates were for countries with above-average public spending on food and agricultural R&D (specifically Australia, Canada, France, the Netherlands, Japan, New Zealand, the United Kingdom, and the United States), such that half of the overall spending total for the high-income countries was based on national estimates. While OECD sources accounted for 17.2 percent of the observations, these countries spent less on average such that OECD-sourced data constituted just 13.2 percent of the high-income spending total.

[Table 2: *Public Food and Agricultural R&D (agPERD) Data Sources by Country*]

As denoted in Table 1 (data rows 1-6), direct R&D spending estimates from national, OECD, ASTI and various other sources were available for 69.3 percent of the observations (96.0 percent of the spending

total). The remaining estimates were imputed using various methods including: (i) using agricultural intensity ratios to estimate missing data; or (ii) linearly interpolating between (near) adjacent estimates. The choice of a given method was tailored to the specifics of the missing data problem and designed to make the best use of the available estimates. The "OECD sourced" estimates were directly reported in OECD (2014), supplemented with data from other published OECD sources listed in Table 1.

"InSTePP estimates" encompass an assortment of data estimation approaches for Canada, the Netherlands, the United Kingdom, and Switzerland where the nationally sourced data were sometimes problematic (or unavailable from conventional public sources) and the OECD (2014) sourced data were limited. We thus drew on a range of sources and (in-country) expertise to develop estimates for these countries. Our Canadian estimates rely on data from Pardey et al. (1999), Carew (2001), and a government spending series obtained from Agriculture and Agri-Food Canada (unpublished). In developing this series we also consulted widely with knowledgeable local experts from various Canadian universities and Agriculture and Agri-Food Canada (AAFC) (including personnel in AAFC's Agri-Food Chain and IRM Analysis and Agri-Food Support, Measurement and Analysis).

The Netherlands series consists of R&D spending estimates for each of the main research agencies that conducted public food and agricultural research in that country, including Wageningen University and Research Center (which resulted from the consolidation of the Department of Agricultural Research (DLO) and Wageningen Agricultural University), Van Hall Larenstein (which emerged from a consolidation of the Van Hall Institute and the International Agricultural College Larenstein in 2003), the faculty of Veterinary Science at the University of Utrecht, and TNO food. To construct our series we used estimates reported in *Annual Report Wageningen UR* (various years) along with data published in Roseboom and Rutten (1999), and data obtained directly from TNO food. We also consulted widely with knowledgeable local experts. The Swiss series combined information from various sources, including published and unpublished data obtained from personnel at the Swiss Federal Statistical Office as well as published data reported in Boyce and Evenson (1975), Bundesamt für Statistik (1983), and Kurath (1994). The United Kingdom estimates drew on data obtained from the Department for Business, Innovation and Skills (2014), Thirtle and Piesse (1999), Thirtle, Piesse, and Schimmelpfenning (2008), purchased data from HESA (2014), plus unpublished data obtained from personnel at the Northern Ireland Department of Agriculture and Rural Development.

Core Global Compilation

Table 3 summarizes the sources-cum-methods used to develop the core public food and agricultural R&D spending series for each decade since 1960 and for the entire sample period. Table 2 gives a more detailed account of sources by country. The core series includes estimates for the 37 high-income countries, 64 middle-income countries, and 29 low-income countries. Estimates for 28 Eastern European and Former Soviet Union countries are held in a separate set of satellite R&D accounts (as discussed below). Once again, the left-hand side of the table indicates the share of observations from each source for each decade and overall; the right-hand side of the table shows the shares of R&D spending by source.

[Table 3: *Summary of Data Sources and Estimation Methods for Core agPERD Global Compilation, 1960-2011*]

The basis for the estimates in the data series changes over time. For a substantial share of the entries (specifically 25.8 to 52.7 percent, depending on the time period), proximate agricultural research intensities (i.e., agricultural R&D spending relative to agricultural GDP) were used in conjunction with corresponding annual, country-specific measures of agricultural GDP to develop estimates of the amount of agricultural R&D spending per country per year.[9] However, estimates formed in this fashion often pertain to the smaller R&D countries in the sample and, for the entire 1960-2011 sample period, accounted for only 12.0 percent of the estimated amount of spending for the entire period. Comparatively solid sources of data were used to form the estimates for a sizeable share of the countries in our sample, and especially the larger R&D spending countries. For example, data from the sources-cum-methods reported in rows 1 to 4 of Table 3 accounted for around 64 percent of the reported global spending total, and about 86 percent of the total if data from rows 5 and 6 are also included.

For the low- and middle-income countries, the only estimates derived using "other methods" were for Brazil in the years 1976-1980 and 2007-2011. The agricultural R&D series for these years were obtained by adding Embrapa[10] R&D spending to estimated R&D spending from other government (e.g. states), higher education, and private non-profit. From 1976 to 1980, Brazilian estimates for each sector of performance (i.e., other government, higher education, and private non-profit) was based on their 1981 ratio of R&D spending to Embrapa's spending. From 2007 to 2011, data for each sector of performance were forward-casted using the average growth rate from the previous years for which data were available.

China Estimates

The substantive and influential changes in the agPERD estimates for China reported in this version of the InSTePP series warrant specific attention. There are alternative, but not entirely consistent, estimates of public food and agricultural R&D spending in China for the more recent years.[11] After assessing the scope, completeness and robustness of alternative data sources, we opted to benchmark our China estimates on unpublished data from Ruifa Hu, Jikun Huang and colleagues of the Chinese Center for Agricultural Policy (CCAP) in Beijing. The CCAP estimates were derived from official records and publications documenting Chinese investments in food and agricultural R&D. These estimates were compiled such that, to the extent possible, they are consistent with the other data in the InSTePP accounts. The public sector series from CCAP spans the period 2002-2013. These data were backcast to 1960 using the rate of change in the public agricultural R&D series reported by Fan et al. (2006) and Fan and Pardey (1992).

[9] The AgGDP estimates were taken from WDI (2014) supplemented with data from UN (2014a, 2014c) when estimates were missing from World Bank sources.

[10] Embrapa is a state-owned company affiliated with the Brazilian Ministry of Agriculture and is dedicated to basic and applied research on agriculture. Embrapa is the main provider of agricultural R&D in Brazil, accounting for 53.7 percent of the country's agricultural R&D spending in 1981 and 74.5 percent in 2011 (the most recent year of available data).

[11] These include, but are not limited to, estimates reported by Pardey and Roseboom (1989), Fan and Pardey (1992), Fan et al. (2006), Chen and Zhang (2011), Hu et al. (2011), OECD (2014) for the years 1998, 1999 and 2000 and online at ASTI (see www.asti.cgiar.org/china).

Satellite Accounts for Eastern Europe and Former Soviet Union Countries

The OECD online statistical database (OECD 2014) reports agricultural R&D spending for eight Eastern European and Former Soviet Union (EE&FSU) countries, namely: Estonia, Romania, Slovenia, Slovakia, the Czech Republic, Poland, the Russian Federation, and Hungary. Data are only available for selected years between 1991 and 2011 with the exception of Poland and Hungary. For these two countries, annual estimates are reported between 1987 and 2011. Data for these EE&FSU countries were estimated back to 1969 using agricultural intensity ratios in conjunction with AgGDP estimates from the UN (2014a, 2014c) and estimates of AgGDP based on USDA-ERS (2013) and Gapminder (2013).

For other countries in the EE&FSU—specifically Albania, Bulgaria, Bosnia and Herzegovina, Serbia and Montenegro, Armenia, Azerbaijan, Belarus, Croatia, Georgia, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Macedonia, Republic of Moldova, Tajikistan, Turkmenistan, Ukraine, and Uzbekistan—where no food and agricultural R&D data were reported we used an alternative estimation technique. First we extended the available GERD estimates for each of these countries back to 1974 using the total R&D intensity ratio (measured as total R&D spending as a share of GDP) in conjunction with GDP. We then applied the average share of agricultural R&D in total R&D for Estonia, Romania, Slovenia, Slovakia, Czech Republic, Poland, Russian Federation, and Hungary to each of these additional EE&FSU countries to derive a public food and agricultural R&D spending estimate back to 1974. The public food and agricultural R&D spending estimates were then extended to 1960 using the rate of change of agricultural R&D spending series reported in Boyce and Evenson (1975). [12]

2.1 Data Sources

Individuals

The listing below includes individuals who assisted the authors in constructing the public food and agricultural R&D series. They helped unearth obscure or unpublished national statistics, steered us toward critical published data sources or other knowledgeable individuals or information assets, and, importantly, provided critical institutional, policy and other insights that enabled us to process and interpret the data appropriately. These individuals and the countries for which they provided assistance are listed below.

High income Countries: Alan Spedding, Freelance rural consultant, United Kingdom; Alistair Ramsden, Ministry of Research, Science and Technology, New Zealand; Caroline Falize, INRA-SupAgro, France; Catherine Moreddu, OECD, France; Catherine Neumeyer, Agriculture and Agri-Food Canada, Canada; Catherine Schmit, INRA Versailles-Grignon, France; Christian Ott, Head of Section, Statistics Denmark, Denmark; Daniel Cordier, CEMAGREF, France; Daniel Griffiths, Statistics New Zealand, New Zealand; Douglas Hedley, The Canadian Faculties of Agriculture and Veterinary Medicine, Canada; Ebbe Krogh Graversen, University of Aarhus, Denmark; Fabien Riesen, Federal Office for Agriculture, Switzerland;

[12] Boyce and Evenson (1975) reported agricultural R&D estimates for selected years between 1959 and 1974 for the following EE&FSU countries: Bulgaria, Romania, Czechoslovakia, Hungary, Poland, and the USSR. The rate of change for USSR agricultural R&D spending was applied to all FSU countries. For Bulgaria and the Czech Republic, we used, respectively, the rate of change of Bulgarian and Czechoslovakian agricultural R&D spending. For all other Eastern European countries, we applied the rate of change of Eastern Europe included in Boyce and Evenson (1975), which include only five countries.

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3. Global Business Domestic Expenditure on Food and Agricultural R&D (agBERD) Series, 1980-2011

This version of the InSTePP R&D accounts includes entirely new estimates of expenditures on food and agricultural R&D undertaken by private entities for the period 1980-2011. The method we used to construct estimates for the high-income countries drew heavily on OECD sources, with the important exception of the United States for which a purpose-built series using firm-level data was constructed. Direct estimates using various national and international sources of information were also developed for China, India, Brazil, Mexico, Chile, Turkey, and South Africa. For the rest-of-the-world, a parsimonious and replicable econometric approach was developed and deployed.

High-Income Countries

A purpose-built series of privately performed food and agricultural R&D spending (agBERD) estimates was developed for the United States (see Section 5 below for construction details). For the other rich countries in the InSTePP series, a proximate private-sector food and agricultural R&D series was derived using a judicious compilation of the food and agriculturally related components of R&D spending reported for the "agriculture, hunting, and forestry," "food, beverages and tobacco," "machinery," and "chemical and pharmaceutical" business sectors found in various OECD statistical compilations.[13]

Tables 4 and 5 give classification details of the sub-sectors included in the ISIC Rev. 4.0 and Rev 3.1 used by the OECD to report R&D data for the business sector. All of the R&D spending reported for the "agriculture, hunting, and forestry" and "food, beverages and tobacco" sectors was deemed to be food and agriculturally related, and so included as part of our private sector total.[14] The "machinery" sector encompasses R&D spending for various sub-sectors that are largely unrelated to food and agriculture. For this compilation we took 9 percent of the spending for the machinery and equipment n.e.c. (not elsewhere classified) sub-sectors(s) and included that as part of our private sector food and agricultural R&D total.[15] Similarly, the "chemical and pharmaceutical" sector includes a substantial amount of R&D

[13] A variant of this method was first used (to our knowledge) by Pardey, Roseboom and Craig (1999) to develop the private sector spending estimates reported in that chapter (see also Pardey and Beintema 2001, Table2).

[14] Notably, research on pet food is considered part of "manufacture of food products" research by way of the ISIC 1080 sub category that relates to "Manufacture prepared animal feeds."

[15] For the purposes of forming these estimates we deemed the long-run average U.S. shares to be representative of the respective shares throughout the other rich countries. Applying long-run U.S. average shares to generate year-by-year estimates for the other rich countries is an approximation with obvious limitations, not least that even for the United States these shares varied over time. For instance, during the period 1973-2010 the relevant chemical and pharmaceutical sector food and agricultural related R&D share oscillated between 3.1 and 6.6

spending that does not have a food and agriculturally related socio-economic objective, so estimates of that non-agriculturally related spending were also excluded from our compilation. Specifically, we included 4 percent of the spending on R&D in the chemicals and chemical products subsector as part of our agBERD total. The shares of "machinery" and "chemical and pharmaceutical" research deemed food and agriculturally related was determined after a detailed investigation of the concordance between the firm (and sub-sector) specific U.S. data described in Section 6 below and the corresponding "mechanical" and "chemical and pharmaceutical" sub-sector U.S. totals reported in OECD sources.

[Table 4: *Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 4.0*]

[Table 5: *Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 3.1*]

This agBERD compilation relies heavily on three versions of the Analytical Business Enterprise Research and Development (ANBERD) data reported by OECD: one is their revision 2.0 series, which includes data for 1973-1987, another is their revision 3.1 series, which covers the period 1987-2010, and finally their revision 4.0 with data from 1987 to 2012.[16] ISIC rev. 2.0 was adopted by the United Nations in 1968 (United Nations 2008). To take into account new technological developments and changes in economic activity, the United Nations adopted ISIC revision 3 in 1990 and rev. 3.1 in 2002. To accommodate the shifting structure of global economies, revision 4.0 published in 2008 contains a revised set of industry classifications.[17] The most important difference between ISIC rev. 2.0, ISIC rev. 3.1, and ISIC rev. 4.0 is the addition of more details in the subdivisions of each industry. For example, in ISIC rev. 2.0, "agriculture, hunting, forestry and fishing" is subdivided into only three categories at the highest level of disaggregation (three digit level in the ISIC coding) with: (i) agriculture and livestock production; (ii) agricultural services; and (iii) hunting, trapping and game propagation. In rev 3.1, "agriculture, hunting and related service activities" is divided into five different groups at the three digit level: (i) growing of crops, market gardening, horticulture; (ii) farming of animals; (iii) growing of crops combined with farming of animals (mixed farming); (iv) agricultural and animal husbandry service activities, except veterinary activities; and (v) hunting, trapping and game propagation including related service activities. In rev. 4.0, "agriculture, hunting and related service activities" is renamed "crop and animal production, hunting, and related service activities" and is divided into seven categories at the three digit level: (i) growing of non-perennial crops; (ii) growing of perennial crops; (iii) plant propagation; (iv) animal production; (v) mixed farming; (vi) support activities to agriculture and post-harvest crop activities; (vii)

percent, whereas during the 2005-2010 period that share was comparatively stable, hovering between 3.1 and 3.6 percent. The corresponding machinery sector share bounced around between 5.5 and 12.0 percent over the 1973-2010 period. In developing an earlier private-sector compilation for the OECD countries, Pardey, Roseboom and Craig (1999) used 10 percent as the indicative food and agriculturally related share of "chemical and pharmaceutical" research in forming the private food and agricultural R&D totals they reported, thus likely overstating the corresponding research totals in light of this newer and more extensive U.S. evidence.

[16] Data coverage varies across countries and years among these three data series. For example, for Greece, rev. 4.0 includes data for 2011 only, whereas rev. 3.1 has Greek data available for the period 1988-2007. Thus, we used rev. 4.0 as our primary OECD source, supplemented with estimates from rev. 3.1 and rev.2.0.

[17] See Table 5 for the ISIC Revision 3.1. classification relevant to food and agriculture.

hunting, trapping, and related service activities. Each of these groups is further subdivided into finer categories at the four digit level.

The OECD-ANBERD revision 2.0, 3.1, and 4.0 figures in conjunction with estimates from various OECD *Statistical Yearbooks*, the OECD-BERD (Business Enterprise R&D) database,[18] and other secondary data sources were used to construct our private food and agricultural R&D spending estimates for the period 1980-2011. Table 6 summarizes the sources-cum-methods we used to develop these estimates for the high-income countries for each decade since 1980 and for the entire sample period. Once again, the left-hand side of the table indicates the share of observations from each source for each decade and overall; the right-hand side of the table shows the shares of the R&D spending total by source. The notes to Table 6 provide details about the types of sources we drew from and the estimation methods we used when directly reported data were not available.

[Table 6: *Summary of agBERD Data Sources and Methods for High-income Countries, 1970-2011*]

Eighty-four percent of the private-sector spending estimates were developed from the firm-level data used to form the InSTePP estimates for the United States, plus various OECD sources for the other high-income countries. While the OECD-ANBERD revision 4.0 series was the primary source of data for any particular country (or R&D sub-sector therein), for the more recent years, we chose to use the rate of change in R&D spending reported in the corresponding ANBERD revision 2.0 series (which runs from 1973-1987) and revision 3.1 series or various OECD *Statistical Yearbooks* to backcast the revision 4.0 series (which runs from 1987-2012). While it may be more transparent and parsimonious to simply splice two (or more) series together, we decided against that approach given the underlying classification schemes used to construct these two series are not fully comparable.

To deal with missing data for particular sub-sectors in specific country-years, we employed a variety of estimation methods (as summarized in Table 6, with the general objective of maximizing the use of relevant, related data (and other country specific information or intelligence we could gather) when developing these estimates. Table 7 provides country-by country details on the data sources we used to compile the private sector R&D component of this InSTePP series.

[Table 7*: Private Food and Agricultural R&D (agBERD) Data Sources by Country*]

Other Countries

The basis for forming estimates of private food and agricultural R&D for countries elsewhere in the world is much more limited. One approach is to survey firms based in or operating in the low- and middle-income countries of the world (see, for example, Pray and Fuglie 2001; Fuglie et al. 2011). While much valuable information can be gleaned from these firm-level surveys it is not clear whether this method yields reliable country- or regional-level estimates of overall trends in private food and agricultural R&D spending. For instance, to what extent does the sample of surveyed firms represent the relevant population of firms in each country, and how well does a contemporary sample of firms

[18] The estimates reported in the OECD-ANBERD are based on the BERD series but the OECD make adjustments for missing data and other anomalies in the BERD series (OECD 2013, pp. 5).

track the relevant population of firms over the longer run?[19] What share of each surveyed firm's overall R&D expenditures pertain to food and agriculture (which is especially problematic for firms undertaking machinery and chemically related R&D)? And, to what extent does total R&D spending represent research undertaken in the jurisdiction in which a sampled firm is headquartered (or is operating)?

Cognizant of these and other measurement problems, we pursued a different approach to generate private food and agricultural R&D spending (agBERD) estimates for the low- and middle-income countries. For countries that were likely to account for an important share of ROW (rest-of-the-world) private food and agricultural R&D spending (and where data were available) we used relevant national-level data from local or international statistical agencies to develop our country-level estimates. For the remaining countries, we used an econometric method in conjunction with the (public and private) GERD estimates developed by InSTePP, and described in a companion document, to form the required estimates.

Statistical data were obtained and processed for Brazil (2001-2005), India (2002-3 to 2009-10), Mexico (1995-2011), Chile (2007-2010), Turkey (1990-2008) and South Africa (2001-2009), and used in conjunction with other data (notably our GERD estimates) to form our country-level estimates for these seven countries. The China data came from OECD (2014a, 2013), the Brazilian data from FAPESP (2011), India from Department of Science and Technology (DST) of the Indian Ministry of Science and Technology (2007-08 and 2010-11), and Mexico, Chile, Turkey and South Africa from (OECD 2013, 2014a, and 2014c).[20]

Particular attention was paid to rendering robust estimates for China. Colleagues from the Chinese Center for Agricultural Policy (CCAP) provided estimates of total food and agricultural R&D spending, parsed into spending by government, universities, private (for profit) firms and state-owned enterprises for the period 2003-2013. With these data, we derived the public share of total Chinese R&D spending (where "public" was the sum of government and university spending). A logit regression of these shares on an annual trend was used in conjunction with the CCAP-InSTePP public data to backcast the shares to 1980.[21] Combined with the complete public agricultural R&D series developed for China (see above),

[19] Compounding the problems of inter-temporal consistency in firm-level data is the difficulty of tracking firm entries, exits, mergers and spin-offs, and the associated problems related to tracking changes in the business segment orientations of these firms.

[20] To more fully exploit the available information, missing data for these countries were estimated based on the ratio of public to private food and agricultural R&D from the closest year for which data were available. This yielded a full 1970-2011 series for all seven countries. Hu et al. (2011) report China agBERD estimates for 2000, 2004, 2005 and 2006 based on a nationwide survey of 1,359 firms, which represent only a subset of all firms involved in agricultural and food in China. Only firms supervised by the Chinese agricultural administration system were surveyed. Firms owned by foreign companies as well as those that are not supervised by the agricultural administration system were excluded. Hu et al also note that their estimates exclude a number of firms involved in pesticides and agricultural machinery research. Chen and Zhang (2011) report data from secondary sources, namely, (a) China Statistical Yearbook of Science and Technology for food processing; and (b) Hu et al (2009) for crop, livestock, fisheries and agricultural input. The Chen and Zhang estimates also exclude forestry and machinery related R&D. Where there was overlap, the China agBERD estimates we derived from OECD sources were larger than both the Hu et al. (2011) estimates and the Chen and Zhang (2011) estimates.

[21] The shares estimates were formed using a beta regression with a logit link function, yielding a pseudo R^2 of 0.90.

the series public shares enabled calculation of a complete (1980-2013) series for private (and thus total) agricultural R&D for China.

The above procedures yielded a complete 1980-2011 time series of total private agricultural R&D spending estimates for 40 countries (specifically, the 31 OECD countries plus Brazil, Chile, China, India, Mexico, Romania, the Russian Federation, Singapore, and South Africa).

Noting that private agricultural R&D in the missing lower- and middle-income countries is largely targeted to agricultural production and food processing (and not towards chemical and machinery R&D), we endeavored to estimate "primary agricultural R&D", i.e., agricultural R&D net of that portion focused on chemicals and machinery. Rather than attempting to directly estimate agBERD totals, we estimated the ratio of primary agricultural R&D to total agricultural R&D spending per country-year. While a number of techniques were explored, one of the most parsimonious performed among the best: a logit regression in which the primary agricultural R&D share is the dependent variable, with per-capita GDP and the private total R&D (i.e., BERD) to total (private and public, i.e., GERD) R&D ratio as independent variables. With estimates of the primary agricultural R&D shares in hand, along with the full time series of public agricultural R&D estimates, we recovered estimates of private agricultural R&D spending levels for all country-years, adding back private chemical and machinery R&D as appropriate. The procedure performed well, with an in-sample approximate coefficient of determination of 0.941 for these initial estimates of primary agricultural R&D spending.[22]

To make full use of the additional data in the Brazil, India, and South Africa series, we used the ratio of estimated private R&D to the observed values for these countries to fill in missing observations, exploiting the full time series of total private R&D estimates for each country. Finally, the econometrically estimated private agricultural R&D values were only used when plausible values estimated by other means were missing from the dataset. Overall, only about 6 percent of global private agricultural R&D spending in the 1980-2011 series was estimated using the econometric procedures described in this section.

3.1 Data Sources

DST (Department of Science & Technology Government of India), National Science and Technology Management Information System. "Research and Development Statistics 2011-2012. Table 13: Expenditure on Research and Development by Industry Groups for Private Sector". September 2013. Available from www.nstmis-dst.org/SnT-Indicators2011-12.aspx

DST (Department of Science & Technology Government of India), National Science and Technology Management Information System. "Research and Development Statistics 2007-08. Table 12: Expenditure on Research and Development by Industry Groups for Private Sector," May 2009. Available from www.nstmis-dst.org/Rndstst07-08.aspx

[22]These estimates were derived using a beta regression with a logit link function (as described and implemented by Cribari-Neto and Zeileis (2010)). Admittedly, these estimates are based on data largely reflecting OECD countries and therefore may not be applicable to the mostly low- and middle-income countries for which we must estimate values. Arguably, China, India, Brazil and South Africa are more representative of those countries than are others in the dataset. The approximate coefficient of determination calculated over the recovered, primary agricultural R&D spending estimates for those countries was 0.888.

FAPESP (Sao Paulo Research Foundation). “ST&I and the Agricultural Sector in Sao Paulo State.” Chapter 10 in *Science, Technology and Innovation Indicators in the State of Sao Paulo/Brazil 2010*, Sao Paulo: FAPESP, 2011.

Hall, J. and G.M. Scobie. *The Role of R&D in Productivity Growth: The Case of Agriculture in New Zealand: 1927 to 2001.* Working Paper 06/01. Wellington: New Zealand Treasury 2006. Available at www.treasury.govt.nz/publications/research-policy/wp/2006/06-01/21.htm.

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OECD (Organisation for Economic Co-operation and Development). “ANBERD database, Structural ANalysis Database (STAN) Research and Development Expenditure in Industry (ISIC Rev. 4.0) (last updated June 18th 2014).” Paris: OECD, 2014a. Downloaded October 2014 from www.oecd-ilibrary.org/statistics.

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OECD (Organisation for Economic Co-operation and Development). “BERD Database, Business Enterprise R&D Expenditure by Industry (ISIC Rev. 3.1.) (last updated March 2014).” Paris: OECD, 2014c. Downloaded October 2014 from www.oecd-ilibrary.org/statistics.

OECD (Organisation for Economic Co-operation and Development). *International Survey of the Resources Devoted to R&D in 1967 by OECD Member Countries. Volume 5: Total Tables, Statistical Tables and Notes*. Paris: OECD, August 1970.

OECD (Organisation for Economic Co-operation and Development). *Survey of the Resources Devoted to R&D in 1969 by OECD Member Countries. Volume 1: Business Enterprise Sector, Statistical Tables and Notes*. Paris: OECD, June 1973.

OECD (Organisation for Economic Co-operation and Development). *Survey of the Resources Devoted to R&D by OECD Member Countries. International Statistical Year 1971. Volume 1: Business Enterprise Sector, Statistical Tables and Notes*. Paris: OECD, August 1974.

OECD (Organisation for Economic Co-operation and Development). *International Statistical Year 1975. International Survey of the Resources Devoted to R&D by OECD Member Countries. International Volume: Statistical Tables and Notes*. Paris: OECD, March 1979.

OECD (Organisation for Economic Co-operation and Development). *Basic Science and Technology Statistics*. Paris: OECD, 1991.

Office fédéral de la statistique. “Dépenses de recherche et développement (R-D) des entreprises privées.” Neuchâtel, Switzerland: Office federal de la statistique, 2014. Last updated June 19th 2014. Downloaded November 17th 2014 from http://www.bfs.admin.ch/bfs/portal/fr/index/themen/15/09/key/ind2.indicator.20202.202.html

Statistics New Zealand. *Research and Development in New Zealand 2002*. Wellington, NZ: Statistics New Zealand and Ministry of Research, Science and Technology, September 2003.

4. U.S. Public Expenditure on Food and Agricultural R&D Series, 1889-2013

Research expenditures consist of annual data on the funds appropriated or made available to each state agricultural experiment station (SAES) and various other cooperating institutions (OCI) in the same state for the period 1889–2009 as well as spending on intramural research undertaken by the United States Department of Agriculture.[23] SAES and OCI expenditures are designated according to three broad sources of support (federal government sources, state government sources, and miscellaneous fees and sales) and reported on a by-performer basis.

4.1 SAES Research

The state-specific SAES research expenditure data sets compiled for this study drew from a number of sources, including the annual *Report on the Agricultural Experiment Stations* (or variants thereof), published over the years by USDA (1890), Atwater (1891), Harris (1892 and 1893), True (1895 and 1898–1901), USDA Office of Experiment Stations (1895, 1897, 1902–1915, 1916, 1918–1926, 1926–1954) and USDA Agricultural Research Service (1955–1960 and 1961). After 1960, the report was published annually by the USDA Cooperative State Experiment Station Service (later known as the Cooperative State Research Service, CSRS, then the Cooperative State Research, Education and Extension Service, CSREES, and from 2008 the National Institute for Food and Agriculture, NIFA) from 1961 to 1975 as the *Funds for Research at State Agricultural Experiment Stations* (or variants thereof). The *Inventory of Agricultural Research* was published by USDA RPDES (1967– 1969), USDA SES (1970–1972), USDA CSRS (1972–1977), USDA SEA (1979–1981), USDA CSRS (1982–1994), and USDA CSREES (1995–1998).[24] Beginning in 1970, data were also made available in electronic file format from the USDA's Current Research Information Service (or USDA CRIS), a USDA agency formed in 1967 with the express purpose of documenting the pattern of agricultural R&D spending by the SAESs and their cooperating agencies, as well as agencies of the USDA. Summary digests of the CRIS data are available on-line at http://cris.csrees.usda.gov/fsummaries.html

We compiled SAES expenditures as hand-tallied data for the period 1889–1979 and electronic extractions from detailed versions of the annual USDA CRIS data files for the period 1980–2013.[25] With

[23] In keeping with OECD (2002, p. 139) norms, we adopted the premise that funds made available or appropriated for research were obligated or spent in the fiscal year in which they were committed. Through fiscal year 1976, the official U.S. fiscal year was July 1–June 30; beginning October 1976 the fiscal year was October 1–September 30. The 3-month period from July 1, 1976 through September 30, 1976 was reported as a separate fiscal period and designated as a "transition quarter" (see USDA CSRS 1977). To avoid an accounting-induced discontinuity in the R&D series, we set aside expenditures incurred during this transition quarter. All data are reported on a fiscal year (FY) ending basis, and so, for example, FY 2000–2001 is designated year 2001 data. For the purposes of this series, "SAES Research" includes research conducted by the state agricultural experiment stations, 1890 institutions, forestry schools, veterinary colleges, and other cooperating institutions (OCI) including small business innovation research (SBIR) and EXT (extension-related research).

[24] From 1969 to 1981, the *Inventory* was published as a three-volume set. Publication of Volume I was discontinued in 1982, and Volumes II and III were combined into a single format in 1983.

[25] Personnel at USDA CRIS have been especially generous in periodically providing these data tapes over the past several decades and in assisting Pardey and Chan-Kang in extracting and interpreting compilations made from

overlapping hand-tallied and electronically supplied data available for the period 1970–1986, 1980 was selected as the year in which to splice the two sources of data together. A careful comparison of data from both sources indicated discrepancies between the published *Inventory* series and the corresponding figures extracted from the CRIS data files in the early-1970s. By the mid-1970s, SAES research expenditure estimates from both sources tracked each other closely, and they continued to do so until FY1995–1996, which is the last year of data published in the *Inventory of Agricultural Research*.

The state-specific components of the hand-tallied SAES expenditure series for the years 1889–1979 include:

- SAES expenditures using funds from all federal government sources
- SAES expenditures using funds from all non-federal government sources (including state government funds and miscellaneous fees and sales, MFS)
- SAES expenditures using MFS, a subset of non-federal funds
- total SAES expenditures (defined as the sum of all expenditures of funds from the federal
- government and all non-federally sourced funds)
- SAES expenditures funded from state government sources (estimated by subtracting MFS funds from all non-federally sourced funds).

The counterpart series for the 1980–2013 data extracted from the USDA CRIS files include:

- SAES federally sourced expenditures (the sum of three sub-totals reported in the CRIS files, namely "CSREES Admin Funds," "Other USDA" and "Other Federal" funds)
- SAES non-federally sourced expenditures (the sum of "State Appropriations" and MFS sourced funds, described next)
- SAES MFS-sourced funds available (the sum of "Self-Generated Funds," "Industry Grants/Agreements," and "Miscellaneous non Federal Funds," a subset of SAES non-federally sourced expenditures)
- SAES total expenditures (the sum of all federal and non-federally sourced funds)
- SAES expenditures of funds from state government sources, taken in this instance to be the CRIS series of "State Appropriations."

Minnesota and Vermont Corrections

As part of the diagnostic and cleaning processes in compiling the SAES expenditure series, a detailed analysis of the Minnesota data extracted from the CRIS data files revealed some abnormally large and implausible jumps in the agricultural research spending time series. Notably, the reported "Other Federal Funds" series for Minnesota went from $70 million in 2004 down to $12 million in 2005 then jumped to an implausible $288 million in 2006. After much investigation using unpublished University of Minnesota budget files, the problem was identified as a gross misreporting of the relevant expenditures by a "state cooperating agency" (in the parlance of CRIS), specifically the University of Minnesota

these files. Special thanks are recorded here to Dennis Unglesbee, Allen Moore, Ed Kane, Brenda Barnett, Barry Sims, Tina Buch, Janet Downey, Donald Prindle, and other colleagues from USDA CRIS for their outstanding help over the years.

Veterinary School.[26] In some years, data from this agency were not reported and therefore were not included in the CRIS totals for Minnesota. In other years the agency, administratively part of the University's large Health Science unit, erroneously reported to CRIS *all* federal funding (including most likely *all* funding from the National Institutes of Health) coming to the Health Sciences units at the University, rather than reporting only the amount of federally-sourced funding spent specifically on veterinary research. We determined that this reporting error caused the Minnesota total (and thereby the SAES totals reported by CRIS for the United States) for FY2007 to be overstated by $298 million. Thus, the Minnesota total for FY2007 and FY 2008 reported in USDA CRIS (2007 and 2008, Table G) are respectively $404.0 and $407.8 million compared with our corrected estimates of $99.9 million and $105.7 million. In FY2009, no data were reported for the veterinary school. These under- and over-reporting problems for the veterinary school at the University of Minnesota persisted, on and off, back to 1980 and were corrected in all the relevant national and state SAES spending totals for this series.

Total spending in 2007 by the Vermont "SAES and other cooperating institutions" was substantially underreported; in the USDA CRIS (2008, Table B) report, the reported value for Vermont "Total Funds" was $3.5 million in 2007 compared with $10.3 million in 2006. An analysis of the CRIS data files revealed that the $3.5 million included funding for the Forestry School and other cooperating institutions (OCI funds in CRIS parlance), and vastly underreported SAES funding for that year. We took the 2006 estimate of SAES funds available ($7.5 million, the $10.3 million net of OCI funds) as the best indication of the corresponding 2007 figure, added that to the reported 2007 OCI and forestry school figures to get a corrected 2007 Vermont "SAES and other cooperating institutions" total of $10.4 million for 2007.

The reported 50-state total for the SAESs and other cooperating institutions (including forestry schools, Washington, D.C., and all U.S. territories) for fiscal year 2009 is $3,666,899,000 (USDA CRIS 2009, Table A) versus our corrected estimate of $3,682,277,617, with the difference reflecting our corrections for both Minnesota and Vermont.[27]

Post-2009 Corrections

Beginning in fiscal year 2010, two major changes were introduced into the CRIS data collection procedures. First, CRIS ceased collecting data on the non-formula components of federally funded special grants, NRI/AFRI grants, SBIR, other grants, and state grants. Second, CRIS ceased to report funds expended by "non-state partners" (i.e., Other Cooperating Institutions, Cooperating Extension Institutions, and SBIR or Small Business Innovation Research program). These data collection and reporting changes induced a substantive and spurious discontinuity in the reported agPERD series for the United States. For example, the reported U.S. total of spending by non-federal institutions engaged

[26] We gratefully acknowledge and thank Lynn Moore and Peter Held from the Minnesota Agricultural Experiment Station, and Catherine Elzinga and Kersten Anderson from the College of Veterinary Medicine for their efforts to help us identify and resolve these substantial data problems.

[27] At this point in time, 2009 is the latest year in which we can discern data discrepancies attributable to the problems in the Minnesota and Vermont data discussed in this section, and discrepancies attributable to changes in NIFA reporting norms described in the following section.

in food an agricultural R&D dropped from $3.68 billion in 2009 to $2.86 billion in 2010.[28] Notably, the reported funds for SAES and Other Cooperating Institutions research received from CSREES/NIFA administered sources plunged by half in just one year; from $558.1 million in 2009 to only $253.6 million in 2010 (USDA, CRIS various years, Summary Table A).

To correct for these post-2009 changes in data collection and reporting standards, we proceeded as follows. For Minnesota, we replaced the SAES and VetMed data with the corrected estimates obtained from unpublished data files maintained by colleagues at the Minnesota Agricultural Experiment Station and the College of Veterinary Medicine. For all other states we made adjustments for the lack of reported data for other cooperating institutions and related agencies by assuming that the 2009 spending totals from these institutions were representative of the corresponding 2010, 2011, 2012, and 2013 spending totals.[29] Finally, to adjust for the failure to report expenditures from non-formula funds made available to the SAESs, we applied the 2009 ratio of formula-to-non formula funds on the reported formula funds from 2010 to 2013 to estimate the corresponding non-formula funds for those years.[30]

4.2 USDA Intramural Research

The intramural USDA research expenditure series draws from two primary sources. For the period 1889–1999, the series was developed by hand tallies of various U.S. Department of Treasury reports to the U.S. House of Representatives; for the period after 1999 we used data extracted from NSF's obligation series.[31] Using the Treasury reports, we compiled the most disaggregated figures available, often parsing out individual account categories within the totals for specific agencies. These account categories facilitated compilation of a time series of R&D expenditures drawing on information regarding the creation, closure and merger status of agencies and bureaus within the USDA, as well as information concerning the changing research versus non-research (e.g., regulatory) activities of these agencies.[32] Since many USDA bureaus, and even some of the reported projects identified within a

[28] Total U.S. spending from non-federal institutions totalled $2.95 billion in 2011, $2.86 billion in 2012, and $2.65 billion in 2013.

[29] These particular adjustments were generally inconsequential to the reported totals. For example, in 2009, summing across all 50 states, other cooperating institutions and related agencies accounted for only 1.61 percent of the total U.S. spending from non-federal institutions.

[30] The edict to cease collecting certain data was issued by USDA, NIFA to NIFA Awardees in a memo titled "Modification of Award Terms and Conditions" dated December 23, 2010 (available at nifa.usda.gov/resource/modification-award-terms-and-conditions). The edict was rescinded in a USDA, NIFA memo titled "Reinstatement of Funding Sources Reporting Requirements for NIFA Awards" dated August 12, 2014 (available at nifa.usda.gov/resource/reinstatement-funding-sources-reporting-requirement-nifa-awards).

[31] The hand-tallied data were taken from U.S. Department of Treasury (1889 and 1890, 1894–1907, 1908–1911, 1912–1926, 1927–1939, 1940–1975, 1976–1983, and 1984–2000). Patricia Zambrano's considerable help in compiling these data is gratefully acknowledged.

[32] For example, the Agricultural Research Service (ARS) did not exist as such until November 1953. To construct an R&D series for the antecedent agencies of ARS for the period 1889–1953 we tracked data for each of the bureaus that were consolidated into ARS in fiscal year 1953–1954 (and, where required, compiled data for specific programs within each bureau). The relevant bureaus, as of 1954, included the Bureau of Animal Industry (BAI), the Bureau of Plant Industry Soil and Agricultural Engineering (BPI), the Bureau of Entomology and Plant Quarantine (BEPQ), the Bureau of Agricultural and Industrial Chemistry (BAIC), the Bureau of Human Nutrition and Home Economics (BHE), and the Bureau of Dairy Industry (BDI). These bureaus—with the exception of BAI—were not established until at least 1907, and thereafter went through several name changes that sometimes involved

relevant bureau, carried out regulatory as well as R&D functions, we augmented the disaggregated appropriations and expenditure data with information (in the form of allocative rules of thumb) obtained from knowledgeable sources within USDA to develop estimates of a series of R&D appropriations and expenditures separate from a series related to regulatory (and other) functions.[33]

For the period 1970-2013, estimates of USDA intramural spending were available in the CRIS electronic data files. However, for several years where we had both hand-tallied estimates and the CRIS estimates, there were substantial differences between the two series. CRIS personnel advised us that the electronic estimates may not consistently include spending by all USDA agencies. Thus to continue the series forward for the more recent years, we opted to use data on USDA intramural obligations for R&D reported in NSF (2003, 2004, 2005, 2006, 2007, 2008, 2009, 2010, 2011, 2012, 2013 and 2014).[34] To form an estimate of *intramural* food and agricultural R&D spending (net of forestry), we excluded the research conducted by the U.S. Forest Service from NSF estimates of total USDA intramural research obligations. We compared the resulting totals-net-of-forestry with the corresponding 1970-1999 estimates we had compiled directly from USDA budget sources and opted to extend that series forward in time by simply splicing the adjusted, NSF-sourced data to the budget-sourced data in 2000 when the estimates from these two sources were almost identical.

4.3 Forestry Research

To ensure that the scope of SAES, OCI and USDA intramural research conformed with the public food and agricultural R&D totals we constructed for other countries, forestry research was included in the U.S. estimates incorporated into this version of InSTePP's global public food and agricultural R&D series.

changing regulatory and R&D-related responsibilities. Thus, rather than simply track bureau totals, we collected information for the activities and projects listed under each bureau that we identified as pertaining to R&D.

[33] We were careful to separate research spending from other functions, recognizing that not doing so may cause large errors in the data. For example, the USDA intramural spending series presented in Huffman and Evenson (1993, Appendix Table 4A, p.128) contain some questionable spikes. They present two series from 1888 to 1990 that represent "Chemical, Biological, and Physical Science Research" and "Economics and Statistics Research" conducted by the USDA, the sum of which represents total USDA intramural research spending. Their "Chemical, Biological, and Physical Science Research" time series reports $31.9 million in 1946, $54.7 million in 1947, $69.8 million in 1948, $46.1 million in 1949, and $27.4 million in 1950. For their total USDA time series, spikes involving year-on-year changes of greater than 40 percent occurred in years 1890, 1901, 1909, 1922, 1947 and 1976. Some of these spikes may indicate aggregation errors associated with unrecorded agency merger, creation and closure activity, coupled with changes in the research, regulatory and other functions performed by these agencies. The large jump in the series from 1975 to 1976 apparently stems from the inclusion of the transition quarter (i.e., the three-month period occasioned by a shift from a fiscal year ending June 30 to a fiscal year ending September 30) in the figure for 1976, such that the data reported by Huffman and Evenson for this year include expenditures and appropriations incurred for a 15-month rather than a 12-month period (see Huffman and Evenson 1993, Table 4.3, note c).

[34] The data summarized in Pardey et al. (2013a) were based on version 3.0 of the InSTePP R&D accounts. In this earlier version, the U.S. intramural agricultural R&D estimates were projected after 2000 using USDA outlays.

However, for some purposes it is desirable to exclude forestry research (see, for example, Alston et al. 2010).[35]

By construction, our intramural USDA series could be used to readily identify (and thus parse out) research performed by the USDA Forestry Service. However, to identify (and thus, if required, exclude) forestry from the SAES and OCI spending totals required some effort, tailored to the specifics of the SAES data sources. We began by extracting estimates of R&D expenditures by individual forestry schools from unpublished CRIS data files for the period 1970-2013. We also compiled a list of forestry schools and their dates of establishment (Table 8) to determine the extent of missing forestry-related R&D spending in the reported statistics beginning in the year of establishment of each forestry school through to the first available state-specific estimate reported in the electronic CRIS files, which was not necessarily 1970, the first year of these files. Thus, for example, forestry related R&D expenditures for Alabama were first reported in the CRIS files in 1997, even though we determined the state forestry school was established in 1946. To estimate data for the missing years, we calculated the share of forestry school spending in total SAES R&D spending for the earliest available year, then used that share to net out forestry spending for the prior year. Forestry R&D shares for even earlier years were derived by linearly backcasting shares to zero in the year immediately prior to the establishment of each forestry school. These estimated shares were then used to parse out the respective forestry-related R&D expenditures from the reported SAESs and OCI totals (that for these years were inclusive of forestry R&D expenditures).

[Table 8: *State Forestry Schools—Dates of Establishment*]

4.4 Data Sources

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Harris, A.W. 1892 and 1893. "Report of the Director of the Office of Experiment Stations for [1891 and 1892]." in *Report of the Secretary of Agriculture for [1891 and 1892].* United States Department of Agriculture. Washington, D.C.: U.S. Government Printing Office.

National Science Foundation, Division of Science Resources Studies. "Federal Funds for Research and Development, Detailed Historical Tables: Fiscal Years 1951–2002 (NSF 03-325), Table 9 Federal Obligations to Intramural Performers for Research and Development, by Agency: Fiscal Years 1970–2002" Arlington, VA: National Science Foundation, August 2003. Downloaded March 2015 from www.nsf.gov/statistics/nsf03325/.

National Science Foundation, Division of Science Resources Statistics. "Federal Funds for Research and Development: Fiscal Years 2001, 2002, and 2003 (NSF 04-310), Table C8: Federal obligations for Total Research and Development, by Agency and Performer: Fiscal Year 2001" Arlington, VA: National Science Foundation, 2004 (corrected August 2011). Downloaded March 2015 from www.nsf.gov/statistics/nsf04310/sectc.htm#agency.

[35] For example, Huffman (2009, p. 15, footnote 8) noted "My most recent measures of public agricultural research expenditures also exclude all types of forestry research. The primary reason is that forest products are a relatively unimportant output of farms in all but a few states."

National Science Foundation, Division of Science Resources Statistics. “Federal Funds for Research and Development: Fiscal Years 2002, 2003, and 2004 (NSF 05-307), Table C8: Federal obligations for Total Research and Development, by Agency and Performer: Fiscal Year 2002” Arlington, VA: National Science Foundation, 2005 (corrected August 2011). Downloaded March 2015 from www.nsf.gov/statistics/nsf05307/sectc.htm#group1.

National Science Foundation, Division of Science Resources Statistics. “Federal Funds for Research and Development: Fiscal Years 2003-05 (NSF 06-313), Table 16: Federal Obligations for Research, by Agency and Performer: FY 2003” Arlington, VA: National Science Foundation, 2006. Downloaded March 2015 from www.nsf.gov/statistics/nsf06313/tables.htm#group1.

National Science Foundation, Division of Science Resources Statistics. “Federal Funds for Research and Development: Fiscal Years 2004-06 (NSF 07-323), Table 16: Research Obligations by Agency and Performer: FY 2004” Arlington, VA: National Science Foundation, 2007. Downloaded March 2015 from www.nsf.gov/statistics/nsf07323/content.cfm?pub_id=3766&id=2.

National Science Foundation, Division of Science Resources Statistics. “Federal Funds for Research and Development: Fiscal Years 2005-07 (NSF 09-300), Table 16: Research Obligations by Agency and Performer: FY 2005” Arlington, VA: National Science Foundation, 2008. Downloaded March 2015 from www.nsf.gov/statistics/nsf09300/content.cfm?pub_id=3898&id=2.

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5. U.S. Business Expenditure on Food and Agricultural R&D Series, 1950-2013

Constructing estimates of the spending on food and agricultural R&D performed by private firms is difficult, and this difficulty is often compounded by a lack of data availability, data consistency, and, in some instances, data secrecy. Prior efforts to construct such estimates for the United States have relied heavily (but not exclusively) on surveys and assessments of R&D spending by leading firms in the sector.[36] In constructing the InSTePP series we have implemented an entirely different approach, with the aim of standardizing (where possible) the construction of the series, making it comparable with other relevant firm-level data to facilitate analysis of important trends in private food and agricultural R&D, seeking to capture a more inclusive set of relevant firms (beyond just the major firms), and ensuring the series can be replicated and more systematically updated over time. To do this we relied

[36] These prior U.S. private R&D estimates are to be found in Wilcke and Sprague (1967) for FY1965, Wilcke and Williamson (1977) for 1976 and 1977, Crosby (1987) for circa 1984, Benbrook (1989) for 1986, Pray and Neumeyer (1989) for 1960-1986, Pray and Neumeyer (1990) for 1961, 1965, 1976 and 1984, Huffman and Evenson (1994, pp. 105-106) for 1965-1984 and by decade from 1850-59 to 1970-1979 and 1980-1985, Klotz, Fuglie and Pray (1995) for 1960-1992, and Fuglie et al. (2011) for 1970-2007 (see also USDA-ERS 2012). Kalton and Richardson (1983), Kalton et al. (1989) and Frey (1996) provide data on private R&D related to plant breeding in the United States.

heavily on firm-level spending estimates using financial reporting data complemented with other firm-level data, where doing so enabled us to improve or better assess the accuracy of the estimates derived from the financial reporting sources.

Our primary data source is the Standard & Poor's Compustat database (as hosted by Wharton Research Data Services). The Compustat database contains extensive firm-level data from financial filings of publicly-held companies, and our estimates are based on annually reported research and development expenditures. We extracted these reported measures for firms with industry classifications (by SIC code) that we identified as being closely aligned with agricultural and food activities (see Tables 9 and 10) to develop a U.S. series spanning the period 1950-2013.

[Table 9: *Agricultural Industry Classifications for U.S. Food and Agricultural R&D: Private Series*]
[Table 10: *Food Industry Classifications for U.S. Food and Agricultural R&D: Private Series*]

In some of these industries, the business activities of some firms are only partially associated with the agricultural and food sectors, or span multiple sub-sectors within the general scope of food and agricultural research. For example, a single firm may undertake chemical research (only some of which is related to food and agriculture) and also undertake biological or varietal development research related to agriculture, and the mix of that research may change over time. For this subset of industries (indicated by an asterisk in Tables 9 and 10), we parsed each firm's total R&D spending in line with the share of sales associated with that firm's agricultural or food-related business segments. In this version of the series, this parsing procedure was applied to firms with median, inflation-adjusted annual R&D expenditures for the sample period of $100 million or more. To do this, we used historical business segment sales data reported in 10-k filings (collected from either the Security and Exchange Commission's EDGAR database or the Orbis database published by Bureau van Dijk). In the best cases, these data were generally only available back to the early 1990s, and we backcast R&D attribution shares based on the earliest available reported sales shares data.

The intent of this exercise was to develop a series of private food and agricultural R&D performed in the United States (whether by domestic or foreign-owned firms), distinct from, say, a series of private food and agricultural R&D performed by firms headquartered (or operating) in the United States, irrespective of where in the world the research occurred.[37] Doing so requires parsing research spending totals into U.S. versus rest-of-world components, a distinction that is increasingly difficult to make as many large multinational companies (U.S.-based and foreign) continue to diversify their R&D activities globally, but only report total company-wide spending. To approximate the jurisdictional extent of R&D spending—specifically in this case, U.S. versus rest-of-the-world (ROW) performed R&D—we constructed a formula based on historical sales by geographical segment. To do this, we used historical geographic segment sales data also reported in 10-k filings for firms with median inflation-adjusted annual R&D expenditures for the sample period of $100 million or more. Once again, in the best cases these data were generally only available back to the early 1990s, and so we backcast R&D attribution shares based on the earliest available reported sales data. We assumed that prior to 1970 all R&D expenditures were attributable to

[37] A major motivation for limiting this series to research performed in the United States is to avoid double counting research expenditures when combining the U.S. estimates with private food and agricultural R&D performed elsewhere in the world.

the country in which the firm was incorporated. For 1970-1989, we assumed the first 75 percent of R&D expenditures were attributable to the country of incorporation, and the remaining 25 percent was attributed proportionally according to geographic segment sales. Finally, for 1990 and thereafter, we assumed that the first 50 percent of R&D expenditures were attributable to the country of incorporation, and the remaining 50 percent was attributed proportionally according to geographic segment sales. For this version of the series, for all firms with 1950-2010 median inflation-adjusted annual R&D expenditures less than $100 million, we assumed that 100 percent of R&D activities were performed in the firm's country of incorporation.

Every effort to develop private food and agricultural R&D spending estimates is an exercise in making do with less than ideal and less than complete data, necessitating the use of rules of thumb or a set of measurement assumptions and procedures when constructing the estimates. Our approach is no exception, but has the distinct advantage of being explicit in these assumptions, replicable, and subject to robustness testing. For many of the larger companies in the InSTePP series, we gathered an extensive collection of annual reports, contacted company officials for information and advice, secured access to unpublished data and made adjustments to the baseline estimates where the additional information indicated that doing so improved the accuracy and completeness of the estimates. These "larger" companies included Altria Group Inc., Anheuser-Busch Inbev., Aventis SA, BASF SE, Bayer Ag, CNH Global NV, Danone, Deere & Co., Dow Chemical, Du Pont (E I) De Nemours, FMC Corp., Kimberly-Clark Corp., Kirin Holdings Co. Ltd, Kraft Foods Inc., Kubota Corp., Lilly (Eli) & Co, Merck & Co, Monsanto Co, Montedison SPA, Nestle SA/AG, Novartis AG, Pepsico Inc., Pfizer Inc., Procter & Gamble Co., Sanofi, Schering-Plough, Stora Enso Oyj, Syngenta AG, Unilever Group, and Wyeth.

Agricultural and Food R&D Spending by Privately-held Companies

Our approach using public financial filings to estimate agricultural and food R&D expenditures in the business sector does not work for privately-held firms that are not required to disclose detailed financial information. Nevertheless, there are large privately-held firms that make significant investments in agricultural and food related R&D. To account for this, we included separate estimates for two of the largest: Cargill and Mars Inc.

To estimate R&D expenditures by Mars Inc. we first found estimates of gross sales for the years 1923, 1959, 1963, 1973, 1996, 2010, and 2011. For the intervening years, we interpolated sales by applying the constant arithmetic growth rate between any two "hard" estimates. Absent any better information, we assumed that Mars Inc.'s research activities would have similarities to those of its competitor/peer firms in the industry. We used Hoover's company profile to identify these peer firms, which include Hershey Co., Kraft Foods Inc., Nestle SA/AG, Caribou Coffee Co., Colgate-Palmolive Co., ConAgra Foods Inc., General Mills Inc., Green Mountain Coffee Roasters, Heinz (HJ) Co., Smucker (JM) Co., Sara Lee Corp., Starbucks Corp., Topps Chewing Gum, and Unilever NV. One of our requirements was to distinguish between research performed in the United States and research performed elsewhere, so we also looked to these peer firms for an estimate of this distribution.

Our approach to estimating R&D expenditures of Cargill was similar. We first found estimates of gross sales for the years 1950, 1952-53, 1955-62, 1971-73, 1976-77, 1984-2007, and 2011. For the intervening years, we interpolated sales by applying the constant arithmetic growth rate between any two "hard" estimates. Absent any better information, we again assumed that Cargill's research activities would

have similarities to those of its competitor/peer firms in the industry. We used weighted average research intensities of the top 10 food and agricultural companies/business units, by sales, including Altria (formerly Philip Morris), Pepsico, Coca-Cola, Kraft, Nabisco, Tenneco, ConAgra, Archer-Daniels-Midland, and Esmark. During the earlier phase of our sample period, Cargill's business earnings were primarily derived from commodity trading, which is likely to involve much lower amounts of research effort compared with Cargill's other lines of business. Thus, we discounted Cargill's sales figures to be more in line with the research intensities calculated from the "net sales" of the peer firms. We applied a linearly interpolated discount rate, beginning with 60 percent in 1950 and ending with 35 percent in 2007, based on confidential advice from individuals knowledgeable about the history of Cargill's (research) operations.

5.1 Comparisons with Prior Estimates

There are a number of prior estimates of (food and) agricultural R&D spending for the United States. While the InSTePP series runs from 1950-2011, there is a USDA-ERS (2014) series that runs from 1970 to 2007, a Fuglie at al. (2011) series from 1960 to 2010, 1960-1998 series reported by Klotz, Fuglie and Pray (1995), a 1960-1990 series by Huffman and Evenson (1993), and a 1960-1986 series by Pray and Neumeyer (1989). There are also a number of estimates for specific years such as US Department of Agriculture (1962) for 1961, Wilcke and Sprague (1967) for 1965, Wilcke and Williamson (1977) for 1976, Crosby (1987) for 1984, and Benbrook (1989) for 1986.

The InSTePP series generally sits at the upper end of the range of the prior estimates, except for the Huffman and Evenson (1993) series which ends in 1990 with a terminal (nominal) value of $4,214 billion, 33 percent higher than the corresponding $2,810 billion estimate in the InSTePP version 3.5 series. The Fuglie at al. (2011) series has a terminal value of $6,709 billion in 2007 (5.7 percent lower than the InSTePP estimate for that year of $7,110 billion).

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Appendix 1: A Brief History of Global Compilations of Food and Agricultural R&D Data

Bob Evenson and colleagues can take credit for the first comprehensive compilation of national estimates of investments in agricultural R&D.[38] Their efforts over a number of years culminated in a 1975 volume by Boyce and Evenson (1975) titled *National and International Agricultural Research and Extension Programs*.[39] This publication included time-series data on research and extension spending and personnel from the early 1960s (although in some instances 1950 and 1959 figures were also provided) through to 1973. Two subsequent publications (Judd, Boyce, and Evenson 1983 and 1986) built upon these prior studies and reported "constructed time-series" for 106 countries for three time periods: 1959, 1970 and 1980. Drawing directly on this body of work and other sources, Oram and Bindlish (1981) developed annual agricultural R&D expenditure estimates for 51 developing countries for the period 1970 to 1980.

Evenson's pioneering work notwithstanding, much of the data to this point were fragmented in scope and coverage, difficult to access, uneven in quality, and varied markedly in the degree of documentation. With initial input and on-going guidance from Howard Elliott and Eduardo Trigo, the International Service for National Agricultural Research (ISNAR) launched an undertaking in late 1984 led by Philip Pardey and co-executed by Han Roseboom, to expand the available agricultural R&D data while also striving to standardize both the data collected and the way they are treated. Where possible, data were collected and compiled in adherence with *Frascati Manual* (OECD 2002) guidelines to increase the compatibility of the agricultural R&D indicators with other R&D series reported by the Organisation for Economic Cooperation and Development (OECD), the United Nations Educational, Scientific and Cultural Organization (UNESCO), and others.[40]

This led to the Pardey and Roseboom (1989) publication *ISNAR Agricultural Research Indicators Serie*s, an extensively documented compilation of statistics on basic spending and (full-time equivalent) personnel employed by national agricultural research systems (NARSs) that drew on three benchmark ISNAR surveys (which yielded usable data for nearly 70 developing-country NARSs) plus information from almost 900 additional data sources. The series includes data on 154 developed and developing countries spanning the period 1960–86 (although complete data for all countries for all years were not available). This series, like the one published by Oram and Bindlish (1981), encompassed agriculture,

[38] The U.N. Food and Agriculture Organization produced a great deal of published and unpublished agricultural research system reviews, directories of agricultural research organizations, regional overviews of national agricultural research activities, conference and workshop reports, and so on that included data on investments and scientific personnel as well as institutional information on national agricultural research efforts. However, no comprehensive cross-country compilation of agricultural R&D spending data appears to have existed prior to the work led by Evenson, although the United Nations Educational, Scientific and Cultural Organization (UNESCO), and several collaborating agencies, did (and still do) produce *Statistical Yearbooks* and other reports and maintain on-line data repositories that contain relevant information.

[39] Evenson and Kislev (1975a and b, Appendix 1) reported research and extension expenditure and personnel estimates for 84 countries for circa 1965.

[40] The latest incarnation of these guidelines is the 2002 version of the *Frascati Manual*, which had its beginnings in a June 1963 meeting convened by the OECD at the Villa Falcioneri in Frascati, Italy.

forestry and fisheries research undertaken by public agencies. Boyce and Evenson's 1975 series sought to exclude forestry and fisheries research.[41]

During the 1990s, ISNAR (in collaboration with the International Food Policy Research Institute, IFPRI) evolved its on-going country survey and data compilation work into the Agricultural Science and Technology Indicators (ASTI) initiative. This involved a second round of survey effort undertaken by Philip Pardey, Han Roseboom and Nienke Beintema, data from which were used to form the regional and global summaries for the period 1976–1995 published in Pardey and Beintema (2001). Since 2002 the ASTI initiative has been led by Nienke Beintema at IFPRI. Pardey et al. (2006) updated the regional and global summaries for the period 1981–2000, to which data for selected countries and regions were added in the 2010 report by Beintema and Stads. In addition to this "global" update, and another published in 2012, with global estimates spanning the period 1980-2008 (see Beintema et al. 2012), the ASTI initiative has continued to maintain a large number of country-specific series, with accompanying country briefs and regional summaries for 64 developing countries.[42]

[41] Pardey, Roseboom and Anderson (1991, p. 268) estimated that in 1981–85 about 7.3 percent of the research in developing countries was related to forestry and 5.7 percent to fisheries.

[42] The more recent regional summaries are for sub-Saharan Africa (Beintema and Stads 2011), Latin America & Caribbean (Stads and Beintema 2009), and Asia & Pacific (Beintema and Stads 2008). The ASTI country reports and data can be downloaded from www.asti.cgiar.org. ASTI data are also available via FAO at http://faostat3.fao.org/home/E.

Table 1: Summary of agPERD Data Sources and Estimation Methods for High-Income Countries, 1960-2011

	Classification of sources	Share of observations						Share of AgRD spending					
		1960-1969	1970-1979	1980-1989	1990-1999	2000-2011	1960-2011	1960-1969	1970-1979	1980-1989	1990-1999	2000-2011	1960-2011
							(percent)						
1	National	10.8	17.0	20.3	26.2	20.5	19.0	38.5	36.8	47.3	61.9	50.5	49.5
2	ASTI			4.9	5.4	3.2	2.7			0.8	1.1	0.6	0.6
3	Various sources	6.2	16.5	12.2	3.0		7.3	19.0	26.0	16.6	2.4		9.3
4	OECD based	2.2	1.4	18.6	23.8	36.3	17.2	0.8	0.4	10.4	15.3	22.5	13.2
5	InSTePP estimates	4.6	8.1	8.1	9.2	10.8	8.3	13.0	14.2	13.5	12.5	14.2	13.5
6	Rate of change	30.3	28.1	8.9	1.9	6.5	14.8	16.8	18.0	8.2	2.5	10.5	9.8
7	ARI based	38.1	15.4	18.9	21.1	18.2	22.2	10.1	0.6	1.2	0.5	0.6	1.5
8	Interpolate	7.8	13.5	8.1	9.5	4.5	8.5	1.7	4.2	2.1	3.9	1.1	2.5
	Total	100	100	100	100	100	100	100	100	100	100	100	100

Notes: Includes 37 high-income countries which are: Australia, Austria, Barbados, Belgium, Canada, Chile, Cyprus, Denmark, Finland, France, Germany, Greece, Guam, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Puerto Rico, Qatar, Republic of Korea, Saint Kitts and Nevis, Singapore, Spain, Sweden, Switzerland, Trinidad and Tobago, United Arab Emirates, United Kingdom, United States, United States Virgin Islands, and Uruguay.

1. Data obtained from national statistical agencies; 2. Data downloaded from ASTI (http://www.asti.cgiar.org/) in October 2014; 3. Data from Pardey and Roseboom (1989), Alston et al. (1999), and ISNAR Statistical briefs downloaded from http://www.asti.cgiar.org/publications/country-briefs; 4. Data based on: (i) Gross Domestic Expenditure on Research and Development (GERD) data series downloaded from OECD.Stat (http://stats.oecd.org/); (ii) OECD's International Survey of the Resources Devoted to R&D (various years); (iii) Science & Technology Indicators, Basic Statistical Series (various years); 5. InSTePP estimates based on data obtained from various sources; 6. Series back- or forward-cast using rate of change in relevant agricultural R&D data obtained from various sources, including those cited in 4; 7: Proximate agricultural research intensities (i.e., agricultural R&D spending relative to agGDP) used in conjunction with corresponding annual, country-specific measures of agGDP to develop estimates of the amount of agricultural R&D spending per country per year; 8. Missing values derived by linear interpolation.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011

Country	Data sources
High Income	
Australia	Mullen (2010) and OECD (2014).
Austria	OECD (1970), OECD (1974), OECD (2014). Some estimates were linearly interpolated or derived from ARIs.
Barbados	Pardey and Roseboom (1989). Some estimates were derived from ARIs.
Belgium	Pardey and Roseboom (1989) and OECD (2014). 1960 estimate derived from ARI; 1981 to 1999 estimates derived using average share of AgR&D in total R&D on total R&D data.
Canada	Carew (2001), Agriculture and Agri-Food Canada (2015), Pardey, Roseboom, and Craig (1999).
Chile	Pardey and Roseboom (1989); ASTI (2014a); OECD (2014); Some estimates were derived from ARIs.
Cyprus	Pardey and Roseboom (1989); Some estimates were derived from ARIs.
Denmark	OECD (1970), OECD (1974), OECD (2014); some estimates were linearly interpolated or derived from ARIs.
Finland	Pardey and Roseboom (1989) and OECD (2014). Some estimates were linearly interpolated or derived from ARIs.
France	Cranney (1996), Pardey and Roseboom (1989), Pardey, Roseboom, and Craig (1999), and MESR (2011). 2010 and 2011 estimates derived using the 2009 average share of AgR&D in total R&D on total R&D data.
Germany	Pardey and Roseboom (1989) and OECD (2014). Some estimates were linearly interpolated or derived from the total R&D spending series.
Greece	Pardey, Roseboom, and Craig (1999) and OECD (2014); Some estimates were derived from ARI or estimated using the share of AgR&D in total R&D.
Guam	USDA, CRIS (various reports and unpublished data files).
Iceland	Pardey and Roseboom (1989) and OECD (2014). Some estimates were linearly interpolated or based on ARIs.
Ireland	Pardey and Roseboom (1989), OECD (1973), OECD (1974), and OECD (2014). Some years were linearly interpolated or based on ARIs.
Israel	Pardey and Roseboom (1989), Odedand Brenner (2012) . Some estimates were linearly interpolated or based on ARIs.
Italy	Esposti (2011) and OECD (2014), 1997 was linearly interpolated.
Japan	Pardey and Roseboom (1989), Kinoshita (2011) and OECD (2014).

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
Luxembourg	OECD (2014). Most estimates were derived from ARIs.
Netherlands	Roseboom and Rutten (1999), Wageningen UR (various years), de Bruin (2010). Some estimates were derived from ARIs.
New Zealand	Hall and Scobie (2006) and Statistics New Zealand (various years). Some estimates were linearly interpolated.
Norway	Pardey and Roseboom (1989), OECD (1970), OECD (1973), OECD (1974), and OECD (2014). Some estimates were linearly interpolated or based on ARIs.
Portugal	Pardey and Roseboom (1989) and OECD (2014).
Puerto Rico	Pardey and Roseboom (1989), USDA, CRIS (various reports and unpublished data files). Some estimates were linearly interpolated or based on ARIs.
Qatar	Pardey and Roseboom (1989). Most estimates were derived from ARIs.
Republic of Korea	Pardey and Roseboom (1989), Choi et al. (2006) and OECD (2014). A few estimates were linearly interpolated or based on ARIs.
Singapore	Pardey and Roseboom (1989) and OECD (2014). Some estimates were linearly interpolated or based on ARIs.
Spain	Pardey and Roseboom (1989), INE (2013), and OECD (2014). Some estimates were linearly interpolated or based on ARIs.
Sweden	Pardey and Roseboom (1989), OECD (1970), OECD (1973), OECD (1974), OECD (2014). Some estimates were linearly interpolated or based on ARIs.
Switzerland	Pardey and Roseboom (1989), Martin (2010), Boyce and Evenson (1975), Bundesamt fur Statistik (1983), and Kurath (1994), and Office Fédéral de la Statistique (2014a, 2014b).
Trinidad and Tobago	Pardey and Roseboom (1989). Most estimates were derived from ARIs.
United Arab Emirates	Pardey and Roseboom (1989). Most estimates were derived from ARIs.
United Kingdom	Thirtle et al. (1999), McFarlane (2010), Nicholls (2014), HESA (2015), and Thirtle, Piesse, and Schimmelpfennig (2008), Department for Business, Innovation & Skills (2014).
United States	USDA, CRIS (various reports and unpublished data files), U.S. Department of Treasury (various years), U.S. SEA, CSRS and SES, and NSF (various years). InSTePP's U.S. agPERD series, see Section 5 of this document.
U.S. Virgin Islands	USDA, CRIS (various reports and unpublished data files).
Uruguay	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
East/South Asia and Pacific	
Bangladesh	Pardey and Roseboom (1989); ASTI (2014a); Some estimates derived from ARIs.
China	Fan and Pardey (1992); Fan et al (2006); Hu et al. (2011); Huang and Hu (2012). 2010 and 2011 were derived from ARIs.
Fiji	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
India	Pal and Byerlee (2006); ASTI (2014a); 1960, 2010 and 2011 were derived from ARIs.
Indonesia	Fuglie and Piggot (2006); ASTI (2014a); FAO (2013); OECD (2012). Some estimates derived from ARIs.
Lao	ASTI (2014a); Some estimates derived from ARIs.
Malaysia	Pardey and Roseboom (1989); ASTI (2014a). 2011 was derived from ARIs.
Myanmar	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Nepal	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Pakistan	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Papua New Guinea	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Philippines	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Samoa	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Solomon Islands	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Sri Lanka	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Thailand	Pardey and Roseboom (1989); Some estimates were derived from ARIs.
Tonga	Pardey and Roseboom (1989); Some estimates were derived from ARIs.
Tuvalu	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Vanuatu	Pardey and Roseboom (1989); Most estimates were derived from ARIs.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
Vietnam	Boyce and Evenson (1975); ASTI (2014a); Some estimates were derived from ARIs.
Latin America and Caribbean	
Argentina	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Belize	ASTI (2014a); Some estimates were derived from ARIs.
Bolivia	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Brazil	ASTI (2014a); Avila (2012); Some estimates were derived from ARIs. 1976 to 1980 agricultural R&D expenditures from other government, higher education, and private non-profit were based on the 1981 ratio of Embrapa to these sectors of performance spending. 2007-2011 data were estimated using average agricultural R&D spending growth rate from previous years.
Colombia	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Costa Rica	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Cuba	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Dominican Republic	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Ecuador	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
El Salvador	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Guatemala	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Guyana	Pardey and Roseboom (1989); Most estimates were derived from ARIs.
Haiti	Pardey and Roseboom (1989); Most estimates were linearly interpolated or derived from ARIs.
Honduras	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Jamaica	Pardey and Roseboom (1989); Most estimates were linearly interpolated or derived from ARIs.
Mexico	Pardey and Roseboom (1989); Beintema et al (2001); ASTI (2014a); Some estimates were derived from ARIs.
Nicaragua	Pardey and Roseboom (1989); ASTI (2014a); Most estimates were linearly interpolated or derived from ARIs.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
Panama	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Paraguay	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Peru	Pardey and Roseboom (1989); Most estimates were linearly interpolated or derived from ARIs.
Saint Kitts and Nevis	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Saint Lucia	Pardey and Roseboom (1989); Most estimates were derived from ARIs.
Venezuela	Pardey and Roseboom (1989); Most estimates were linearly interpolated or derived from ARIs.
Middle East and North Africa	
Egypt	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Iran	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Jordan	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Morocco	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were derived from ARIs.
Syria	Pardey and Roseboom (1989); ASTI (2014a); Most estimates were linearly interpolated or derived from ARIs.
Tunisia	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Central Asia and Europe	
Turkey	Pardey and Roseboom (1989); OECD (2014a); Some estimates were linearly interpolated or derived from ARIs.
Sub-Saharan Africa	
Angola	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Benin	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Botswana	Mazzucato and Ly (1993); ASTI (2014a, 2014b); 1960 was derived from ARIs.
Burkina Faso	Mazzucato (1994a); ASTI (2014a, 2014b); Some estimates were derived from ARIs.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
Burundi	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were linearly interpolated or derived from ARIs.
Cameroon	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Cape Verde	Beintema et al (1994a); Some estimates were linearly interpolated or derived from ARIs.
Central African Rep.	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were derived from ARIs.
Chad	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
Congo	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were linearly interpolated or derived from ARIs.
Côte d'Ivoire	Roseboom and Pardey (1994a); ASTI (2014a); Some estimates were derived from ARIs.
Dem. Rep. of Congo	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were linearly interpolated or derived from ARIs.
Eritrea	ASTI (2014a, 2014b); Some estimates were linearly interpolated or derived from ARIs.
Ethiopia	Roseboom et al (1994a); ASTI (2014a, 2014b); 1960 was derived from ARI.
Gabon	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Gambia	ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Ghana	Roseboom and Pardey (1994b); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Guinea	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Guinea-Bissau	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were derived from ARIs.
Kenya	Roseboom and Pardey (1993a); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Lesotho	Beintema et al (1995a); ASTI (2014b); Some estimates were derived from ARIs.
Liberia	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were linearly interpolated or derived from ARIs.
Madagascar	Pardey and Roseboom (1989); Roseboom and Pardey (1994c); ASTI (2014a, 2014b); 1960 was derived from ARI.
Malawi	Roseboom and Pardey (1993b); ASTI (2014a, 2014b); 1960 was derived from ARI.

Table 2: Domestic Public Expenditures on Food and Agricultural R&D (agPERD) Data Sources by Country, 1960-2011 (continued)

Country	Data sources
Mali	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Mauritania	Pardey and Roseboom (1989); ASTI (2014a); Some estimates were linearly interpolated or derived from ARIs.
Mauritius	Beintema et al. (1995b); ASTI (2014a, 2014b); 1960 was derived from ARIs.
Mozambique	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were linearly interpolated or derived from ARIs.
Namibia	Beintema et al (1994b); ASTI (2014b); Some estimates were derived from ARIs.
Niger	Mazzucato and El-Habib (1993); ASTI (2014a); Some estimates were derived from ARIs.
Nigeria	Roseboom et al (1994b); ASTI (2014a, 2014b); 1960 was derived from ARIs.
Rwanda	Roseboom and Pardey (1993c); ASTI (2014b); Some estimates were derived from ARIs.
Sao Tome and Principe	Pardey and Roseboom (1989); Most estimates were derived from ARIs.
Senegal	Mazzucato (1994b); ASTI (2014a, 2014b); 1960 was derived from ARIs.
Sierra Leone	Pardey and Roseboom (1989); ASTI (2014b); Some estimates were derived from ARIs.
Somalia	Pardey and Roseboom (1989); Some estimates were linearly interpolated or derived from ARIs.
South Africa	Liebenberg (2012).
Sudan	Beintema et al (1995c); ASTI (2014a, 2014b); 1960 was derived from ARIs.
Swaziland	Beintema et al (1995d); ASTI (2014b); Some estimates were derived from ARIs.
Togo	Beintema et al (1995e); ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Uganda	ASTI (2014a, 2014b); Some estimates were derived from ARIs.
Tanzania	Pardey and Roseboom (1989); ASTI (2014a, 2014b); Some estimates were linearly interpolated or derived from ARIs.
Zambia	Roseboom and Pardey (1995); ASTI (2014a); Some estimates were derived from ARIs.
Zimbabwe	Roseboom et al (1995); ASTI (2014b); Some estimates were linearly interpolated or derived from ARIs.

Table 3: Summary of Data Sources and Estimation Methods for Core agPERD Global Compilation, 1960-2011

	Classification of sources	Share of observations						Share of AgRD spending					
		1960-1969	1970-1979	1980-1989	1990-1999	2000-2011	1960-2011	1960-1969	1970-1979	1980-1989	1990-1999	2000-2011	1960-2011
							(percent)						
1	National	3.8	5.9	6.6	8.9	7.2	6.5	25.8	26.0	28.6	44.8	38.1	35.3
2	ASTI			22.2	35.4	36.2	19.4			13.8	21.6	18.7	14.5
3	Various sources	7.5	21.4	15.5	2.1		8.9	12.2	20.8	11.6	1.4		6.2
4	OECD based	0.6	0.4	5.3	7.5	11.1	5.2	0.5	0.2	5.8	9.3	11.8	7.6
5	InSTePP estimates	1.3	2.3	2.3	2.6	3.4	2.4	7.6	8.4	7.6	6.9	8.8	8.0
6	Rate of change	22.8	29.1	7.6	1.5	1.9	12.1	27.7	33.6	22.5	5.7	5.0	14.0
7	ARI based	52.7	25.8	33.6	38.5	38.7	37.9	20.7	5.3	7.9	8.2	17.0	12.0
8	Interpolate	11.2	15.2	6.8	3.5	1.5	7.4	5.4	5.7	2.2	2.2	0.6	2.3
	Total	100	100	100	100	100	100	100	100	100	100	100	100

Notes: Includes 130 countries. Excludes Eastern Europe and Former Soviet Union countries.

1. Data obtained from national statistical agencies; 2. Data downloaded from ASTI (http://www.asti.cgiar.org/) in October 2014; 3. Data from Pardey and Roseboom (1989), Alston et al. (1999), and ISNAR Statistical briefs downloaded from http://www.asti.cgiar.org/publications/country-briefs; 4. Data based on: (i) Gross Domestic Expenditure on Research and Development (GERD) data series downloaded from OECD.Stat (http://stats.oecd.org/); (ii) OECD's International Survey of the Resources Devoted to R&D (various years); (iii) Science & Technology Indicators, Basic Statistical Series (various years); 5. InSTePP estimates based on data obtained from various sources; 6. Series back- or forward-cast using rate of change in relevant agricultural R&D data obtained from various sources, including those cited in 4; 7: Proximate agricultural research intensities (i.e., agricultural R&D spending relative to AgGDP) used in conjunction with corresponding annual, country-specific measures of AgGDP to develop estimates of the amount of agricultural R&D spending per country per year; 8. Missing values derived by linear interpolation.

Table 4: Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 4.

ISIC	Description
1-5	**Agriculture, Forestry and Fishing**
	011 – Growing of non-perennial crops
	012 – Growing of perennial crops
	013 – Plant propagation
	014 – Animal production
	015 – Mixed farming
	016 – Support activities to agriculture and post-harvest crop activities
	017 – Hunting, trapping and related service activities
	020 – Forestry, logging and related service activities
	021 – Silviculture and other forestry activities
	022 – Logging
	023 – Gathering of non-wood forest products
	024 – Support services to forestry
	031 – Fishing
	032 – Aquaculture
10-12	**Food Products, Beverages and Tobacco**
	101 – Processing and preserving of meat
	102 – Processing and preserving of fish, crustaceans and molluscs
	103 – Processing and preserving of fruit and vegetables
	104 – Manufacture of vegetable and animal oils and fats
	105 – Manufacture of dairy products
	106 – Manufacture of grain mill products, starches and starch products
	107 – Manufacture of other food products
	108 – Manufacture of prepared animal feeds
	110 – Manufacture of beverages
	120 – Manufacture of tobacco
20	**Chemicals and Chemical Products**
	201 – Manufacture of basic chemicals, fertilizers and nitrogen compounds, plastics and synthetic
	2011 – Manufacture of basic chemicals
	2012 – Manufacture of fertilizers and nitrogen compounds
	2013 – Manufacture of plastics and synthetic rubber in primary forms
	202 – Manufacture of other chemical products
	2021 – Manufacture of pesticides and other agrochemical products
	2022 – Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	2424 – Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and
	2029 – Manufacture of other chemical products n.e.c.
	203 – Manufacture of man-made fibres
	2030 – Manufacture of man-made fibres

Table 4: Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 4. (continued)

ISIC	Description
21	**Manufacture of basic pharmaceutical products and pharmaceutical preparations**
	210 – Manufacture of pharmaceuticals, medicinal chemical and botanical products
	2030 – Manufacture of pharmaceuticals, medicinal chemical and botanical products
28	**Machinery and equipment, n.e.c**
	281 – Manufacture of general-purpose machinery
	2811 – Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
	2812 – Manufacture of fluid power equipment
	2813 - Manufacture of pumps, compressors, taps and valves
	2814 - Manufacture of bearings, gears, gearing and driving elements
	2815 - Manufacture of ovens, furnaces and furnace burners
	2816 - Manufacture of lifting and handling equipment
	2817 – Manufacture of office machinery and equipment (except computers and peripheral
	2818 – Manufacture of power driven hand tools
	2919 - Manufacture of other general-purpose machinery
	282 - Manufacture of special-purpose machinery
	2821 - Manufacture of agricultural and forestry machinery
	2822 - Manufacture of metal-forming machinery and machine tools
	2823 - Manufacture of machinery for metallurgy
	2824 - Manufacture of machinery for mining, quarrying and construction
	2825 - Manufacture of machinery for food, beverage and tobacco processing
	2826 - Manufacture of machinery for textile, apparel and leather production
	2829 - Manufacture of other special-purpose machinery

Source: United Nations Statistics Division (2015).

Table 5: Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 3.1.

ISIC	Description
1-5	**Agriculture, Hunting, Forestry and Fishing**
	011 - Growing of crops; market gardening; horticulture
	012 - Farming of animals
	013 - Growing of crops combined with farming of animals (mixed farming)
	014 - Agricultural and animal husbandry service activities, except veterinary activities
	015 - Hunting, trapping and game propagation including related service activities
	020 - Forestry, logging and related service activities
	050 - Fishing, aquaculture and service activities incidental to fishing
15-16	**Food Products, Beverages and Tobacco**
	151 - Production, processing and preservation of meat, fish, fruit, vegetables, oils and fats
	152 - Manufacture of dairy products
	153 - Manufacture of grain mill products, starches and starch products, and prepared animal feeds
	154 - Manufacture of other food products
	155 - Manufacture of beverages
	160 - Manufacture of tobacco products
24	**Chemicals and Chemical Products**
	241 - Manufacture of basic chemicals
	2411 - Manufacture of basic chemicals, except fertilizers and nitrogen compounds
	2412 - Manufacture of fertilizers and nitrogen compounds
	2413 - Manufacture of plastics in primary forms and of synthetic rubber
	242 - Manufacture of other chemical products
	2421 - Manufacture of pesticides and other agrochemical products
	2422 - Manufacture of paints, varnishes and similar coatings, printing ink and mastics
	2423 - Manufacture of pharmaceuticals, medicinal chemicals and botanical products
	2424 - Manufacture of soap and detergents, cleaning and polishing preparations, perfumes and
	2429 - Manufacture of other chemical products n.e.c.
	243 - Manufacture of man-made fibres
	2430 - Manufacture of man-made fibres
29	**Machinery and equipment, n.e.c**
	291 - Manufacture of general-purpose machinery
	2911 - Manufacture of engines and turbines, except aircraft, vehicle and cycle engines
	2912 - Manufacture of pumps, compressors, taps and valves
	2913 - Manufacture of bearings, gears, gearing and driving elements
	2914 - Manufacture of ovens, furnaces and furnace burners
	2915 - Manufacture of lifting and handling equipment
	2919 - Manufacture of other general-purpose machinery
	292 - Manufacture of special-purpose machinery
	2921 - Manufacture of agricultural and forestry machinery

Table 5: Industry Classification of Agricultural and Food Related R&D Spending by the Business Enterprise Sector, ISIC Rev 3.1. (continued)

ISIC	Description
	2922 - Manufacture of machine tools
	2923 - Manufacture of machinery for metallurgy
	2924 - Manufacture of machinery for mining, quarrying and construction
	2925 - Manufacture of machinery for food, beverage and tobacco processing
	2926 - Manufacture of machinery for textile, apparel and leather production
	2927 - Manufacture of weapons and ammunition
	2929 - Manufacture of other special-purpose machinery
	293 - Manufacture of domestic appliances n.e.c.
	2930 - Manufacture of domestic appliances n.e.c.

Source: United Nations Statistics Division (2013).

Table 6*:* Summary of agBERD Data Sources and Methods for High-income Countries, 1980-2011

		Share of observations				Share of AgRD spending			
Classification of sources		1980-1989	1990-1999	2000-2011	1960-2011	1980-1989	1990-1999	2000-2011	1960-2011
					(percent)				
1	OECD based	29.4	56.0	63.3	43.6	33.4	54.6	63.4	48.4
2	U.S. InSTePP series	2.9	2.9	2.6	3.0	36.4	39.1	33.3	36.1
3	National	2.0	0.3	0.7	1.5	0.2	0.3	0.6	0.4
4	Rate of change	26.3	2.6		18.8	24.4	1.1		11.4
5	Econometric	25.7	25.7	25.7	20.9	0.5	0.5	0.5	0.4
6	Other	2.6	4.6	2.6	2.6	3.3	1.9	0.2	1.2
7	Interpolated		2.6	3.1	1.6		1.5	1.8	1.1
8	Ratio private-to-public	11.1	5.4	1.9	8.0	1.8	1.1	0.2	1.0
	Total	100	100	100	100	100	100	100	100

Notes. Data series include a total of 35 high income countries but for nine countries of them data are available only between 1980 and 2011: Barbados, Cyprus, Luxembourg, Puerto Rico, Qatar, Saint Kitts and Nevis, Trinidad and Tobago, United Arab Emirates and Uruguay. For the remaining 26 countries data are available from 1980 to 2011: Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Netherlands, New Zealand, Norway, Portugal, Republic of Korea, Singapore, Spain, Sweden, Switzerland, United Arab Emirates, United Kingdom, United States, and United States Virgin Islands.

1. Data based on: OECD-ANBERD, OECD-BERD, and OECD yearly statistical reports. Estimates for some industry and years were derived by authors based on available information; 2. U.S data sourced from Dehmer and Pardey; 3. Data obtained from national statistical agencies; 4. Rate of change: observed agricultural R&D data back cast or forward cast using the rate of change of comparable data reported mainly in OECD-ANBERD Rev 2, OECD-ANBERD Rev 3.1, OECD *Survey of the Resources Devoted to R&D,* various years, and for new Zealand from Hall and Scobie (1986); 5. Data estimated econometrically; 6. Data derived from various nationally sourced statistics, OECD sources for Israel and Switzerland; 7. Linear interpolation; 8. An estimate of the ratio of private-to-public spending was applied to the respective public sector total.

Table 7: Private Food and Agricultural R&D (agBERD) Data Sources for High-Income Countries

Country	Data sources
Australia	OECD-ANBERD Rev.2 and 4.0. 1970-72 estimates derived from private-to-public AgRD ratio. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Austria	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 3.1., OECD-ANBERD Rev. 4.0.; Estimates for some industries were linearly interpolated for some years.
Barbados	InSTePP estimates based on econometric methods.
Belgium	OECD (1970), OECD (1973), OECD (1974), OECD (1979), OECD (1991), and OECD-ANBERD Rev. 3.1 and Rev. 4.0; Estimates for some industries were linearly interpolated for some years.
Chile	OECD-ANBERD Rev. 3.1 and OECD-BERD Rev 3.1. 1970 to 1997 estimates derived from private-to-public AgRD ratio.
Cyprus	InSTePP estimates based on econometric methods.
Canada	OECD (1970), OECD (1973), OECD (1974), OECD-ANBERD Rev. 2.0, 3.1. and 4.0, and OECD-BERD Rev.3.1. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Denmark	OECD (1970), OECD (1973), OECD (1974), OECD-ANBERD Rev. 2.0, 3.1. and 4.0, and OECD-BERD Rev.3.1. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Finland	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0, and OECD-BERD Rev.3.1. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
France	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0. Estimates for some industries were linearly interpolated for some years.
Germany	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0., and OECD-BERD Rev.3.1. Estimates for some industries were linearly interpolated for some years.
Greece	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Iceland	OECD (1974), OECD (1979), OECD (1991), OECD-ANBERD Rev.3.1. and Rev. 4.0. 1970 estimate based on private-to-public AgR&D ratio. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Ireland	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Israel	OECD-ANBERD Rev 3.1, Oded and Brenner (2012). 1970-1988 estimates based on private-to-public AgR&D ratio. Estimates of each industry for 2011 was estimated using their 2010 share in total private R&D spending.
Italy	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1. and 4.0., and OECD-BERD Rev.3.1. Estimates for some industries were linearly interpolated for some years.

Table 7: Private Food and Agricultural R&D (agBERD) Data Sources for High-Income Countries (continued)

Country	Data sources
Japan	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0 and 4.0. Estimates for some industries were linearly interpolated for some years.
Luxemburg	InSTePP estimates based on econometric methods.
Netherlands	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2.0, 3.1 and 4.0. Estimates for some industries and years were estimated using their respective private share in total or linearly interpolated.
New Zealand	OECD-ANBERD Rev. 3.1. and Rev 4.0., Hall and Scobie (1986), and Statistics New Zealand (2003). Estimates for some industries and some years were estimated using their respective share in total or linearly interpolated.
Norway	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-BERD Rev. 2.0., Rev.3.1 and Rev 4.0. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Qatar	InSTePP estimates based on econometric methods.
Portugal	OECD (1974), OECD (1979), OECD (1991), OECD-ANBERD Rev. 3.1. and Rev 4.0. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Puerto Rico	InSTePP estimates based on econometric methods.
Republic of Korea	OECD-ANBERD rev. 4.0. Estimates from 1970 to 1994 were derived using the private-to-public AgR&D ratio.
Singapore	OECD-ANBERD Rev. 3.1. and Rev 4.0. Estimates for agriculture was estimated using its private share in total for some years. 1970 to 1993 estimates derived from private-to-public AgRD ratio.
Spain	OECD (1974), OECD (1979), OECD (1991), OECD-ANBERD Rev. 3.1. and Rev. 4.0.
St Kitts and Nevis	InSTePP estimates based on econometric methods.
Sweden	OECD (1970), OECD (1973), OECD (1974), OECD (1991), OECD-ANBERD Rev. 2, 3.1. and 4.0, and OECD-BERD Rev.3.1. Estimates for a few years were linearly interpolated.
Switzerland	OECD (1973), OECD (1974), OECD (1979), OECD (1991), OECD-ANBERD Rev. 2., and Office Federal de la Statistique 2014 (Swiss Federal Office of Statistics). Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
Taiwan	OECD-ANBERD Rev. 4. 1970 to 1997 estimates derived from private-to-public AgRD ratio.
Trinidad and Tobago	InSTePP estimates based on econometric methods.
United Arab Emirates	InSTePP estimates based on econometric methods.

Table 7: Private Food and Agricultural R&D (agBERD) Data Sources for High-Income Countries (continued)

Country	Data sources
United Kingdom	OECD (1970), OECD (1973), OECD (1974), OECD-ANBERD Rev. 2, 3.1 and 4.0. Estimates for some industries and some years were estimated using their respective private share in total or linearly interpolated.
United States	InSTePP's U.S. agBERD series, see Section 6 of this document
Uruguay	InSTePP estimates based on econometric methods.

Table 8: State Forestry Schools—Dates of Establishment

Location	State	Year Established
Northeast		
Syracuse	New York	1911
Burlington	Vermont	1946
Southern		
Auburn	Alabama	1946
Ruston	Louisiana	1945
Mississippi State	Mississippi	1954
Raleigh	North Carolina	1937
Clemson	South Carolina	1956
Nacogdoche	Texas	1946
North Central		
Carbondale	Illinois	1958
Ann Arbor	Michigan	1927
Houghton	Michigan	1936
Western		
Flagstaff	Arizona	1958
Arcata	California	1954
San Luis Obispo	California	1975
Fort Collins	Colorado	1909
Moscow	Idaho	1909
Missoula	Montana	1913
Corvallis	Oregon	1908
Seattle	Washington	1907

Sources: Compiled by authors via a phone survey of forestry schools and online searches. For Acarta, San Louis Obispo, and Fort Collins, the year of establishment we determined differed from that reported in FAO (1994), which was 1890 for Fort Collins, 1900 for St Louis Obispo, and 1913 for Acarta.

Table 9: Agricultural Industry Classifications for U.S. Food and Agricultural R&D: Private Series

Industry Name	SIC	Industry Name	SIC
AGRIC PROD-LVSTK,ANIMAL SPEC	200	GEN FARMS-LVSTK, ANIMAL SPEC	291
AGRICULTURAL SERVICES	700	GEN LIVESTK,EX DAIRY,POULTRY	219
AGRICULTURE CHEMICALS	2870	GENERAL FARMS,PRIMARILY CROP	190
AGRICULTURE PRODUCTION-CROPS	100	GENERAL FARMS,PRIMARILY CROP	191
ANIMAL AQUACULTURE	273	GRAPES	172
ANIMAL SERVICE, EX VETERINARY	750	*INDUSTRIAL ORGANIC CHEMICALS	2860
ANIMAL SPEC SERVICES, EX VET	752	IRRIGATION SYSTEMS	4970
ANIMAL SPECIALTIES	270	IRRIGATION SYSTEMS	4971
ANIMAL SPECIALTIES, NEC	279	KNITTING MILLS	2250
BEEF CATTLE FEEDLOTS	211	LEATHER AND LEATHER PRODUCTS	3100
BEEF CATTLE, EXCEPT FEEDLOTS	212	LIVESTOCK SVCS,EX VETERINARY	751
BEET SUGAR	2063	LIVESTOCK,EX DAIRY AND POULTRY	210
BERRY CROPS	171	*MEDICINAL CHEMS,BOTANICL PDS	2833
BRDWOVEN FABRIC MILL, COTTON	2210	*MISC CHEMICAL PRODUCTS	2890
BRDWOVEN FABRIC MILL, COTTON	2211	*MISC FABRICATED TEXTILE PDS	2390
BRDWOVN FABRIC MAN MADE,SILK	2220	NITROGENOUS FERTILIZERS	2873
BRDWOVN FABRIC MAN MADE,SILK	2221	PESTICIDES, AGRIC CHEMS, NEC	2879
CANE SUGAR REFINING	2062	*PHARMACEUTICAL PREPARATIONS	2834
CANE SUGAR, EXCEPT REFINING	2061	PHOSPHATIC FERTILIZERS	2874
CHEM, FERTILIZER MINERAL MNG	1470	*PLASTIC MATL,SYNTHETIC RESIN	2820
CHEM,FERTLIZER MINRL MNG, NEC	1479	*PLASTICS,RESINS,ELASTOMERS	2821
*CHEMICALS & ALLIED PRODS	2800	POULTRY AND EGGS	250
CHEW AND SMOKE TOBACCO, SNUFF	2130	POULTRY AND EGGS, NEC	259
CHEW AND SMOKE TOBACCO, SNUFF	2131	POULTRY HATCHERIES	254
CHICKEN EGGS	252	RICE	112
*CIGARETTES	2110	RICE MILLING	2044
*CIGARETTES	2111	SHEEP AND GOATS	214
CIGARS	2120	SHELLFISH	913
CIGARS	2121	SOIL PREPARATION SERVICES	710
CITRUS FRUITS	174	SOIL PREPARATION SERVICES	711
COMMERCIAL FISHING	910	SOYBEAN OIL MILLS	2075
CORN	115	SOYBEANS	116
COTTON	131	SPECIAL PRODUCT SAWMILLS,NEC	2429
COTTON GINNING	724	SUGARCANE AND SUGAR BEETS	133
COTTONSEED OIL MILLS	2074	TEXTILE BAGS	2393
CROP HARVESTING-BY MACHINE	722	TEXTILE GOODS, NEC	2299
CROP PLNTNG,CULTVTNG,PROTECT	721	TEXTILE MACHINERY	3552
CROP PREP SVCS,EX COTTON GIN	723	TEXTILE MILL PRODUCTS	2200

Table 9: Agricultural Industry Classifications for U.S. Food and Agricultural R&D: Private Series (continued)

Industry Name	SIC	Industry Name	SIC
CROP SERVICES	720	THREAD MILLS	2284
DAIRY FARMS	240	TOBACCO	132
DAIRY FARMS	241	TOBACCO PRODUCTS	2100
DECIDUOUS TREE FRUITS	175	TOBACCO STEMMING AND REDRYING	2140
FARM AND GARDEN MACHINERY AND EQ	3520	TOBACCO STEMMING AND REDRYING	2141
FARM LABOR AND MANAGEMENT SVCS	760	TREE NUTS	173
*FARM MACHINERY AND EQUIPMENT	3523	TURKEYS AND TURKEY EGGS	253
FARM MANAGEMENT SERVICES	762	VEG OIL MILLS,EX CORN AND OTH	2076
FARM PD WAREHOUSE AND STORAGE	4221	VEGETABLES AND MELONS	160
FARM-PRODUCT RAW MATL-WHSL	5150	VEGETABLES AND MELONS	161
FERTILIZERS, MIXING ONLY	2875	VETERINARY SERVICE-LIVESTOCK	741
FIELD CROPS, EX CASH GRAINS	130	VETERINARY SERVICES	740
FIELD CRPS,EX CASH GRAIN,NEC	139	VETERINARY SVCS-ANIMAL SPECS	742
FISH HATCHERIES AND PRESERVES	920	WEFT KNIT FABRIC MILLS	2257
FISH HATCHERIES AND PRESERVES	921	WET CORN MILLING	2046
FISHING, HUNTING AND TRAPPING	900	WHEAT	111
FOOD CROPS GROWN UNDER COVER	182	YARN AND THREAD MILLS	2280
FRUITS AND TREE NUTS	170	YARN SPINNING MILLS	2281
FRUITS AND TREE NUTS, NEC	179	YARN TEXTURIZE, THROW, TWIST	2282
GEN FARMS-LVSTK, ANIMAL SPEC	290		

Source: Standard and Poors (2012).

Notes: For industries tagged with an asterisk, we estimated food and agriculturally related R&D expenditures using the percentage of sales associated with a firm's agricultural or food-related business segments.

Table 10: Food Industry Classifications for U.S. Food and Agricultural R&D: Private Series

Industry Name	SIC	Industry Name	SIC
ANIMAL AND MARINE FATS AND OILS	2077	FOOD PRODUCTS MACHINERY	3556
BAKERY PRODUCTS	2050	FROZEN BAKERY PDS, EX BREAD	2053
BEVERAGES	2080	FROZEN FRUIT,JUICE,VEGETABLE	2037
BREAD, BAKERY PDS, EX COOKIE	2051	FROZEN SPECIALITES, NEC	2038
CAN FRUIT,VEG,PRESRV,JAM,JEL	2033	*GRAIN MILL PRODUCTS	2040
CAN,FROZNPRESRV FRUIT & VEG	2030	ICE CREAM & FROZEN DESSERTS	2024
CANDY AND OTH CONFECTION PRODS	2064	*INDUSTRIAL CONGLOMERATES	9997
CANDY, NUT, CONFECTNRY STORES	5440	IRISH POTATOES	134
CANDY, NUT, CONFECTNRY STORES	5441	MACARONI,SPAGHETTI AND NOODLES	2098
CANNED SPECIALTIES	2032	MALT	2083
CANNED, CURED FISH, SEAFOODS	2091	MALT BEVERAGES	2082
CEREAL BREAKFAST FOODS	2043	MEAT PACKING PLANTS	2011
CHEWING GUM	2067	MEAT PRODUCTS	2010
CHOCOLATE AND COCOA PRODUCTS	2066	MISC FOOD PREPS, KINDRED PDS	2090
COOKIES AND CRACKERS	2052	NAT, PROCESS, IMITATN CHEESE	2022
CREAMERY BUTTER	2021	PICKLD FRUIT,VEG,SAUCE,SEAS	2035
DAIRY PRODUCTS	2020	POTATO CHPS,CORN CHPS,SNACKS	2096
DISTILLED AND BLENDED LIQUOR	2085	POULTRY SLAUGHTER & PROCESS	2015
DRY, DEHYDR FRUIT, VEG, SOUP	2034	PREP FRESH,FROZN FISH, SEAFD	2092
DRY,CONDENSD,EVAP DAIRY PDS	2023	ROASTED COFFEE	2095
FATS AND OILS	2070	SALTED AND ROASTED NUTS, SEEDS	2068
FLAVORING EXTRACT,SYRUP, NEC	2087	SAUSAGE,OTH PREPARED MEAT PD	2013
FLOUR AND OTHER GRAIN MILL PDS	2041	SOAP AND OTHER DETERGENTS	2841
FLUID MILK	2026	*SOAP,DETERGENT,TOILET PREPS	2840
*FOOD AND KINDRED PRODUCTS	2000	SUGAR & CONFECTIONERY PRODS	2060
FOOD PREPARATIONS, NEC	2099	WINE,BRANDY & BRANDY SPIRITS	2084

Source: Standard and Poors (2012).

Notes: For industries tagged with an asterisk we estimated food and agriculturally related R&D expenditures using the percentage of sales associated with a firm's agricultural or food-related business segments.