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NATIONAL SECURITY RESEARCH DIVISION

# Reducing the Cultivation of Opium Poppies in Southern Afghanistan

## Appendixes A–E

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# Appendix A: Tables Concerning Chronology of Factors Affecting Opium Poppy Cultivation

**Table A.1. Environmental Shocks in Afghanistan, 1999–2013**

| Growing Season | Environmental Shock Experienced |
|---|---|
| 1999–2000 | Drought, disease |
| 2000–2001 | Drought |
| 2001–2002 | Good climactic year |
| 2002–2003 | Good climactic year, low disease rates |
| 2003–2004 | Drought/insufficient rain, historic disease/parasites, late frost |
| 2004–2005 | Good climactic year, low disease rates (namely in northeastern region), some drought in northeast |
| 2005–2006 | Some drought (particularly in west, central regions) |
| 2006–2007 | Good climactic year, no disease, some drought in rain-fed west |
| 2007–2008 | Good weather in south, no disease, drought (in rain-fed western areas, but not in irrigated south, southwest), extremely cold winter, conditions unfavorable for second spring crop |
| 2008–2009 | Good climactic year, heavy rains during harvest reduced yield in northeast |
| 2009–2010 | Historic disease (particularly in south; western crops less affected), bad weather, frost in west, rain shortage at harvest |
| 2010–2011 | Good climactic year, heat wave in south |
| 2011–2012 | Disease, bad weather (particularly in south, west, east), frost in late March affected early growing regions |
| 2012–2013 | Bad weather in south and west (type unspecified) |

SOURCE: UNODC, *Afghanistan Opium Survey*, various years, describing environmental conditions affecting opium poppy cultivation, some of which might also affect wheat and other cultivation.

**Table A.2. Counternarcotics and Other Policy Shocks in Afghanistan, 1999–2013**

| Growing Season | Gross Cultivation (hectares) | Counternarcotics and Other Policy Shocks |
|---|---|---|
| 1999–2000 | 82,172 | Taliban orders farmers to reduce area of opium poppy cultivation by one-third, modest compliance follows; negligible eradication occurs. |
| 2000–2001 | 7,598 | Taliban orders ban in July 2000; vigorous implementation in November–December; price boom follows. |
| 2001–2002 | 73,905 | Power vacuum in Kabul post 9/11; Afghan borders closed; Afghan Interim Administration formed; ban with compensation (voluntary). |
| 2002–2003 | 101,829 | Eradication campaign begins.[a] |
| 2003–2004 | 126,328 | Eradication data unpublished/unavailable.[a] |
| 2004–2005 | 107,845 | First post-Taliban presidential elections (Karzai); constitution signed; first comprehensive eradication program implemented (governor's programs [GLE] and central government-led [PEF] eradication begin).[a] |
| 2005–2006 | 180,158 | First post-Taliban parliamentary/provincial/district elections; impunity in south growing (while governance in other regions improving); Taliban issuance of "Night Letters"[b] in south; eradication increases significantly.[a] |
| 2006–2007 | 212,491 | Good Performers Initiative (GPI) begins; insecurity/violence spreading; cultivation linked with insurgency; record levels of eradication; "containment" policy implemented (decision to focus on elimination in Nangarhar and Badakshan).[a] |
| 2007–2008 | 162,732 | Punitive restraint increasingly urged by some governors, *shuras*, and village elders; cultivation increasingly geographically concentrated in south; global grain crisis begins; eradication efforts limited, hampered by insecurity. |
| 2008–2009 | 128,446 | ISAF and Afghan forces surge in the south begins, intensification of counternarcotics activities (southern, eastern provinces); Helmand Food Zone (HFZ) begins. |
| 2009–2010 | 124,648 | Second post-Taliban presidential/provincial elections; ISAF and Afghan forces surge in south continues; AGE control rising again in east (particularly, Nangarhar); central government-led (PEF) eradication ends; governor-led eradication declines concurrently due to worsening security situation. |
| 2010–2011 | 134,875 | Second post-Taliban parliamentary elections; governor's eradication threat in Helmand contributes to reductions in cultivation in the provincial center, but encourages opium poppy cultivation in peripheral areas; improper enforcement of eradication and increasing AGE influence in the east. |
| 2011–2012 | 164,108 | Improved governance in HFZ; shift to—and expansion in—opium poppy cultivation in ungoverned desert areas accelerates. |
| 2012–2013 | 216,731 | ISAF surge ends and withdrawal begins; HFZ ends; peripheral, ungoverned desert areas continue to serve as alternative venue for opium poppy cultivation. |

SOURCES: UNODC, *Afghanistan Opium Survey*, various years (2000-2013)
NOTE: AGE = antigovernment elements; PEF = Poppy Eradication Force.
[a] Over the years, the eradication data have been verified to varying degrees. Based on UNODC reporting (*Afghanistan Opium Survey*, various years), we assume little or no verification through 2003–2004 and partial to complete verification for subsequent years. For 2002–2003, UNODC reported that the eradication data were not verified. UNODC did not present an eradication estimate for 2003–2004. For 2004–2005 through 2006–2007, UNODC reported verification of the majority of each of the estimates that it presented in the annual surveys. From 2007–2008 onward, UNODC reported full verification of the eradication data.
[b] Night letters, or *shabnameh*, are a tool that the Taliban has used in the past to coerce poppy cultivation, but the Taliban has not done so recently. See Table 3.1 and accompanying note.

# Appendix B: Crop Budgets and Documentation

To better understand the drivers of opium poppy cultivation decisions in southern Afghanistan—and as a means to further validate the factor map—we conducted a detailed analysis of the returns to opium poppy production and, for comparative purposes, those of wheat. This appendix describes the resulting crop budgets for each commodity: that is, the revenues, costs, and returns associated with the production of opium poppy and wheat, respectively. The appendix also includes an item-by-item discussion of the parameter estimates and assumptions that support the calculations. We do not claim to be the first to compare the net returns across different crops. Kuhn (2009, 2010) and others have also done so; however, our comparison offers the benefit of comprehensive documentation and the flexibility to consider alternative scenarios under different assumptions about each parameter.

In the case of opium poppy, we examined revenues, costs, and returns with respect to land-owning households that either act as owner-operators or "let" land to sharecroppers and with respect to the sharecroppers themselves. As noted in Chapters Two and Three, land tenure has an important bearing on cultivation decisions and returns. In the case of wheat, we consider only the owner-operator. Although sharecropping arrangements can take many forms, we focus on a particular form that gives most of the decisionmaking authority to the landowner and, at the same time, places much of the production-related risk on the landowner. We calculate returns for the plausible circumstance in which the landowner selects the crop and provides all of the non-labor inputs, including room and board; the sharecropper provides all the necessary labor, either through household or hired labor; and the landowner and sharecropper cover *ushr* and other such crop payments or "taxes" in direct proportion to their crop shares.[1] In effect, the sharecropping arrangement serves primarily as a labor arrangement.

On the basis of the available data, we were able to produce nearly comprehensive budgets for opium poppy and wheat production in the CCA. Although we were not able to create separate budgets for either commodity in the *dasht*, we were able to collect enough information on desert-specific cultivation practices to highlight some important differences between the desert and non-desert areas.[2]

[1] This last statement is algebraically equivalent to saying that they make the payments jointly off the top of the harvest and then divide the remainder according to their distribution agreement, e.g. one-quarter to the sharecropper and three-quarters to the landowner. Mansfield (2013a, p. 86) implies such an arrangement in his depiction of a sharecropping arrangement in Table 6b: the sharecropper obtains his share of the yield "After Ushr and payment on opium is made."

[2] Note that Mansfield provides a table of net returns of opium poppy cultivation on one jerib (one-fifth of one hectare) of land in that area. See Mansfield, 2014, p. 67. That table also includes detailed comparisons of net returns for different land tenure arrangements and claimants.

In broad terms, each crop budget consists of two primary blocks of information, one pertaining to revenues and the other pertaining to costs, which, in combination, yield a bottom line: the net return for a given commodity, either opium poppy or wheat, from a given hectare, in a given growing season.

The challenge lies in parsing the revenues and costs and in populating the blocks with calculations drawn from plausible parameter estimates, given limited evidence on underlying production technologies and agricultural practices. Even in those instances in which we have substantial information about Afghan agricultural practices, we cannot know whether these practices reflect biological imperatives or the confluence of political and socio-economic circumstances and, thus, are changeable. For example, we might observe farmers using more of one type of fertilizer on opium poppy than on wheat, but that need not imply that, as a biological matter, opium poppy "requires" more of that fertilizer than wheat to grow, only that the marginal benefits of application are greater for opium poppy, given differences in the prices of the commodities, the costs of marketing, etc.

This appendix proceeds in three sections. In the first section, we describe our approach to organizing revenues and costs. We then present populated versions of the opium poppy and wheat budgets using a set of benchmark parameter estimates. Although we present the budgets in their static "snapshot" form for a particular set of benchmark parameter estimates, we have constructed the budgets as "live" spreadsheet models so that we can explore the implications of using alternative parameter values to test the sensitivity of the results to the estimates. In the second section, we present the evidence for the parameter estimates and discuss its limitations. We end the appendix with concluding remarks on the sensitivity of the budgets to the parameter estimates, including some pertaining to the *dasht*.

## The Structure of the Crop Budgets

Following the conventions of agricultural economics, each crop budget consists of two primary blocks of information, one on revenues and the other on costs, which, on balance, yield an estimate of net returns per growing season for a given amount of land—in this case, one hectare.[3] We, like others, have assumed that the revenues and costs associated with one hectare are the same for the second hectare and all additional hectares. We also assume that, for each hectare, inputs such as labor and fertilizer are used in fixed proportions. By "fixed proportions," we mean that farmers use inputs in a particular and unvarying combination on each hectare, e.g., 40 days of tilling labor, 6 kilograms of seed, 250 kilograms of fertilizer, etc. In economic

[3] See, for example, Pennsylvania State University, College of Agricultural Sciences, Penn State Extension, *The Agronomy Guide*, "Part 1. Crop and Soil Management, Section 12. Farm Management: Enterprise Budgets," 2014; or Gary Schnitkey, "Release of 2015 Crop Budgets," *Farmdoc Daily* blog, University of Illinois at Urbana-Champaign, Department of Agricultural and Consumer Economics, July 8, 2014.

parlance, we assumed a combination of price-taking behavior, constant returns to scale, and a Leontief production technology.

The revenue block shows the yields, prices, and sharecropping terms that give rise to cash inflows in each growing season. In our analysis, we include only the primary sources of revenue (i.e., opium and wheat) and do not include additional revenue from byproducts.[4]

The cost block consists of variable and fixed seasonal costs. The former includes costs tied directly to the decision to cultivate land and, in some instances, differ by crop. Examples include fertilizer, seed, crop payments, hired labor, hired tractors, and fuel. Although we recognize the potential importance of other forms of "payments," such as bribes to police, we lacked sufficient, consistent evidence to include estimates in the crop budgets. Fixed costs accrue each season, regardless of cultivation. Although we have left placeholders for equipment depreciation and canal maintenance, we do not have parameter estimates for either. The benchmark specification focuses on tractor rentals and concentrates on an area, i.e., the CCA, in which tube wells and pumps are not germane. Regarding canal maintenance, the costs could be substantial, but the evidence is not solid enough to merit inclusion.

Finally, we include a block titled "addenda" that includes two subsections. The first provides alternative calculations of costs and net returns for households that obtain cash advances to purchase non-labor inputs. The second includes information on possible investments in land and equipment and some additional placeholders for evidence that might become available in the future and for analyses in other locales. Although we model households as renting tractors, we provide a line for purchase, in the event that depreciation costs drop below the rental cost and purchasing becomes economically feasible. We note the break-even points for purchasing tractors for opium poppy and wheat cultivation, respectively, beneath the budgets.

In support of the crop budgets, we also present estimates of input requirements and yields, representative of the production technologies, input prices, and output prices—i.e., opium and wheat prices. In characterizing units of measure, we draw the distinction between base and loss-adjusted hectares to allow the possibility of both environmental shocks, such as drought or disease, which can either affect the number of plants per hectare or the yield per plant, and eradication. Although not readily apparent in the static budgets, the spreadsheet models accommodate two different kinds of environmental shocks, having different implications for the accrual of labor and other costs. A shock that occurs early in a growing season could spare the use of some inputs, whereas a shock that occurs late in the growing season cannot.

Tables B.1 and B.2 show the benchmark crop budgets for landowners and sharecroppers in the CCA and a summary of the parameter estimates, respectively.

---

[4] Paoli, Greenfield, and Reuter (2009) suggest that revenues from opium poppy byproducts are non-negligible in the case of opium poppy cultivation in India; Kuhn (2010) reports "other income from byproducts" for several commodities and suggests that they could amount to about 10 percent of gross income in the case of wheat, 8 percent in the case of corn, and 35 percent in the case of apricots, but that, for all other reported commodities, they would represent only a small fraction of a household's commodity-generated intake.

## Table B.1. Crop Budgets for Opium Poppy and Wheat

| | Opium from opium poppy | | | Wheat |
|---|---|---|---|---|
| | Land owner Owner-operator | Land owner w/share cropper | Share cropper | Land owner Owner-operator |
| Yield in kilograms per hectare | 35 | 35 | 35 | 3613 |
| Price per kilogram | | | | |
| Farmgate | 161 | 161 | 161 | na |
| Market place | na | na | na | 0.32 |
| Share cropping terms | na | 0.67 | 0.33 | na |
| Revenue per hectare | 5649 | 3766 | 1883 | 1156 |
| Variable seasonal costs per hectare | | | | |
| Land treatment | | | | |
| DAP | 185 | 185 | na | 201 |
| Urea | 123 | 123 | na | 88 |
| Manure | 170 | 170 | na | 170 |
| Total land treatment | 477 | 477 | na | 458 |
| Herbicides | unknown | unknown | na | unknown |
| Pesticides | unknown | unknown | na | unknown |
| Seed | 0 | 0 | na | 49 |
| Storage | na | na | na | unknown |
| Marketing | na | na | na | unknown |
| Crop payments | | | | |
| Ushr | 565 | 377 | 188 | 116 |
| Taliban | na | na | na | na |
| Total crop payments | 565 | 377 | 188 | 116 |
| Other payments | unknown | unknown | unknown | unknown |
| Labor hire (w/use of hhld labor) | | | | |
| Non-harvest | 0 | na | 0 | na |
| Harvest | 980 | na | 980 | na |
| Unallocated | na | na | na | 0 |
| Total hired labor | 980 | na | 980 | 0 |
| Labor hired (w/o use of hhld labor) | | | | |
| Non-harvest | 1116 | na | 1116 | na |
| Harvest | 1960 | na | 1960 | na |
| Unallocated | na | na | na | 242 |
| Total hired labor | 3076 | na | 3076 | 242 |
| Threshing services | na | na | na | 47 |
| Tractor hire | 83 | 83 | na | 100 |
| Fuel | | | | |
| Tractor | unknown | unknown | na | unknown |
| Tube-wells and pumps | na | na | na | na |
| Total fuel | unknown | unknown | na | unknown |
| Total variable seasonal costs | | | | |
| With use of household labor | 2105 | 937 | 1168 | 770 |
| Without use of household labor | 4201 | 937 | 3264 | 1012 |
| Fixed seasonal costs | | | | |
| Depreciation | | | | |
| Tractor | na | na | na | na |
| Tube-wells and pumps | na | na | na | na |
| Total depreciation | na | na | na | na |
| Canal maintenance | unknown | unknown | na | unknown |
| Total fixed seasonal costs | unknown | unknown | na | unknown |
| Total non-land costs | | | | |
| With use of household labor | 2105 | 937 | 1168 | 770 |
| Without use of household labor | 4201 | 937 | 3264 | 1012 |
| Operator and land returns | | | | |
| With use of household labor | 3544 | 2829 | 715 | 386 |
| Without use of household labor | 1448 | 2829 | -1381 | 144 |

Addenda

| | | | | |
|---|---|---|---|---|
| Non-labor input costs | 560 | 560 | 0 | 607 |
| Credit cost on non-labor inputs | 280 | 280 | 0 | 304 |
| Total non-land costs with borrowing | | | | |
| With use of household labor | 2385 | 1217 | 1168 | 1074 |
| Without use of household labor | 4481 | 1217 | 3264 | 1316 |
| Operator and land returns with borrowing | | | | |
| With use of household labor | 3264 | 2549 | 715 | 82 |
| Without use of household labor | 1168 | 2549 | -1381 | -160 |
| Potential investment costs, e.g., | | | | |
| Land per hectare | 30960 | 30960 | na | 30960 |
| Tractor purchase | 4128 | 4128 | na | 4128 |
| (5-year depreciation) | 826 | 826 | na | 826 |
| (10-year depreciation) | 413 | 413 | na | 413 |
| Tube-well and pump w/installation | na | na | na | na |
| Storage facility | na | na | na | unknown |
| Vehicle | unknown | unknown | unknown | unknown |

Source: RAND calculations derived from parameters whose sources are given in the text.
NOTES: Prices are in nominal U.S. dollars, valued for the 2012–2013 growing season unless noted otherwise in Table B.2, and yields are at historical averages.
na = not applicable; unknown = information not available or not sufficiently reliable.
Tractor purchase would be "economic" with 5-year depreciation at about 10 hectares for poppy and about 8 hectares for wheat.
Tube wells and pumps pertain only to the *dasht*.
Format based on Schnitkey (2014) and Pennsylvania State University (2014) templates.

## Table B.2. Summary of Parameter Estimates

| Parameter | Opium | Wheat | Unit of measure |
|---|---|---|---|
| **Output quantities** | | | |
| Yield | 35 | 3613 | kilograms per hectare |
| Share cropping terms | | | |
| (Landowner covers all non-labor inputs and share of crop payments) | | | |
| Landowner | 0.67 | n/a | index (0,1), share of harvest |
| Sharecropper | 0.33 | n/a | index (0,1), share of harvest |
| **Output prices** | | | |
| (Prices in U.S. dollars, nominal, valued at time of harvest for 2012-2013 growing season, unless noted otherwise) | | | |
| Farmgate | 161 | n/a | per kilogram |
| Market place | n/a | 0.32 | per kilogram (2012) |
| **Input quantities** | | | |
| Base hectares | 1 | 1 | land allocated to crop cultivation |
| Loss adjusted hectares | 1 | 1 | land allocated to crop cultivation, net of losses, e.g., eradication |
| Land treatment | | | |
| DAP | 225 | 245 | kilograms per hectare (base) |
| Urea | 350 | 250 | kilograms per hectare (base) |
| Manure | 5 | 5 | trailers per hectare (base) |
| Herbicides | unknown | unknown | liters per hectare (base) |
| Pesticides | unknown | unknown | liters per hectare (base) |
| Seed | 6 | 145 | kilograms per hectare (base) |
| Storage | n/a | unknown | n/a or unknown |
| Marketing | n/a | unknown | n/a or unknown |
| Crop payments | | | |
| Ushr | 0.1 | 0.1 | rate per harvest value of non-perishable crops |
| Taliban | n/a | n/a | kilograms per hectare (base) |
| Other payments | unknown | unknown | unknown |
| Labor | | | |
| Non-harvest | 180 | n/a | man-days per hectare (base) |
| Harvest | 200 | n/a | man-days per hectare (loss adjusted) |
| Unallocated | n/a | 41 | man-days per hectare (base) |
| Household share of labor | | | |
| Non-harvest | 1 | n/a | index (0,1), share of labor provided by household, if available for on-farm use |
| Harvest | 0.5 | n/a | index (0,1), share of labor provided by household, if available for on-farm use |
| Unallocated | n/a | 1 | index (0,1), share of labor provided by household, if available for on-farm use |
| Threshing services | n/a | 47 | U.S. dollars per hectare (loss adjusted), units unspecified |
| Tractor hire | 5 | 6 | hours per hectare (base) |
| Fuel | | | |
| Tractor | unknown | unknown | liters per hour |
| Irrigation system | n/a | n/a | liters per hour or application |
| **Input prices** | | | |
| (Prices in U.S. dollars, nominal, valued at time of application for 2012-2013 growing season, unless noted otherwise) | | | |
| Land treatment | | | |
| DAP | 0.82 | 0.82 | per kilogram |
| Urea | 0.35 | 0.35 | per kilogram |
| Manure | 34 | 34 | per trailer (2011) |
| Herbicides | unknown | unknown | per liter |
| Pesticides | unknown | unknown | per liter |
| Seed | 0 | 0.34 | per kilogram (2010) |
| Storage | n/a | unknown | n/a or unknown |
| Marketing | n/a | unknown | n/a or unknown |
| Labor | | | |
| Non-harvest | 6.2 | n/a | per man-day |
| Harvest | 9.8 | n/a | per man-day |
| Unallocated | n/a | 5.9 | per man-day |
| Tractor hire | 16.63 | 16.63 | per hour of rental |
| Fuel | 1.07 | 1.07 | per liter |
| Credit | 0.5 | 0.5 | rate per dollar of non-labor input |

The results clearly indicate that opium poppy cultivation is preferable to wheat cultivation for all types of landowners and irrespective of access to household labor.[5] In the absence of access to household labor, the results indicate that a landowner would rather enter into a sharecropping arrangement than cultivate opium as an owner-operator.[6] For households of average size, we might expect a landowner to have access to enough household labor to plant and maintain a single hectare of opium poppy, but need to bring in some outside labor at harvest.[7] (See the discussion in Chapter Two and later in this appendix.) That same household would not be able to maintain or harvest a second or third hectare. Thus, the results are consistent with typical observations that small landowning households operate their own land and that medium to large landowning households are more likely to retain sharecroppers.

We find substantial differences in the relative importance of inputs in the cultivation of opium poppy and wheat under current agricultural practices. Labor accounts for almost one-half to three-quarters of the costs of cultivating opium poppy—and producing opium—but no more than about one-quarter of the costs of growing wheat. Fertilizer and other soil treatments, which both crops use in similar absolute amounts, account for only about one-tenth to one-quarter of the costs of producing opium poppy, but over one-half the costs of producing wheat. Given the amount of labor required to maintain and harvest opium poppy, it comes as no surprise to find that it is more labor-intensive than wheat.

The budgets can also be used to tease out information on living conditions among households engaging in cultivating opium poppy, be they landowners or sharecroppers. Taking an average household size of 11 members, we calculate that none are living above the World Bank's poverty standards, if cultivating only one hectare of opium poppy, which is plausible, given what we know about the distribution of landholdings across farms and the role of food crops.[8] A household with 2.7 hectares of irrigated land, which is the national average, might allocate about one hectare to wheat to meet the household's cereal needs and, at most, another hectare to opium poppy.[9] Although substantially better-off than their fully-wheat-growing counterparts, those households that are allocating the hectare to opium poppy are not meeting the historical $1 per day standard, let alone the more recent $2 per day standard.

---

[5] Our results are within "range" of those of Kuhn (2010, p. 6), using a similar yield figure for opium poppy. That report found a net return of $4,437 per hectare for opium poppy and $433 for wheat.

[6] Adding in a value for room and board, although potentially substantial, would be unlikely to change this result in the benchmark crop budgets, assuming all else constant. We discuss some possible values and the implications of their inclusion in the next two sections on parameter estimates.

[7] On the same basis, we might expect a landowner to have access to enough household labor to maintain and harvest a single hectare of wheat. In the case of wheat, the data do not distinguish between harvest and other labor and so we describe all wheat labor in the crop budgets as "unallocated."

[8] These findings are roughly consistent with those of Mansfield in prior reports.

[9] See Maletta, 2007, and the discussion in Chapter Two.

Table B.3 presents summary findings on implied incomes per person per year and per day, with and without access to household labor. The table does not include credit costs, but, if households need credit to finance input costs, their net returns would be substantially lower. We have made these calculations in the addenda to the crop budget.

**Table B.3. Income from Opium Poppy and Wheat Cultivation (With and without access to household labor)**

| | With household labor | | Without household labor | |
|---|---|---|---|---|
| | $/year | $/day | $/year | $/day |
| Opium poppy | | | | |
| Landowner, owner-operator | **322** | **0.88** | 132 | 0.36 |
| Land owner, with sharecropper | 257 | 0.70 | **257** | **0.70** |
| Sharecropper | **65** | **0.18** | -126 | -0.34 |
| Wheat | | | | |
| Landowner, owner-operator | **35** | **0.10** | 13 | 0.04 |

NOTES: Calculations do not include potential costs of credit. Bold text indicates dominant strategy for each household type, based on returns alone. If landowner lacks access to household labor or values own labor in excess of on-farm returns, then sharecropping dominates; if not, own production dominates. By implication, the landowner would farm the first hectare himself, absent alternatives, and sharecrop additional hectares.

## Evidence for the Parameter Estimates

In this section, we document the parameter estimates in the opium poppy and wheat crop budgets and address some of the limitations of the data. For each parameter, we select a benchmark value with which to populate the crop budgets, as presented in the preceding section, but our use of a "live" spreadsheet model affords the flexibility to test the sensitivity of the results to those values.

To develop the crop budgets, it was necessary to sift through the literature—primarily grey literature—to locate information on the amounts of labor and other inputs that farmers use in southern Afghanistan in the production of each crop and then map that information to data on prices, such as wage rates, the price of opium poppy, the price of a kilogram of fertilizer, etc. Absent hard-and-fast selection criteria, we exercised professional judgment over the range of options and triangulated across the evidence. To the extent that others, including NGOs and intergovernmental agencies, have prepared crop budgets or considered commodity returns previously, we looked to them for insights and for comparisons.

We present our discussion of the estimates by type. We begin with quantitative input requirements, e.g., the amount of harvest labor for a given hectare in a growing season, then proceed to yields, and finish with prices. Although we did not create separate crop budgets for producers in the *dasht*, we provide relevant evidence, as available.

### *Input Requirements*

For each estimate of input requirements, we describe the input type, present the benchmark estimate, provide notes on the estimate, and list our sources.

#### Labor for Opium Harvesting[10]

**Benchmark quantity estimate:** 200 labor days per hectare.
**Notes on benchmark and other estimates:** Mansfield frequently cites this figure of 200 total labor days. (See, for instance, Mansfield, 2012b, 2009, 2004.) According to the UNODC (2003), this equates to about 14 person-labor-days per hectare over the course of the 2–3 week harvest period. According to our calculations, the 200-labor-day estimate would amount to about 14 person-labor-days on the high end, for a 14-day harvest, and about 10 person-labor-days on the low end, for a 21-day harvest. See below for additional notes on the total on-farm labor requirement.
**Sources of benchmark and other estimates:**

- David Mansfield, "Briefing Paper 3: Central Helmand in the 2011/2012 Growing Season," internal briefing paper for the British Embassy Kabul, January 2012, p. 45.
- David Mansfield, *Challenging the Rhetoric: Supporting an Evidence-Based Counter Narcotics Policy in Afghanistan: Testimony Before the U.S. House of Representatives, Subcommittee on National Security, Committee on Oversight and Government Reform*, October 1, 2009, p. 4.
- David Mansfield, "What is Driving Opium Poppy Cultivation? Decision Making Amongst Opium Poppy Cultivators in Afghanistan in the 2003/4 Growing Season," paper prepared for the UNODC/ONDCP Second Technical Conference on Drug Control Research, April 2004, p. 20.
- UNODC, *The Opium Economy in Afghanistan: An International Problem*, 2003, pp. 105–106.

#### Labor for Opium Poppy Cultivation (Non-Harvesting)

**Benchmark quantity estimate:** 180 labor days per hectare in total, consisting of 40 days for land preparation and sowing, 100 days for weeding, and another 40 days for seed collection and field clearance after harvest.
**Notes on benchmark and other estimates:** Mansfield (2004) estimates a total of about 180 non-harvest labor days per hectare, which breaks down to about 40 days for land preparation and sowing, 100 days for weeding, and 40 days for seed collection and field clearance after harvest.[11] As a secondary source, the UNODC (2003) has estimated 150 non-harvest labor days per

[10] This consists of labor for lancing and gumming.

[11] In a personal communication (January 21, 2015), Mansfield noted that this is an old estimate and that more-recent estimates are somewhat lower.

hectare, but does not provide a breakdown of the labor days by task or level of skill (i.e., unskilled, semi-skilled, or skilled labor). At least speculatively, it is possible that the UNODC estimate does not include the days required for post-harvest land clearance and seed collection. Alternatively, the Mansfield estimate of 180 non-harvest labor days might be high. For example, Mansfield and Fishstein (2013) estimate that the labor requirements for weeding and thinning labor can be reduced by about 25 percent to 33 percent with the use of herbicides.[12]

**Sources of benchmark and other estimates:**

- David Mansfield, "What is Driving Opium Poppy Cultivation? Decision Making Amongst Opium Poppy Cultivators in Afghanistan in the 2003/4 Growing Season," paper prepared for the UNODC/ONDCP Second Technical Conference on Drug Control Research, April 2004, p. 20.
- UNODC, *The Opium Economy in Afghanistan: An International Problem*, 2003, pp. 105–106.
- David Mansfield and Paul Fishstein, "Eyes Wide Shut: Counter-Narcotics in Transition," Afghanistan Research and Evaluation Unit, Briefing Paper Series, September 2013, p. 15.

In total, our benchmark estimate for the on-farm labor requirement for opium poppy production is about 380 days per growing season,[13] recognizing that farmers engage in a variety of strategies, such as staggered planting and unremunerated family labor, to control direct expenditures.[14] By comparison, we note that Roots of Peace reports a total labor requirement—harvest and other labor—of only 245 days of labor, consisting of 120 days of unskilled labor and 125 days of skilled labor, the latter of which might be harvest labor.[15] However, an earlier document by Roots of Peace reported a total of 300 days of labor, without distinguishing between unskilled, skilled, or other labor types.[16]

### Labor for Wheat Harvesting and Cultivation

**Benchmark quantity estimate:** 41 days per hectare.

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[12] We do not have sufficient data on herbicide use and prices to model the potential trade-off.

[13] The off-farm requirement would include labor for transportation, if applicable, and maintenance of irrigation canals. Although the requirements for the latter could be non-negligible, the data did not support a formal estimate. Jonathan Lee's fieldwork indicates that owners of irrigated land face three sources of recurring irrigation fees: annual fees paid to local water masters, annual or semi-annual labor contributions for canal cleaning and maintenance, and periodic fees for canal infrastructure repairs. However, in view of substantial differences across communities and lacking fieldwork specific to Helmand, we cannot estimate these costs in our model.

See Jonathan L. Lee, *Water Management, Livestock, and the Opium Economy: The Performance of Community Water Management Systems*, Afghanistan Research and Evaluation Unit, May 2007; and Jonathan L. Lee, *Water Management, Livestock, and the Opium Economy: Social Water Management*, Afghanistan Research and Evaluation Unit, May 2006.

[14] See discussion on "Household labor contribution rates."

[15] Kuhn, 2010, p. 6, Table 4.

[16] Kuhn, 2009, p. 5, Table 2.

**Notes on benchmark and other estimates:** UNODC (2003) estimates about 41 labor days per hectare of wheat in aggregate.[17] As a secondary source of validation, Roots of Peace estimated 43 labor days and 35 labor days in two separate comparative net income assessments (Kuhn, 2009, and Kuhn, 2010, respectively). In the 2010 study, the 35 labor-day figure is broken down further into 15 days of unskilled labor and 20 days of semi-skilled labor. That assessment also includes a line item for threshing services; the earlier 2009 net income assessment does not. This exclusion of threshing might explain the difference between the two estimates of 43 days and 35 days. As an outlier on the higher end of the estimate spectrum, Mansfield (2009) reports that 54 labor days are required during the harvest for a hectare of wheat.

**Sources of benchmark and other estimates:**

- UNODC, *The Opium Economy in Afghanistan: An International Problem*, 2003, pp. 105–106.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6
- Gary A. Kuhn, "Comparative Net Income from Afghan Crops," Roots of Peace, June 8, 2009, p. 5.
- David Mansfield, *Challenging the Rhetoric: Supporting an Evidence Based Counter Narcotics Policy in Afghanistan: Testimony Before the U.S. House of Representatives, Subcommittee on National Security, Committee on Oversight and Government Reform*, October 1, 2009, p. 4.

### Household Labor Contribution Rates

**Benchmark quantity estimate:** 100 percent of non-harvest labor, about 50 percent of harvest labor for opium poppy, and 100 percent of all on-farm labor for wheat, for the first hectare of each under cultivation.

**Notes on benchmark and other estimates:** Given that approximately 10–14 people are needed to harvest one hectare of opium on each day of the 2–3 week harvest period,[18] and that a typical household consists of approximately 11 members, we assume that a family might be able to provide no more than four to five family members each day and might be able to "borrow" another worker or two from a neighboring farm with staggered harvests,[19] but would have to hire outside laborers to fill the gap and complete the harvest of the first hectare of opium.[20] Roughly speaking, the gap would amount to about one-half of the total harvest labor requirement. As a

[17] In a personal communication (January 21, 2015), Mansfield noted that the current estimate is closer to 54 days, in which case we are overstating the absolute and comparative returns to wheat.

[18] See prior discussion of the harvest labor requirement.

[19] See the discussions of household labor and reciprocity in Chapter Two.

[20] It is plausible that the rates would change for each subsequent hectare. For example, for a fixed family size, a landowner might need to hire 100 percent of labor for the second, third, fourth, etc. hectare(s) of opium; however, past research (Maletta, 2007) shows that family size tends to increase with landholding size.

secondary source, these estimates are roughly consistent with those of the UNODC (2003), citing the United Nations International Drug Control Programme's (UNDCP's) annual 1997 and 1999 surveys as well as a UNDCP Strategic Study (1999) and an FAO/WFP Food Supply Assessment (2001). However, we have been unable to locate the original, underlying 1997, 1999, and 2001 sources. We assume that households can provide 100 percent of non-harvest labor for opium and 100 percent of all labor for wheat.[21]

**Sources of benchmark and other estimates**:

- UNODC, *The Opium Economy in Afghanistan: An International Problem*, 2003, pp. 105–106.
- As cited in UNODC (2003, p. 106): UNDCP, Afghanistan Annual Opium Poppy Surveys 1997 and 1999; UNDCP, Afghanistan Strategic Study #4, June 1999; and FAO/WFP Food Supply Assessment Mission, May 2001.
- For average household size, see Hector Maletta, "Arable Land Tenure in Afghanistan in the Post-Taliban Era," *African and Asian Studies*, Vol. 6, 2007, pp. 20–21, working with data from the 2002–2003 Winter Survey.

### Room and Board for Sharecroppers[22]

**Benchmark quantity estimate:** 0.5 kilogram of wheat per person per day.

**Notes on benchmark and other estimates:** Mansfield (2009) indicates that sharecroppers receive room and board at the expense of landowners during the growing season. Board includes a sharecropper's daily requirement for wheat bread at a minimum; it could include substantially more. Lacking information concerning the number of individuals covered—for example, some or all household members, the period of coverage, and the form of coverage—we did not include estimates of the value of board in the relevant crop budgets, but note that it could be substantial. According to Mansfield (2011), a typical individual requires about 35 to 45 *man* annually, equivalent to 158 kilograms to 203 kilograms. Taking the midpoint of approximately 180 kilograms of wheat per person, this amount equals roughly 0.5 kilogram of wheat per person per day. If we were to assign board—in the form of wheat—to the total number of labor days provided by a sharecropping household, the value of board would amount to about $45 per growing season, based on 2012 wheat prices.[23] If, instead, we were to assign board to the entire household for the full growing period, i.e., October to May, the value of the coverage could amount to more than $420 per growing season.[24]

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[21] Were we developing estimates for off-farm labor, we would further assume that the household provides 100 percent of the necessary labor for canal maintenance, storage, and transportation, absent farm-gate collections.

[22] Treating "room" as a non-recurring cost, we consider "board" only here.

[23] This calculation assumes that the sharecropping household supplies all of the on-farm non-harvest labor—e.g., tilling, sowing, weeding, etc.—and one-half of the harvest labor, amounting to a total of 280 labor days.

[24] This calculation assumes that the sharecropping household consists of 11 "typical" individuals.

**Sources of benchmark and other estimates:**

- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, pp. 25–26.
- David Mansfield, *Challenging the Rhetoric: Supporting an Evidence-Based Counter Narcotics Policy in Afghanistan: Testimony Before the U.S. House of Representatives, Subcommittee on National Security, Committee on Oversight and Government Reform*, October 1, 2009, p. 4.

### Seed for Opium Poppy

**Benchmark quantity estimate:** 6 kilograms per hectare.
**Notes on benchmark and other estimates:** UNODC's annual *Afghanistan Opium Survey* of 1996 provides a range of 2 kilograms to 10 kilograms per hectare. We have chosen the midpoint (6 kilograms per hectare). A scientific study of poppy cultivation in India (Kapoor, 1995) estimates a sowing rate of 3 kilograms per hectare, thus, suggesting that 6 kilograms is the right order-of-magnitude.
**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, 1996, annex, p. 7.
- L. Kapoor, *Opium Poppy: Botany, Chemistry, and Pharmacology*, Binghampton, N.Y.: The Haworth Press, 1995, pp. 65–67.

### Seed for Wheat

**Benchmark quantity estimate:** 145 kilograms per hectare.
**Notes on benchmark and other estimates:** A University of California–Davis (U.C. Davis) factsheet (Sharifi and Bell, 2012) reports a range of 110 kilograms to 175 kilograms per hectare, another U.C. Davis factsheet (undated) indicates 140 kilograms per hectare, and an FAO analysis (Kugbei and Shahab, 2007) estimates approximately 161 kilograms per hectare. Both estimates are for irrigated land, so they are potentially applicable to the CCA. We have chosen the approximate midpoint of the U.C. Davis 2012 estimate (145 kilograms), which is roughly consistent with the second U.C. Davis estimate, FAO's estimate, and the average of the four figures.
**Sources of benchmark and other estimates:**

- Hussain Sharifi and Mark Bell, "Wheat—Overview," factsheet, University of California–Davis, College of Agricultural and Environmental Sciences, 2012..
- University of California–Davis, "Wheat Growth Stages," factsheet, undated.
- Sam Kugbei and Shahabuddin Shahab, *Analysis of the Seed Market in Afghanistan*, Rome: Food and Agriculture Organization of the United Nations, 2007, p. 13.

### Diammonium Phosphate Fertilizer for Opium

**Benchmark quantity estimate:** 225 kilograms per hectare.
**Notes on benchmark and other estimates:** UNODC surveys (1994, 1995) estimate a range of approximately 200 kilograms to 250 kilograms per hectare in Helmand and Kandahar, whereas Mansfield cites application rates of approximately 250 kilograms per hectare in one study surveying four provinces (Mansfield, 2004) and approximately 500 kilograms per hectare (or 1,200 kilograms per 12 jeribs) in another study surveying the *dasht* (Mansfield, 2013a). Roots of Peace's Crop Income Projection study (Kuhn, 2010) estimated 250 kilograms per hectare. Noting that application rates might be higher in the *dasht* due to the poorer quality of soil in that region, we confine our analysis to the range of estimates from 200 kilograms to 250 kilograms per hectare and have chosen the midpoint of approximately 225 kilograms per hectare for irrigated areas in the south.
**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, 1994, p. 12; and 1995, p. 14.
- David Mansfield, "What Is Driving Opium Poppy Cultivation? Decision Making Amongst Opium Poppy Cultivators in Afghanistan in the 2003/4 Growing Season," paper prepared for the UNODC/ONDCP Second Technical Conference on Drug Control Research, April 2004, p. 20.
- David Mansfield, *All Bets are Off!: Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, p. 85.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Diammonium Phosphate Fertilizer for Wheat

**Benchmark quantity estimate:** 245 kilograms per hectare.
**Notes on benchmark and other estimates:** Citing the FAO's "Near East Fertilizer Use Manual," researchers at U.C. Davis estimate a range of 217 kilograms to 271 kilograms per hectare for medium-fertility soils and 326 kilograms to 391 kilograms per hectare for low-fertility soils. We have taken the approximate midpoint of the former estimate (245 kilograms per hectare) as the benchmark for the CCA. As a secondary source, U.C. Davis researchers cite an ICARDA study that found that farmers with irrigated land apply about 250 kilograms per hectare of DAP. Note, however, that we have been unable to locate either the original FAO study or the ICARDA study referenced by U.C. Davis.
**Sources of benchmark and other estimates:**

- Nick Madden and Mark Bell, "Fertilizer: Diammonium Phosphate," factsheet, University of California–Davis, College of Agricultural and Environmental Sciences, 2012. .
- Nick Madden and Mark Bell, "Fertilizer Use in Afghanistan," factsheet, University of California–Davis, College of Agricultural and Environmental Sciences, 2012

### Urea Fertilizer for Opium

**Benchmark quantity estimate:** 350 kilograms per hectare.
**Notes on benchmark and other estimates:** UNODC annual surveys (1994, 1995) estimate a range of approximately 350 kilograms to 450 kilograms per hectare in Helmand and Kandahar, whereas Mansfield cites application rates of approximately 250 kilograms per hectare in one study surveying four provinces (Mansfield, 2004) and approximately 500 kilograms per hectare (or 1,200 kilograms per 12 jeribs) in another study surveying the *dasht* (Mansfield, 2013a). Roots of Peace's Crop Income Projection study (Kuhn, 2010) estimated usage of about 250 kilograms per hectare. (As national averages, we think that the Mansfield and Roots of Peace figures might be low for the south.) Given a range of approximately 250 kilograms to 450 kilograms per hectare, excluding the *dasht* estimate,[25] we have chosen the midpoint of approximately 350 kilograms per hectare for irrigated areas in the south.
**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, 1994, p. 12; and 1995, p. 14.
- David Mansfield, "What is Driving Opium Poppy Cultivation? Decision Making Amongst Opium Poppy Cultivators in Afghanistan in the 2003/4 Growing Season," paper prepared for the UNODC/ONDCP Second Technical Conference on Drug Control Research, April 2004, p. 20.
- David Mansfield, *All Bets are Off!: Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013a, p. 85.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Urea Fertilizer for Wheat

**Benchmark quantity estimate:** 250 kilograms per hectare.
**Notes on benchmark and other estimates:** U.C. Davis researchers, citing an ICARDA Study, found average urea application rates of about 250 kilograms per hectare (equal to about 115 kilograms of nitrogen per hectare). Roots of Peace (Kuhn, 2010) also estimates 250 kilograms per hectare of urea for wheat.
**Sources of benchmark and other estimates:**

- Nick Madden and Mark Bell, "Fertilizer Use in Afghanistan," factsheet, University of California–Davis, College of Agricultural and Environmental Sciences, 2012.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

[25] As in the case of DAP, we note that application rates might be higher in the *dasht* because soil quality is poorer. On that basis, we do not include Mansfield's 500 kilogram estimate in our calculation of urea usage for the CCA, but would be inclined to bump up a separate calculation for the *dasht*.

### Manure Fertilizer for Opium and Wheat

**Benchmark quantity estimate:** 5 trailers per hectare.
**Notes on benchmark and other estimates:** Mansfield (2013a) reports that farmers apply approximately 1 trailer of natural manure per jerib of land, amounting to 5 trailers per hectare. The 2013 report cites use north of the Bogra canal and in a personal communication (January 21, 2015), Mansfield noted that use is limited to the *dasht*. However, U.C. Davis researchers describe more widespread use of manure, "most farmers apply animal manure," and report applications of 5,000 kilograms to 20,000 kilograms of natural manure per hectare. Having no basis for converting the amount of manure in a trailer to kilogram equivalents and lacking estimates of the price of natural manure per kilogram, we have been unable to cross-reference these estimates. Absent any information on manure application practices for wheat, we have assumed that application rates of natural manure are the same for both opium and wheat.[26]
**Sources of benchmark and other estimates:**

- David Mansfield, *All Bets are Off!: Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013a, p. 85.
- Nick Madden and Mark Bell, "Fertilizer Use in Afghanistan," factsheet, University of California–Davis, College of Agricultural and Environmental Sciences, 2012.

### Herbicides

**Benchmark quantity estimate:** 2.5 liters per hectare.
**Notes on benchmark and other estimates:** Mansfield and Fishstein (2013) estimate application rates of about 0.5 liters per jerib, amounting to 2.5 liters per hectare.[27] We have no other sources of evidence with which to compare or substantiate this estimate.[28]
**Sources of benchmark and other estimates:**

- David Mansfield and Paul Fishstein, "Eyes Wide Shut: Counter-Narcotics in Transition," Afghanistan Research and Evaluation Unit, Briefing Paper Series, September 2013.

### Hiring Tractors for Tilling Opium Poppy Fields

**Benchmark quantity estimate:** 5 hours per hectare.
**Notes on benchmark and other estimates:** Mansfield (2013a) reports that farmers need to hire tractors for 12 hours per 12 jeribs of land in the *dasht*, which equals 1 hour per jerib or 5 hours per hectare; he does not provide an estimate for the CCA. As a secondary source, Roots of Peace

[26] If we have overstated the case for manure in the CCA, then we have done so for both opium poppy and wheat, in which case it would affect the net returns to each, but not the relative net returns.

[27] It is unclear whether poppy farmers who use herbicides to reduce weeding and thinning apply these chemicals once per season or more frequently, but we would assume the former.

[28] Mansfield repeats the estimate in Mansfield, 2014.

(Kuhn, 2010) estimates tractor plowing costs of about $84 per hectare of opium. Assuming an average hiring rate of just over $19 per hour at about that time (see below on tractor hiring rates in the inputs section), this would equate to about 4.4 hours per hectare of opium.[29]

**Sources of benchmark and other estimates:**

- David Mansfield, *All Bets are Off!: Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013a, p. 85.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Hiring Tractors for Tilling Wheat Fields

**Benchmark quantity estimate**: 6 hours per hectare.

**Notes on benchmark and other estimates**: Roe (2009) estimates 6.14 hours of plowing for land preparation for one hectare of wheat. As a secondary source, Roots of Peace (Kuhn, 2010) estimates tractor plowing costs of about $101 per hectare of wheat. Assuming an average price of just over $19 per hour at about that time (circa 2010; see below on tractor hiring prices in the inputs section), this would equate to about 5.2 hours per hectare of wheat.

**Sources of benchmark and other estimates:**

- Alan Roe, "Applied Thematic Research into Water Management, the Opium Economy, and Livestock: Findings from the First Year of Farm and Household Monitoring," Afghanistan Research and Evaluation Unit, April 2009, p. 70.
- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Purchases of Diesel Fuel for Irrigation Pumps (*dasht* only)

**Benchmark quantity estimate:** 375 liters per hectare per season.

**Notes on benchmark and other estimates:** Mansfield (2013a, p. 84) reports a requirement of 50 liters to 100 liters of diesel per jerib, equaling about 250 liters to 500 liters per hectare, for opium production in the *dasht*. We have selected the midpoint of this estimate, 375 liters per hectare per growing season. (We assume that there are no recurring diesel costs for irrigation in the CCA.) Mansfield (2011b, p. 25) estimates that approximately 4 to 6 liters of diesel are required per jerib per episode of irrigation and that the number of episodes per season in the *dasht* ranges from approximately ten to 16 (see also Mansfield, 2013a, pp. 84–85). Consistent with the previous estimate, this would yield a range of 40–96 liters of diesel per jerib, or 200 liters to 480 liters per hectare per season.

[29] Additionally, for expansion of production in desert areas, we recognize that one-time clearing of former desert land might require additional services (including plowing) prior to the first year of cultivation, but we view these as fixed investment costs in our model (i.e., an extension of the land investment price, along with tube well construction and house construction), not as recurring costs.

**Sources of benchmark and other estimates:**

- David Mansfield, *All Bets are Off!: Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, pp. 84–85.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.

### *Opium and Wheat Yields*

For each yield estimate, we describe the output type, present the benchmark estimate(s), provide notes on the estimate(s), and list our sources.

#### Dry Opium[30]

**Benchmark quantity estimate(s):**
48 kilograms per hectare "high-end" yield.
(27 percent average environmental loss rate.)
35 kilograms per hectare average post–environmental-loss yield.
23 kilograms per hectare "low-end" yield.
**Notes on benchmark and other estimates:** For our purposes, we work with the revised (extrapolated) southern averages for the 12-year period post-dating the Taliban ban of 2002–2003, as shown in the last row of Table B.4. Whereas the UNODC has published revised estimates of the national averages for the years 2006–2009 in recent annual surveys, it has not published revised estimates for the southern region of Afghanistan. Given that the south accounts for the large majority of opium production in Afghanistan, we used the percentage changes in the published revisions to the national averages to extrapolate revised estimates for the south. We adopt a potential "high-end" yield of about 48 kilograms per hectare, based on the 12-year high (obtained in the south in 2011) and a potential "low-end" yield of about 23 kilograms per hectare, based on the 12-year low (obtained in the south in 2012). Noting that the average yield for the same 12-year period was about 35 kilograms per hectare, we adopt an average or typical environmental loss rate of about 27 percent from that potential "high" in some of our calculations. For the *dasht*, we would assume somewhat lower yields.[31]

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[30] According to the methodological section on potential yield and production in the 2013 UNODC *Afghanistan Opium Survey* (pp. 90–91), "Opium production was calculated by the estimated regional area under opium cultivation being multiplied by the corresponding regional opium yield. All opium estimates in this report are expressed in oven-dry opium equivalent, i.e., the opium is assumed to contain 0 percent moisture."

[31] Starting with a potential high-end yield in the *dasht* of about 45 kilograms per hectare and applying the same average environmental loss rate (27 percent), we arrive at a post-loss yield of about 33 kilograms per hectare. Mansfield (2013b) reports substantially lower wheat yields in the *dasht*; on that basis, we assume that opium poppy yields are also somewhat lower. We suspect that the differences in yield for opium poppy will not be as dramatic as those for wheat because opium poppy is a more resilient crop in dry areas.

**Table B.4. Dry Opium Yields**

| | Annual Averages (kilograms per hectare) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| National-ur | 46 | 45 | 32 | 39.3 | 37 | 42.5 | 48.8 | 56.1 | 29.2 | 44.5 | 23.7 | 26.3 |
| National-r | 46 | 45 | 32 | 39.3 | 32.2 | 38.5 | 37.8 | 32.2 | 29.2 | 44.5 | 23.7 | 26.3 |
| Southern-ur | 43 | 45 | 27.8 | 37.9 | 36.3 | 42.2 | 52.1 | 58.5 | 29.7 | 48.1 | 22.6 | 23.2 |
| Southern-r(ex) | 43.0 | 45.0 | 27.8 | 37.9 | 31.6 | 38.2 | 40.4 | 33.6 | 29.7 | 48.1 | 22.6 | 23.2 |

SOURCE: UNODC, *Afghanistan Opium Survey*, 2006–2013.
NOTES: ur = unrevised; r = revised; ex = extrapolated. We extrapolated the revised estimates for the south from the unrevised estimates, using the percentage changes in the revisions to the national averages.

**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, various years (2006–2013).
- David Mansfield, "Briefing Paper 6: Central Helmand in the 2012/13 Planting Season," internal briefing paper for the British Embassy Kabul, March 2013b, p 11.

Wheat

**Benchmark quantity estimate(s):**

4,550 kilograms per hectare "high" yield.
(21 percent average environmental loss rate.)
3,613 kilograms per hectare average post–environmental-loss yield.
2,775 kilograms per hectare "low-end" yield.

**Notes on benchmark and other estimates:** The FAO reports only national wheat yield averages; while these are useful for assessing annual changes in yields, they are not indicative of yield levels in the south, where yields are typically higher than in the mountainous, rain-fed areas of Afghanistan. Instead of the national FAO figures, we rely on a combination of several other ad hoc sources, including Mansfield's (2011b) estimates of wheat yields in the CCA. In the 2010–2011 season, which was a good one in the south, Mansfield (2011b) estimates a range of approximately 3,500 kilograms to 4,550 kilograms per hectare for wheat yields in the CCA.[32] According to MAIL data cited in USAID wheat-yield maps for the 2009–2010 and 2010–2011 growing seasons, the average wheat yield in Helmand in both 2010 and 2011 on irrigated lands was 2.61 tons—or 2,610 kilograms—per hectare. By comparison, Niane et al. (2011) reports potential wheat yields ranging from about 4 tons to 7 tons per hectare, depending on seed variety. For our benchmark calculations, we adopt the high end of Mansfield's "good year" (4,550 kilograms per hectare) as our high end. Based on an analysis of the variability of the nationwide FAO data, we apply an average loss rate of about 21 percent and estimate an average post–

[32] Mansfield (2011b) estimates a range of approximately 1,400 kilograms per hectare to 2,800 kilograms per hectare for wheat yields in the former desert areas of the *dasht*.

environmental-loss yield of about 3,613 kilograms per hectare, and we apply a maximum loss rate of about 39 percent and estimate potential low-end yield of about 2,775 kilograms per hectare.

**Table B.5. Wheat Yields**

| | Annual Averages (kilograms per hectare) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| National | 1,542 | 1,500 | 1,266 | 1,822 | 1,376 | 1,818 | 1,226 | 1,967 | 1,925 | 1,518 | 2,010 | – |

SOURCE: FAO, 2013.

**Sources of benchmark and other estimates:**

- FAO, FAOStat database, 2013.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, pp. 25-26.
- Abdoul Aziz Niane et al., *National Catalogue of Wheat Varieties in Afghanistan*, Rome, Italy: Food and Agriculture Organization of the United Nations; and Aleppo, Syria: International Center for Agricultural Research in Dry Areas, GCP/AFG/045/EC Field Document, 2011..
- USAID, "Afghanistan: Irrigated Area, Wheat Yield and Production Contrast 2010-2011," June 8, 2011.

### *Input Prices*

For each price estimate, we describe the type of input, present the benchmark estimate(s), provide notes on the estimate(s), and list our sources.

#### Labor for Opium and Wheat

**Benchmark price estimate(s):**

$9.8 per day for opium harvesting.
$6.2 per day for opium cultivation (non-harvesting).
$5.9 per day for wheat harvesting and cultivation (unallocated).

**Table B.6. Daily Labor Rates**

| | National Annual[a] Averages (nominal U.S. dollars per day[b]) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| Opium harvesting[c] | 7.7 | 9.3 | 9.5 | 8.7 | 9.3 | 12.6 | 11.7 | 9.8 |
| Opium cultivation | 4.8 | 4.6 | 4.4 | 3.6 | 5.4 | 6.6 | 5.7 | 6.2 |
| Wheat (all) | 4.3 | 4.0 | 4.4 | 4.3 | 5.4 | 6.6 | 6.4 | 5.9 |

SOURCE: UNODC, *Afghanistan Opium Survey*, 2006–2013.
[a] Sources do not specify whether the estimates are calendar-year averages, growing-year averages, seasonal averages, or point estimates.
[b] Nominal prices are not adjusted for inflation.
[c] Some harvest labor may be paid in shares of the crop yield, not in daily wages.

**Notes on benchmark and other estimates:** The figures in Table B.6 are UNODC national averages. (UNODC does not provide regional or provincial data.) The UNODC labor rates for opium cultivation and wheat (all) are roughly consistent with MAIL's monthly basic agricultural wage figures. In a personal communication (January 21, 2015), Mansfield noted that itinerants in the south are usually paid in a share of the crop, not cash. Here, we assume that markets equalize and that the effective rates are roughly equivalent. To the extent that we are overstating the rate of pay to itinerants, we are thus understating the absolute and relative returns to opium poppy. However, Mansfield also noted that labor would be provided meals and that those costs could be substantial, which might offset the overage.

**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, 2006–2013.
- MAIL, "Commodity Price Bulletin," monthly editions November 2005–November 2012 (excluding October–November 2010).

### Sharecropping Terms

**Benchmark shares and input contributions:**

Landowner obtains 2/3 share of crop and sharecropper obtains 1/3 share of crop.
Landowner provides all non-labor inputs and room and board.[33]

**Notes on benchmark and other estimates:** The terms of sharecropping arrangements vary widely within and across regions (McEwen and Whitty, 2006). Nevertheless, Mansfield's recent field reports (2013a, 2014) suggest the relevance of the benchmark terms to our analysis with regard to the CCA, if not to the *dasht*.[34] According to Mansfield (2013a, p. 82), "In the canal

[33] As noted previously, Mansfield (2009) indicated that sharecroppers receive room and board at the expense of landowners during the growing season.

[34] Although not with regard to the south, McEwen and Whitty (2006, p. 16) suggest that, although once the most usual arrangement in Nangarhar, the 2/3–1/3 split (with the landowner providing land, water, and all non-labor agricultural inputs, such as seed, fertilizer, and pesticide, and the sharecropper providing all labor), has lost some ground to alternatives in which sharecroppers share the costs of inputs.

command area, sharecroppers would typically receive one-third of the final opium crop with no input costs other than their own labor. In the Dasht, sharecroppers typically receive one-fifth or one quarter of the final opium crop." Moreover, in comparing conditions in the *dasht* to those in the CCA, Mansfield (2014, pp. 51–52) reported, "The sharecropping terms were often less favourable than in the command control area, with landowners often offering one-quarter of the final opium crop compared to the one-third that farmers had received while growing opium when they were in the food zone." Suggesting that sharecroppers less ordinarily cover the costs of non-labor inputs, he described a smaller group of farmers entering into sharecropping arrangements in which "they paid all the recurrent costs of production, including seeds, tractors, oxen, diesel fuel, and all the labor costs for both the weeding and harvest seasons, and gave one-seventh of the final crop to the landowner" (Mansfield, 2014, pp. 51–52).

**Sources of benchmark and other estimates:**

- David Mansfield, "From Bad They Made it Worse," Afghanistan Research and Evaluation Unit, May 2014.
- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013a, pp. 84–85.
- David Mansfield, *Challenging the Rhetoric: Supporting an Evidence Based Counter Narcotics Policy in Afghanistan: Testimony Before the U.S. House of Representatives, Subcommittee on National Security, Committee on Oversight and Government Reform*, October 1, 2009, p. 4.
- Alec McEwen and Brendan *Whitty, Water Management, Livestock, and the Opium Economy: Land Tenure*, Afghanistan Research and Evaluation Unit, June 2006.

### DAP and Urea Fertilizer

**Benchmark price estimate(s):**

$0.82 per kilogram for DAP at approximate time of sowing.

$0.35 per kilogram for urea at approximate time of sowing.

**Notes on benchmark and other estimates:** The nominal Afghani figures in Table B.7 are the monthly DAP and urea prices reported in Helmand provincial center during the months of October and November from 2008 through 2012. The nominal U.S. dollar figures were calculated using mid-month Afghani to U.S. dollar exchange rates. DAP is applied annually in the autumn—just before sowing—and urea is typically applied in several tranches (first at sowing, then approximately 30 to 40 days and 60 to 65 days after sowing). For simplicity, we work with the prices of both fertilizers at the approximate time of sowing—i.e., the average of the October and November prices. For the benchmark, we work with the prices in 2012, as they were post-subsidy prices and would have prevailed at the time of a representative farmer's

decisionmaking for the 2012–2013 growing season. As a secondary source for the price of urea, Roe (2009) estimated a price of approximately $0.28 per kilogram.[35]

**Table B.7. Monthly Fertilizer Prices, in Nominal Afghanis and U.S. Dollars per Kilogram**

| | Oct 2008 | Nov 2008 | Oct 2009 | Nov 2009 | Oct 2010 | Nov 2010 | Oct 2011 | Nov 2011 | Oct 2012 | Nov 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| DAP | | | | | | | | | | |
| Afghanis | 50 | 46 | 34 | 42 | – | – | 41 | 42 | 41 | 48 |
| $U.S. | 0.99 | 0.88 | 0.69 | 0.85 | – | – | 0.86 | 0.87 | 0.78 | 0.86 |
| Urea | | | | | | | | | | |
| Afghanis | 16 | 18 | 13 | 17 | – | – | 18 | 18 | 18 | 20 |
| $U.S. | 0.32 | 0.34 | 0.26 | 0.35 | – | – | 0.38 | 0.37 | 0.34 | 0.36 |
| Exchange Rate | 0.0197 | 0.0191 | 0.0203 | 0.0203 | 0.0221 | 0.0220 | 0.0209 | 0.0206 | 0.0190 | 0.0180 |

SOURCES: For prices in Afghanis, see MAIL, "Commodity Price Bulletin," monthly editions October 2008–November 2012.
NOTE: Nominal prices are not adjusted for inflation.

**Sources of benchmark and other estimates:**

- Ministry of Agriculture, Irrigation, and Livestock, "Commodity Price Bulletin," monthly editions available from November 2005–November 2012 (excluding October–November 2010).
- Alan Roe, "Applied Thematic Research into Water Management, the Opium Economy, and Livestock: Findings from the First Year of Farm and Household Monitoring," Afghanistan Research and Evaluation Unit, April 2009, p. 73.

### Manure

**Benchmark price estimate:** About $34 per trailer of manure.
**Notes on benchmark and other estimates:** Mansfield (2011b, 2013a) estimates a range of 3,000 Pakistani rupees (PR) to 4,000 PR per trailer of natural manure in the *dasht*.[36] We do not have a price for natural manure inside the CCA and have assumed the lower end of this range.[37] Madden and Bell (2012) reported widespread use of manure, but we note, again, that Mansfield (personal communication, January 21, 2015) reported that manure is not in use in the CCA.
**Sources of benchmark and other estimates:**

[35] Mansfield (2011b, 2013a) reports that chemical fertilizer prices may be as much as twice as high in the *dasht* as in the CCA.

[36] Nominal prices in the fall of 2011; the exchange rate at that time was 0.01144 PR per U.S. dollar, implying a nominal U.S. dollar price of about $34 per trailer at the low end of the range.

[37] For calculations for the *dasht*, we assume the midpoint, amounting to about $40 per trailer.

- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.
- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, pp. 84–85.
- Nick Madden and Mark Bell, "Fertilizer Use in Afghanistan," factsheet, U.C. Davis, College of Agricultural and Environmental Science, 2012.

### Herbicides

**Benchmark price estimate:** $4 per liter of concentrate.[38]
**Notes on benchmark and other estimates:** Roe (2009) reported a price of $4 per liter of herbicide and pesticide, but we have no confirming evidence. Taking this estimate in conjunction with the aforementioned 2.5 liters per hectare requirement suggests a total cost per hectare for herbicide of about $10 in 2009. Although we lack sufficient confidence in the components of the overall estimate to include it in our benchmark, we do not believe that the omission of the estimate greatly affects the ultimate calculation of net returns to opium poppy, unless the introduction of herbicide substantially reduces the 100-day labor requirement for weeding.
**Sources of benchmark and other estimates:**

- Alan Roe, "Applied Thematic Research into Water Management, the Opium Economy, and Livestock: Findings from the First Year of Farm and Household Monitoring," Afghanistan Research and Evaluation Unit, April 2009, p. 73.

### Diesel Fuel for Irrigation in the *Dasht*

**Benchmark price estimate:** $1.07 per liter at approximate time of sowing.
**Notes on benchmark and other estimates:** The nominal Afghani figures in Table B.8 are the monthly diesel prices reported in the Helmand provincial center during the months of October and November from 2008 through 2012. The nominal U.S. dollar figures were calculated using mid-month Afghani to U.S. dollar exchange rates. Irrigation occurs from October to May, but we assumed the fall price because farmers seemingly buy diesel in bulk (presumably at the start of the season) in barrels ("bailers") typically delivered to the farm gate. We note, however, that diesel prices might be higher in the *dasht*; for instance, Mansfield (2013a) estimated the price of a bailer of diesel (which contains between 180 liters and 220 liters) at 22,000 PR. Taking the midpoint of this range (200 liters at 22,000 PR) would equal about 110 PR per liter, or about $1.20 per liter at prevailing exchange rates in early 2012. For the benchmark, we worked with the prices in 2012, as they would have prevailed at the time of a representative farmer's decisionmaking for the 2012–2013 growing season.

[38] This is a nominal price for approximately 2009.

**Table B.8. Monthly Prices for Diesel, in Nominal Afghanis and U.S. Dollars per Liter**

| | Oct 2008 | Nov 2008 | Oct 2009 | Nov 2009 | Oct 2010 | Nov 2010 | Oct 2011 | Nov 2011 | Oct 2012 | Nov 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | | | |
| Afghanis | 50 | 52 | 40 | 40 | – | – | 58 | 58 | 58 | 58 |
| $U.S. | 0.99 | 0.99 | 0.81 | 0.81 | – | – | 1.21 | 1.20 | 1.10 | 1.04 |
| Exchange Rate | 0.0197 | 0.0191 | 0.0203 | 0.0203 | 0.0221 | 0.0221 | 0.0209 | 0.0206 | 0.0190 | 0.0180 |

SOURCES: For prices in Afghanis, see MAIL, "Commodity Price Bulletin," monthly editions October 2008–November 2012.
NOTE: Nominal prices are not adjusted for inflation.

**Sources of benchmark and other estimates:**

- Afghan Ministry of Agriculture, Irrigation, and Livestock, "Commodity Price Bulletin," monthly editions November 2005–November 2012 (excluding October–November 2010).
- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, pp. 84–85.

### Poppy Seed

**Benchmark price estimate:** negligible.
**Notes on benchmark and other estimates:** We assumed that most poppy farmers save seed from season to season and do not need to buy seed—except, perhaps, as first-time growers or to acquire higher-yielding varieties. If seed is purchased, the costs are very low. Kuhn (2010) reports a total seed cost of about $5 per hectare.
**Sources of benchmark and other estimates**:

- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Wheat Seed

**Benchmark price estimate:** $0.34 per kilogram.
**Notes on benchmark and other estimates:** Roots of Peace (Kuhn, 2010) estimates the unsubsidized cost of seed for one hectare of wheat to be approximately $50. If we assume a seeding rate of approximately 145 kilograms/hectare (see discussion of seed requirement, above), this would equate to about $0.34 per kilogram. Roe (2009), by comparison, estimates a wheat seed price of $0.24 per kilogram, roughly consistent with prices reported by MAIL for prior years.[39] In this instance, we use the most recent available price: $0.34 per kilogram.
**Sources of benchmark and other estimates:**

[39] MAIL has not published wheat seed prices since February 2008.

- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.
- Afghan Ministry of Agriculture, Irrigation, and Livestock, "Commodity Price Bulletin," monthly editions November 2005–November 2012 (excluding October–November 2010).
- Alan Roe, "Applied Thematic Research into Water Management, the Opium Economy, and Livestock: Findings from the First Year of Farm and Household Monitoring," Afghanistan Research and Evaluation Unit, April 2009, p. 73.

### Tractor Hire for Tilling Opium Poppy or Wheat

**Benchmark price estimate:** $16.63 per hour.
**Notes on benchmark and other estimates:** The nominal Afghani figures in Table B.9 are the monthly tractor hiring prices reported in the Helmand provincial center during the months of October and November from 2008 through 2012. The nominal U.S. dollar figures were calculated using mid-month Afghani to U.S. dollar exchange rates. Mansfield (2011b) estimated a price of 1,800 PR or approximately $21 per hour in the *dasht* in the 2010–2011 growing season.

**Table B.9. Tractor Hiring Rates, in Nominal Afghanis and U.S. Dollars per Hour**

| | Oct 2008 | Nov 2008 | Oct 2009 | Nov 2009 | Oct 2010 | Nov 2010 | Oct 2011 | Nov 2011 | Oct 2012 | Nov 2012 |
|---|---|---|---|---|---|---|---|---|---|---|
| Diesel | | | | | | | | | | |
| Afghanis | 1000 | 1000 | 900 | 1000 | – | – | 900 | 900 | 900 | 900 |
| $U.S. | 19.71 | 19.13 | 18.23 | 20.31 | – | – | 18.81 | 18.58 | 17.10 | 16.16 |
| Exchange Rate | 0.0197 | 0.0191 | 0.0203 | 0.0203 | 0.0221 | 0.0221 | 0.0209 | 0.0206 | 0.01900 | 0.01806 |

SOURCES: For prices in Afghanis, see MAIL, "Commodity Price Bulletin," monthly editions October 2008–November 2012.
NOTE: Nominal prices are not adjusted for inflation.

**Sources of benchmark and other estimates:**

- Afghan Ministry of Agriculture, Irrigation, and Livestock, "Commodity Price Bulletin," monthly editions November 2005–November 2012 (excluding October–November 2010).
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.

### Threshing Services for Wheat

**Benchmark price estimate:** $47 in total.
**Notes on benchmark and other estimates:** This figure appears in Table 4 of Kuhn (2010) without explanation.

**Sources of benchmark and other estimates:**

- Gary A. Kuhn, *Roots of Peace Crop Income Projection Afghanistan, 2010*, Roots of Peace, September 21, 2010, p. 6.

### Credit for Purchasing Non-Labor Inputs

**Benchmark rate estimate:** 50 percent of the cost of non-labor inputs.
**Notes on benchmark and other estimates:** To the extent that households require credit for cultivation, we assumed that they take out loans in the fall to cover the cost of non-labor agricultural inputs.[40] Because hired labor is paid after the harvest, we assumed that farmers do not typically take on debt to cover labor costs. Given that not all households require credit, we provide benchmark estimates with and without credit costs for non-labor inputs. We derived our benchmark from a publically available source (Mansfield, undated) but note that, in a personal communication (January 21, 2015), Mansfield suggested that current rates might be considerably lower—i.e., 10 percent of cash payments—because of better liquidity.
**Sources of benchmark and other estimates:**

- David Mansfield, "The Role of Opium as a Source of Informal Credit in Rural Afghanistan," *Rural Finance in Afghanistan: The Challenge of the Opium Economy*, draft workshop paper #4, undated.

### *Ushr* (payment to mullah or village cleric)

**Benchmark price estimate:** 10 percent of the final crop (opium or wheat) in the CCA; 5 percent of final crop (opium or wheat) in the *dasht*; and 2.5 percent of final crop (perishable fruits or vegetables) in the CCA.
**Notes on benchmark and other estimates:** Farmers pay *ushr* shortly after the harvest, either in-kind or in cash equivalent.
**Sources of benchmark and other estimates:**

- David Mansfield, "Briefing Paper 4: 'Taxation' in Central Helmand," internal working paper for the British Embassy Kabul, June 2012, pp. 3–4.
- David Mansfield, "Briefing Paper 2: 'Taxation' in Central Helmand," internal briefing paper for the British Embassy Kabul, January 2012, pp. 1–6.
- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, p. 86.

### Opium Payments to Taliban in the *dasht*

**Benchmark price estimate:** 1.125 kilograms of opium per hectare cultivated.

[40] We recognize that many land-poor households also take out loans to cover food expenses in the lean winter months, as well as other variable expenses throughout the year such as medical bills and weddings. However, modeling these sources of debt was beyond the scope of our study.

**Notes on benchmark and other estimates:** Mansfield's fieldwork finds consistent payments of 2 khords per jerib of opium (which equals 1.125 kilograms per hectare) in areas in which the Taliban exert control. He also finds reporting of Taliban-imposed taxes on land and wheat, but these appear to be very small and inconsistently enforced. For those reasons, we have not included them in the crop budgets. We assumed the Taliban can only collect taxes effectively on opium poppy grown in the *dasht* but note that, in a personal communication (January 21, 2015), Mansfield noted instances of Taliban taxation in the canal area.

**Sources of benchmark and other estimates:**

- David Mansfield, "Briefing Paper 4: 'Taxation' in Central Helmand," internal working paper for the British Embassy Kabul, June 2012, pp. 4–5.
- David Mansfield, "Briefing Paper 2: 'Taxation' in Central Helmand," internal briefing paper for the British Embassy Kabul, January 2012, pp. 1–6.
- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, p. 86.

#### Bribes to Local Law Enforcement Agents

**Benchmark price estimate:** None.

**Notes on benchmark and other estimates:** Police bribes generally take two forms in Helmand—bribes to avoid eradication inside the CCA and bribes to avoid destruction of tube wells and seizure of generators or water pumps in the *dasht*. Mansfield's fieldwork suggests that (1) the amounts of these bribes vary greatly in the CCA (20,000 PR to 125,000 PR per hectare in 2010–2012); (2) in recent years, the frequency of these bribes has diminished in the CCA; and (3) that they are only sporadically collected in the *dasht*. For those reasons, we have not included bribes to local law enforcement in the crop budgets.

**Sources of benchmark and other estimates:**

- David Mansfield, "Briefing Paper 4: 'Taxation' in Central Helmand," internal working paper for the British Embassy Kabul, June 2012, pp. 5–6.
- David Mansfield and Paul Fishstein, "Eyes Wide Shut: Counter-Narcotics in Transition," Afghanistan Research and Evaluation Unit, September 2013, p. 19.
- David Mansfield, "Briefing Paper 2: 'Taxation' in Central Helmand," internal working paper for the British Embassy Kabul, January 2012, pp. 1–6.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 29.

### *Output Prices*

For each price estimate, we describe the type of output, present the benchmark estimate(s), provide notes on the estimate(s), and list our sources.

### Dry Farm-Gate Price of Opium

**Benchmark price estimate:** $161 per kilogram.

**Table B.10. Dry Farm-Gate Price of Opium**

| Annual Prices (nominal U.S. dollars per kilogram) | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2002** | **2003** | **2004** | **2005** | **2006** | **2007** | **2008** | **2009** | **2010** | **2011** | **2012** | **2013** |
| National | 305 | 425 | 142 | 138 | 125 | 122 | 95 | 64 | 169 | 241 | 195 | 172 |
| Southern | 422 | 481 | 150 | 141 | 122 | 115 | 70 | 62 | 181 | 232 | 173 | 161 |

SOURCE: UNODC, *Afghanistan Opium Survey*, 2006–2013.
NOTE: Nominal prices are not adjusted for inflation.

**Notes on benchmark and other estimates:** These are prices at harvest.
**Sources of benchmark and other estimates:**

- UNODC, *Afghanistan Opium Survey*, annual surveys 2006–2013.

### Wheat

**Benchmark price estimate:** $0.32 per kilogram.
**Notes on benchmark and other estimates:** The nominal Afghani figures in Table B.11 are the monthly wheat prices reported in the Helmand provincial center during the months of April and May—the approximate time of harvest—from 2009 through 2012. Prices were not available for 2013, which was the approximate time of harvest for the 2012–2013 season and, for that reason, we use the average April–May 2012 price for the benchmark estimate. The nominal U.S. dollar figures were calculated using mid-month Afghani to U.S. dollar exchange rates.
**Sources of benchmark and other estimates:**

- Ministry of Agriculture, Irrigation, and Livestock, "Commodity Price Bulletin," monthly editions November 2005–November 2012 (excluding October–November 2010).

**Table B.11. Market Price of Wheat**

| Monthly Prices (nominal Afghanis and U.S. dollars per kilogram) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **April 2009** | **May 2009** | **April 2010** | **May 2010** | **April 2011** | **May 2011** | **April 2012** | **May 2012** | **April 2013** | **May 2013** |
| Wheat | | | | | | | | | | |
| Afghanis | 20 | 18 | 12 | 12 | 17 | 17 | 16 | 16 | – | – |
| $U.S. | 0.3814 | 0.34326 | 0.25116 | 0.25812 | 0.36686 | 0.36941 | 0.32032 | 0.3184 | | |
| Exchange Rate | 0.01907 | 0.01907 | 0.02093 | 0.02151 | 0.02158 | 0.02173 | 0.02002 | 0.01990 | 0.01824 | 0.01818 |

SOURCES: For prices in Afghanis, see MAIL, "Commodity Price Bulletin," monthly editions April 2009–May 2013.
NOTE: Nominal prices are not adjusted for inflation.

### *Potential Investment Costs*

For each type of investment, we describe the investment, present the benchmark estimate(s), provide notes on the estimate(s), and list our sources.

#### Land

**Benchmark cost estimate(s):**
$30,960 per hectare in the CCA
$1,155 per hectare in the *dasht*
**Notes on benchmark and other estimates:** Mansfield (2013b) estimated land prices at between 500,000 PR and 700,000 PR per jerib in the CCA (equal to 2,500,000 PR to 3,500,000 PR per hectare), and a range of about 15,000 PR to 30,000 PR per jerib in the *dasht* for untouched land (equal to 75,000 PR to 150,000 PR per hectare). We have taken the midpoints of these estimates, i.e., 3,000,000 PR per hectare in the CCA (nominal price, fall 2012) and 112,000 PR per hectare in the *dasht* (nominal price, fall 2012) and converted them to then-year dollars, using the mid-September 2012 exchange rate.
**Sources of benchmark and other estimates:**

- David Mansfield, "Briefing Paper 6: Central Helmand in the 2012/13 Growing Season," internal working paper for the British Embassy Kabul, March 2013, p. 10.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.
- Mansfield, David, *All Bets Are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, pp. 85–86.

#### Tractor

**Benchmark cost estimate:** $4,128.
**Notes on benchmark and other estimates:** Mansfield (2013a) estimated a cost of 400,000 PR per tractor. According to his 2011 fieldwork, the price of an "old tractor" was 200,000 PR. Presumably, the price difference reflects the condition of the two options. We have taken the more recent estimate of 400,000 PR per tractor (nominal price, fall 2012) and converted it to then-year dollars using the mid-September 2012 exchange rate.
**Sources of benchmark and other estimates:**

- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit. January 2013, p. 83.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.

Tube Well (not solar powered)

**Benchmark cost estimate(s):**

$2,477 in total, consisting of:

- $516 for generator
- $568 for dynamo
- $826 for water pump
- $568 for labor, etc.

**Notes on benchmark and other estimates:** For the 2012–2013 growing season, Mansfield (2013a, p. 85) reported a total one-time investment cost of about 240,000 PR to install a well in the *dasht*. The total cost consisted of four elements: generator (50,000 PR); dynamo (55,000 PR);[41] water pump (80,000 PR); and the cost of labor for drilling, mechanical work, and pipes (55,000 PR). In an earlier report, Mansfield (2011b, p. 25) cites prevailing prices of 50,000 PR per generator and about 500 PR per meter drilled for tube well installation (80 meters seems to be a reasonable average drilling depth in the *dasht*). In other places, however, he cites prices for hiring local drillers in Helmand at 1,200 PR per meter (Mansfield, 2013b, p. 83) and for Chinese-made water pumps at 20,000 PR (Mansfield, 2013b, p. 84). Alternatively, Mansfield and Fishstein (2013, p. 15) estimated the cost of a solar-powered tube well, including installation, at 1,250,000 PR. For our benchmark, we use the 240,000 estimate and its components, which we converted to then-year dollars using the mid-September 2012 exchange rate.

**Sources of benchmark and other estimates:**

- David Mansfield, *All Bets are Off! Prospects for (B)reaching an Agreement and Drug Control in Helmand and Nangarhar in the Run Up to Transition*, Afghanistan Research and Evaluation Unit, January 2013, pp. 83–85.
- David Mansfield, *Between a Rock and a Hard Place: Counternarcotics Efforts and Their Effects in Nangarhar and Helmand in the 2010–2011 Growing Season*, Afghanistan Research and Evaluation Unit, Case Study Series, October 2011, p. 25.
- David Mansfield and Paul Fishstein, "Eyes Wide Shut: Counter-Narcotics in Transition," Afghanistan Research and Evaluation Unit, September 2013, p. 15.

## Effects of Changes in Parameter Values

In this section, we discuss the sensitivity of the results of the crop budgets to changes in parameter estimates. In turn, we explore a series of scenarios, focusing on yields and eradication, output prices, labor costs, and the terms of sharecropping arrangements.

[41] Mansfield, 2013a, p. 85, lists the dynamo separately, noting that it "reduces the need for running the generator and therefore saves fuel costs."

### *Yields and Eradication*

In the benchmark budgets, we took historical yields as given. However, in recent years, opium yields have fallen while the trend in wheat yields has been rising (see Figure 2.2). In recalculating the budgets, using our low-end yield for opium and our high-end yield for wheat, we found that opium poppy still looks like the best option for a landowner with sharecroppers but, for an owner-operator, the desirability of opium poppy in comparison to wheat hinges on whether the household can provide on-farm labor, as per the benchmark model. If yes, the opium poppy grower's return would drop from $3,544 to $1,735 with the lower opium yield, and the wheat grower's return would rise from $386 to $656 with the higher wheat yield. Even so, opium poppy would still look good by comparison. If not, as might be the case on a second, third, or fourth hectare of land, the return to the opium poppy grower would drop from $1,448 to –$361 with the lower opium yield, implying a substantial loss, and the return to the wheat grower would rise from $144 to $414 with the higher wheat yield. Under these different circumstances, a land owner might not choose to shift to wheat, but would be even less inclined to hire labor—this was not the best option for such a landowner prior to the change in yields—and would be even more inclined to enter into a sharecropping arrangement, if possible.[42]

By comparison, if the wheat yield were to rise and the "effective yield" of opium poppy were to decline—not because of a change in environmental conditions, but because the Afghan government is able to eradicate a significant share of total hectares planted to opium poppy—the differences in net returns would be less extreme because of commensurate adjustments in the use of harvest labor. Because the opium poppy grower would not have to pay for labor to harvest his eradicated crop, the loss would be much less than if yields fell. In the case of eradication, the owner-operator's return would drop to $2,082 with access to household labor and to $335 without. The lesser figure would not look "better" than the return from wheat, were wheat yields to rise, but the difference would not be as stark. Had the wheat yield not increased, opium poppy would continue to dominate, regardless of the landowner's access to household labor.

The comparative analysis of yield and eradication effects suggests that meager yields, particularly if unabated, are more likely to affect the landowner's land-allocation decision than an equivalent amount of eradication enforcement, even if sustained.

If opium yields were to stagnate, but wheat yields were to rise to the high end of the Niane et al. (2011) range, i.e., 7 tons per hectare, opium poppy would still dominate wheat but the difference in the returns from each would narrow substantially and wheat would look like a much closer "second," especially for farmers lacking access to any household labor. In that case,

[42] Returns to sharecroppers would also be declining, which could affect the supply of sharecroppers.

In considering the implications of the results for the *dasht*, we note that both opium poppy and wheat yields might be lower there than in the CCA, but the differences in yields for both crops between the *dasht* and the CCA are likely to be roughly similar.

opium poppy would offer the benchmark return of $1,448 per hectare while wheat would offer a net return of $1,120 per hectare.

### *Output Prices*

We used the crop budgets to identify the extent to which opium prices must drop—or wheat prices rise—to induce a shift from opium poppy to wheat and whether there are any plausible combinations of changes that might do so. Among the many combinations of price changes that could induce a shift, we considered three specific scenarios: a fall in the price of opium absent a rise in the price of wheat; a rise in the price of wheat absent a fall in the price of opium; and a contemporaneous fall in the price of opium to its lowest level in the past decade and a rise in the price of wheat to its highest level in the same period.

The means by which these price changes could occur—and their implications—differ by crop. In the case of opium, Afghanistan produces a very large share of global supply. Therefore, production within Afghanistan likely plays an important role in setting world market prices, and a major supply-side shift in Afghanistan could have global consequences.[43] Absent supply-side shifts, the only other routes to a lower global wholesale price for opium would be a fall in global demand for opiates or a dramatic change in the policies and enforcement practices that surround them. In the case of wheat, Afghanistan is a "price taker." Wheat prices in Afghanistan are heavily affected by conditions in the world market and are largely driven by world market prices. Realization of an increase in the price of wheat in Afghanistan could derive from either short-lived or longer-term global phenomena (such as the 2008–2009 surge in grain prices, an increase in the purchasing power of a net consumer of grain, or a major climatic change) or from enactment of domestic policy that serves to disconnect Afghanistan from the world market. If the latter, we might also consider the attendant costs of maintaining that policy and its distributional effects.

For each of the first and second scenarios, we asked how much each price would need to fall or rise to induce a shift and, for the third scenario, we asked whether these contemporaneous changes would induce a shift.

- In our first scenario, we found that, at a price of $61 per kilogram of opium, an owner-operator with access to household labor will be indifferent to cultivating opium poppy or wheat; below $61 per kilogram, he will prefer wheat. That same landowner would still prefer to cultivate opium poppy, if he were able to attract sharecroppers, but the returns to sharecropping would be so low as to make it unlikely he could attract sharecroppers at a price below $61 per kilogram.
- In the second scenario, we found that, at a price of about $1.29 per kilogram of wheat, an owner-operator with access to household labor will be indifferent to cultivating opium

[43] See Paoli, Greenfield, and Reuter (2009) for a discussion of the effects of the Taliban ban on international markets.

poppy or wheat; above $1.29 per kilogram, he will prefer wheat. That same landowner would not prefer opium poppy, even if he were able to attract sharecroppers.

- In the third scenario, we set the price of opium to $62 per kilogram, which was the lowest price on record in the southern region over the past decade, and we set the price of wheat to $0.76 per kilogram, which was the highest price on record.[44] In this scenario, wheat is the clear winner regardless of the tenancy arrangement.

This analysis suggests that there are plausible, if not highly likely, scenarios under which price alone could induce a shift from opium poppy to wheat. If the price of opium were to fall just below the record low without any increase in the price of wheat, a shift might be possible; if, at the same time, the price of wheat were to rise—even slightly—it would serve to reinforce the effect; were it to rise to its record high, a shift would be probable.

### *Labor Costs*

Several different types of labor feature in the crop budgets, including harvest, non-harvest, unallocated, and household labor. Here, we focus on the cost of harvest labor as it is relevant across tenancy arrangements and, to some extent, enters into the poppy grower's decisionmaking even if that grower has access to household labor. As with the effect of output prices examined in the previous section, we asked "if we increase the price of harvest labor, at what point along the continuum will opium poppy become less attractive than wheat?" In this case, the starting price, i.e., our benchmark, is $9.80 per man-day of labor. We found that the price of labor must rise to about $16.32, or by about 67 percent, for landowners with no access to household labor to prefer wheat and to about $41.40, or about 322 percent, for landowners with access to household labor to prefer wheat, assuming that all other labor prices were to remain constant. In each case, landowners would still prefer opium poppy to wheat were they able to enter into a sharecropping arrangement. At $16.26 per man-day, it might be possible to find a willing sharecropper, e.g., if the sharecropper had access to household labor and the landowner offered room and board, but not at $41.40.[45]

Neither scenario looks particularly realistic, at least in the near term, but the scenarios cannot be ruled out in the longer term. If, in the longer term, all household members, male and female, were able to move more freely into the labor market, absent concerns about security or socio-cultural restrictions, the market supply would increase and wages might decrease but, at the same time, the availability of household labor might also decrease.

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[44] Strictly speaking, these prices are non-comparable. The opium price is a harvest price for the southern region in the 2008–2009 growing season; the wheat price is a point estimate for Helmand in May 2008.

[45] If the landowner were providing room and board, the net returns to that landowner would decline, accordingly. At the lower price, a sharecropper with access to household labor would still be doing slightly better than breaking even, with a net return of $63; at the higher price, the sharecropper could not afford to cultivate opium poppy—he would be operating at a loss, i.e., -$2,145, even with access to household labor. From the sharecropper's perspective the pivotal price might be $16.95, at which point he would just be breaking even.

If all other agricultural labor prices were to rise as well, the switch could occur slightly sooner, but the effect would be partly offset by the increase in the cost of unallocated labor, which plays a part in wheat cultivation if a landowner has no access to household labor. With an across-the-board wage increase of 46 percent, poppy would look less attractive than wheat for landowners that do not have access to household labor, but would still look relatively attractive for a landowner able to enter into a sharecropping arrangement. In this case, sharecroppers' returns would amount to about $234 per season, with access to their own household labor, and they might enter into an agreement, even without housing or food.[46]

Finally, we could consider a slight reformulation of the technology reflected in the crop budgets: specifically, one in which a household can choose to produce opium poppy on one-half of a hectare of land, using only household labor at harvest, and plant something else, that might not require any hired labor, such as wheat, on the other half.[47] In that case, assuming the farmer has access to household labor, the farmer would always choose to allocate one-half hectare to opium poppy, regardless of the increase in the wage rate. For that one-half hectare of opium poppy, the wage rate would be all but irrelevant.

On balance, the analysis suggests that while opium poppy's relative labor intensity—taken in combination with an abundant supply of labor—might encourage its cultivation, it is, by no means, the sole determinant of its cultivation. It would be difficult, through wage increases alone, to force opium poppy out of a landowner's agricultural portfolio.

### *Sharecropping Terms*

Depending on the nature of the sharecropping arrangement, it can be either more or less attractive to would-be sharecroppers and land owners. Here, we consider, first, the point at which sharecroppers can no longer be induced to enter into a sharecropping arrangement and, second, the point at which sharecropping arrangements are strictly preferable to cultivating as an owner-operator.[48] We find, when the sharecropper's take drops below about one-fifth, he would likely lose interest in entering into a sharecropping arrangement, if making decisions solely on the basis of the bottom line. At that point, the sharecropper's return would be close to zero and the arrangement would make sense only if it includes room, board, or other benefits. Moreover, it is at about that same point that a landowner would become indifferent between owner-operator

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[46] To eliminate poppy entirely by making it wholly unattractive to landowners and sharecroppers under all feasible circumstances, prices would still need to more than quadruple. The exact multiple is 4.223, because the change in the price of non-harvest labor is irrelevant to a household that has access to household labor.

If viewing sharecropping as a labor arrangement, rising wages would suggest potentially better alternative opportunities for sharecroppers. On that basis, one would expect the supply of sharecroppers to fall.

[47] In the fixed-proportion specification that we used in the crop budgets, the farmer was required to use both types of labor—half-and-half of each—to harvest the entire hectare.

[48] Because the returns to an owner-operator growing opium poppy, with or without access to household labor, strictly dominate the returns to an owner-operator growing wheat, we can envision no scenarios in which the terms of the sharecropping arrangement, taken in isolation, would rule out poppy production.

production with household labor and entering into a sharecropping arrangement. Thus, it is not until the terms of the arrangement are no longer of interest to the sharecropper that the landowner would uniformly prefer a sharecropping arrangement, regardless of access to household labor. The analysis of the terms of these arrangements suggests that owner-operators will remain part of the poppy cultivating landscape, assuming that at least some continue to have access to household labor, absent other changes in the market that could favor sharecropping.

Finally, we might consider the effects of taking on an arrangement in which the sharecropper provides more than labor. In that case, the landlord and the sharecropper would share more of the risk vis-à-vis other input costs. Consequently, we would expect to see sharecroppers retaining a higher share of the crop, to compensate for at least some of the additional risk.

## Missing Pieces and Their Implications

In this section, we address some of the missing pieces in the crop budgets, including storage and marketing costs, herbicides, canal maintenance, and investment, the last of which is especially relevant to the consideration of cultivation decisions in the *dasht*.

### *Storage and Marketing Costs*

Storage and marketing costs are interesting, in large part, because they are asymmetric: They apply more to wheat and other legal crops than to opium poppy, *per se*. Whereas opium is a high-value commodity by volume and weight, is often collected at the farm gate (even under adverse conditions), and is slow to deteriorate, the alternatives, including wheat, tend to be bulkier, not as amenable to farm-gate collection, more perishable, and more susceptible to pest infestation. On that basis, it is reasonable to assert that the crop budgets, which work with the farm-gate price of opium and the retail price of wheat, overstate the relative returns to wheat.[49] Absent specific information on storage and transportation costs and shrinkage rates, the extent of the overstatement is unknown, but any overstatement would tend to reinforce our findings that, on the basis of net returns, opium poppy looks preferable to wheat in the "benchmark" case and under many different exploratory scenarios.

### *Herbicides*

Herbicides might benefit both opium poppy cultivation and wheat cultivation but, because they tend to be used as a substitute for labor, they might be more beneficial to opium poppy cultivation, which uses labor more intensively. In this case, properly accounting for this missing piece would tend to reinforce our finding that opium poppy is preferable to wheat, especially in those cases in which a farmer does not have access to household labor.

[49] Kuhn (2009, 2010) uses all farm-gate prices, with roughly similar results.

### *Canal Maintenance*

Canal maintenance is likely to be symmetric with respect to opium poppy and wheat. All farmers must participate in local maintenance activities by contributing household labor and paying maintenance fees. The cost of maintenance could have substantial, negative effects on the bottom lines for both.

### *Investment*

We end the review of missing pieces with a discussion of investment. Investment costs do not play a large part in the crop budgets, except as an addendum and a potential depreciation cost, but may have played a substantial part in the shift of cultivation from the CCA to the *dasht*. The development of tube wells at affordable prices made it possible for landowners to shift cultivation into a formerly inhospitable region. At the same time, the relatively low price of land—some settlers initially acquired land at little or no cost—and an abundant supply of would-be sharecroppers made the shift "economic." However, the price of land in the *dasht* has risen, as the region proves itself as an economically viable production center and land in the *dasht* has become less readily available. We would not expect land prices in the *dasht* and the CCA to equalize, given the need to invest in tube wells in the *dasht* and the higher productivity of land in the CCA, but differences in prices have narrowed. The potential for solar-powered tube wells, which involve lower recurring costs, may make opening new land in the desert attractive—land that had previously been considered not arable.

# Appendix C: A Household Model of Opium Poppy Production in Afghanistan

In this appendix, we adapt the household production model of Fafchamps (1992) to Afghan opium poppy production. The original model describes household land use decisions (shares of crops grown) under conditions of possibly non-separable production and consumption decisions. It is assumed that consumption prices (the marginal cost of purchasing a unit of a consumption good) and producer prices (the marginal revenue associated with cultivation) for any crop that is both consumed and produced locally are random and can co-vary.[50] We augmented the original model through inclusion of a (possibly random) term that corresponds to outside income, which allows for a partial exploration of the effects of changes in off-farm, market-based income and debt. In addition, we incorporated an explicit representation of eradication risk and a more structural relationship between producer and consumer prices.

We studied the case of two crops: opium poppy and wheat. Wheat was assumed to be both produced and consumed locally while, for simplicity, opium poppy was assumed to be primarily a cash crop and thus not consumed locally. Only large, wealthy households were assumed to separate production and consumption decisions, i.e., maximize the expected utility of profit; smaller households are exposed to joint consumption and production risk.

The model was used to develop the comparative statics of the land share allocated to opium poppy with respect to model parameters. This allowed for the prediction of behavioral changes with respect to one model parameter while holding all other parameters constant. However, as will be shown, the identified factors of opium poppy cultivation discussed elsewhere in this report often involve changes in more than one parameter; thus, changes in these factors often involve conflicting incentives with respect to opium poppy production.

This appendix proceeds as follows. We first give a general description of the model, highlighting the key assumptions. We then derive the model, following the analysis in Fafchamps (1992). After completing the model, we derive the comparative statics for each model parameter and give some intuition behind the reasons for the results. We then relate the opium poppy cultivation factors to model parameters and discuss how a change in these factors (keeping other factors constant) is likely to change opium poppy production for different types of households and in southern Afghanistan more generally.

[50] Note that these prices may be endogenous "shadow prices" in the presence of additional constraints not explicitly incorporated into the model. We provide one such example in the "Landholding" subsection in the discussion of opium poppy cultivation factors.

### *General Model Description*

To accommodate both production risk (be it rooted in the environment or eradication policy) and consumption price risk, we used a variant of the household model first developed by Fafchamps (1992). The model has the following characteristics:

- Households with a given, fixed land input make land-use decisions across *N* crops
- Production technologies for each crop are Leontief (fixed input shares) and exhibit constant returns to scale[51]
- Returns for each crop per unit of land are random and possibly correlated with consumption prices[52]
- Income used for consumption is determined within the model, in part, by the land use decisions and is random
- Households have preferences over risk
- The household consumes *K* goods, some or all of which may be produced by the household itself
- Crop decisions are made prior to the realization of prices and returns, whereas consumption decisions are made after that realization.[53]

The assumption of constant returns to scale results in a model that is invariant to the size of landholdings. Nevertheless, as in Fafchamps (1992), differences in household wealth can be proxied via changes in model parameters; namely, consumption shares, the level of risk aversion, and income elasticities of consumption. The subsection on landholding in the discussion of opium poppy factors formalizes this notion.

The incorporation of consumption decisions is an important element of the model. It has been shown (e.g., Barrett 1993) that risk-averse agricultural households facing a stochastic price for a crop they both produce and consume tend to "overproduce" (relative to the level associated with maximization of the expected utility of profit) when there is a positive correlation between the marginal utility of income and the price of the commodity. However, because households both produce and consume, there are conflicting incentives when prices change. For example, an increase in commodity price tends to be "good" in terms of production due to the potential for increased income, but "bad" for consumption due to income effects associated with the price change. This coupling of consumption and production decisions is termed *non-separability* in the development economics literature.

Finally, the notion of risk aversion plays a significant role in how a household might respond to a change in a parameter or set of parameters. The coefficient of relative risk aversion is a

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[51] This assumption is not limiting, as different production technologies for each crop could be modeled conceptually as different crops.

[52] The specification of non-zero correlation is the mechanism by which consumption and production decisions are made non-separable in the model.

[53] This is a standard assumption in household production models; see, e.g., Barrett (1993), de Janvry, Fafchamps, and Sadoulet (1991), and de Janvry and Sadoulet (2006).

measure of the curvature of a utility function, with increasing magnitudes of this coefficient indicating a greater aversion to risk. This is equivalent to saying that, when facing the choice between a safe payout and a risky one, individuals or households that are more risk averse would be indifferent between the safe and risky option at a lower level of safe payout. Yet another way of stating this is that the risk premium, or willingness to pay to avoid risk, is higher for the risk-averse individual or household.

Given this background, we now derive the basic model, which was originally developed in Fafchamps (1992).

### *Model Details*

We assumed a household with a fixed amount of land facing a cropping decision. Implicitly, we assumed that the household engages in these production and consumption decisions in a two-stage procedure. In the first stage, the household decides the land share to allocate to each possible crop. In the second stage, the household uses the income provided through agriculture (and perhaps off-farm income) to make consumption decisions. Although we conceptualized the decisionmaking process in stages, we did not explicitly model preferences over income in the two periods.[54]

In the developing world, market failures and transaction costs are significant. This leads to the notion of non-separability, in which production decisions are directly affected by consumption preferences and characteristics (see de Janvry and Sadoulet, 2006). Non-separability in household decisions occur when, due to market failures or transaction costs, a household can both produce and consume the same good, but do so at different prices. The link between production and consumption can result in optimal behaviors that may seem counterintuitive, especially when viewed from the standpoint of production agriculture alone. For example, a decrease in the variance of a crop that is both produced and consumed may not increase production of a crop, especially when returns are correlated with consumption prices.

We represent consumption prices as $p_k$, while per-acre returns are $\pi_i$.[55] Per-acre returns are defined as total revenue less total costs. In the general model, each crop is salable (but need not be sold formally in a market) and each crop may also be a consumption good (though this is not necessary). In the specific example presented here, wheat is both a production and consumption good, while opium poppy is a cash crop used to generate income only.

Consumption prices and returns are random variables in the model, and may be correlated. Off-farm income is represented as a random variable $y^*$, which also may be correlated with returns or consumption prices. We assumed that off-farm income is a model parameter, rather

[54] Andersson (2013) provides such a framework.

[55] Because we drew heavily from Fafchamp (1992), we used that notation whenever possible. Only in those circumstances in which we added new features to the model do we create new notation.

than a choice variable in the problem.[56] At the time of crop share allocation, it is assumed that returns, consumption prices, and outside income are not known. As such, total income $y = \sum_i L_i \pi_i + y^*$, where $L_i$ is the amount of land allocated to each crop *i.*. Total income is random; at the time of consumption, however, the household has realized its income.

This conceptualization is operationalized as follows. The household has preferences over the set of consumption goods (indexed by *k* at prices $p_k$) and, via the demands that are implied by the second stage of the process, has an indirect utility function represented by $V(y, \mathbf{p})$. Assuming $\bar{L}$ is the (fixed) amount of land held by the household, the model is specified as:

$$\max_{L_i} \ \mathrm{E}\left[V(y, \mathbf{p})\right]$$
$$s.t. \ \ y = \sum_i \pi_i L_i + y^*$$
$$\sum_i L_i = \bar{L},$$

where $\mathbf{p} = (p_1, \mathrm{K}\ p_M)$ is a vector of random consumer prices, and all other variables are as previously described. Expectations are over the random prices, returns, and off-farm income.

The first-order conditions to the maximization problem are $E\left[V_y \pi_i\right] = 0 \ \forall i$ and $\sum_i L_i \le \bar{L}$, where $V_y = \dfrac{\partial V(y, \mathbf{p})}{\partial y}$. We assumed the last condition holds with equality, i.e., all land is cropped. From the other conditions, the expected marginal utility from each crop should be equal at the optimum. Also, because the indirect utility function is homogeneous of degree zero, a numeraire is needed and will be incorporated below.

We now develop a useful expression for $E\left[V_y \pi_i\right]$. Taking a second-order Taylor-series expansion of the indirect utility function $V(y, \mathbf{p})$ around mean prices $\bar{\mathbf{p}}$ and income $\bar{y} = \sum_i \bar{\pi}_i L_i + \bar{y}^*$, with $\bar{\pi}_i$ denoting expected per-acre returns from crop *i,* $\bar{y}^*$ denoting expected off-farm income, and $L_i$ the quantity of land allocated to each crop*,* the following expression is obtained:

$$V_y \approx \bar{V}_y + \sum_{k=1}^{M} \bar{V}_{yp_k} (p_k - \bar{p}_k) + \bar{V}_{yy} (y - \bar{y}),$$

[56] That is, it is exogenous to the cropping decision. This term was not included in the original Fafchamps (1992) specification.

where the bar indicates means or evaluation at the means, $\bar{V}_{yp_k} = \frac{\partial V_y(\bar{y}, \bar{\mathbf{p}})}{\partial p_k}$, and $\bar{V}_{yy} = \frac{\partial V_y(\bar{y}, \bar{\mathbf{p}})}{\partial y}$. Using Roy's identity $V_{p_k} = -V_y q_k$, where $V_{p_k} = \frac{\partial V(y, \mathbf{p})}{\partial p_k}$, $q_k$ is demand for consumer good *k*, and differentiating yields $V_{p_k y} = -V_{yy} q_k - V_y \frac{\partial q_k}{\partial y}$. Substitution yields

$$V_y \approx \bar{V}_y \left[ 1 - \left( \sum_{k=1}^{M} \left( \frac{\bar{q}_k}{\bar{y}} \frac{\bar{V}_{yy} \bar{y}}{\bar{V}_y} + \frac{\partial q_k}{\partial y} \cdot \frac{\bar{y}}{\bar{q}_k} \cdot \frac{\bar{q}_k}{\bar{y}} \right) (p_k - \bar{p}_k) - \frac{\bar{V}_{yy}}{\bar{V}_y} \frac{\bar{y}}{\bar{y}} (y - \bar{y}) \right) \right].$$

The term $\Psi = \frac{\bar{V}_{yy} \bar{y}}{\bar{V}_y} < 0$ is the (negative of the) coefficient of relative risk aversion toward income risk, evaluated at expected income. The notion of risk aversion is closely tied to the curvature of the utility function; here, the indirect utility function with respect to income. A risk-averse individual has greater utility from the expected value of a gamble than the expected utility of the gamble itself, or equivalently, a concave utility function. This induces a risk premium, defined as the difference between the expected value of the gamble and the certainty equivalent of the gamble. The certainty equivalent of the gamble is the dollar amount that would give the same utility as the expected utility from the gamble.

For example, assuming constant relative risk aversion, the certainty equivalent for a gamble for which it is equally likely that payouts of $500 and $1500 occur (with an expected value of $1,000) is $866 for $\Psi = -1$, $750 for $\Psi = -2$, $593 for $\Psi = -5$, and $540 for $\Psi = -10$. This is approximately equivalent to shares of 87, 74, 67, 62, and 54 percent of the expected payout, respectively.[57] The household characterized by $\Psi = -1$ is thus willing to pay a risk premium of $134 to avoid the gamble, while the household with $\Psi = -10$ would be willing to pay $460 to avoid the gamble. Note that in this latter case, the risk premium is approaching the lowest possible outcome of the lottery, suggesting an extreme dislike of lotteries.

Empirical evidence about the size of this coefficient is not always in agreement, with estimates ranging from close to zero to less than –10, though it appears that most studies suggest a range of zero to –5 for households in developing countries (see, e.g., Gandelman and Hernandez-Murillo, 2014; Fafchamps, 1992; and Binswanger, 1980).[58]

Furthermore, let $\eta_k = \frac{\partial q_k}{\partial y} \cdot \frac{\bar{y}}{\bar{q}_k}$ be the income elasticity of good $q_k$ evaluated at mean prices and income. The income elasticity represents the percentage change in demand given a percentage change in income. We expect that, for normal goods considered to be necessities,

[57] For similar lotteries with scaled payoffs, these shares are identical at identical relative risk aversion coefficients.

[58] These studies are often performed at the country level, rather than at the individual or household level.

$0 < \eta_k < 1,$ and poorer households will be more responsive to income changes (i.e., larger income elasticities) than wealthier households.

Substituting these terms yields

$$V_y \approx \bar{V}_y \left[ 1 - \left( \sum_{k=1}^{M} \bar{q}_k \left( \frac{\Psi}{\bar{y}} + \frac{\eta_k}{\bar{y}} \right) (p_k - \bar{p}_k) - \frac{\Psi}{\bar{y}} (y - \bar{y}) \right) \right].$$

Multiplication by $\pi_i$ yields

$$V_y \pi_i \approx \bar{V}_y \left[ \pi_i - \left( \sum_{k=1}^{M} s_k \pi_i \left( \Psi + \eta_k \right) \left( \frac{p_k}{\bar{p}_k} - 1 \right) - \pi_i \Psi \left( \frac{y}{\bar{y}} - 1 \right) \right) \right],$$

where $s_k = \frac{\bar{q}_k}{\bar{p}_k \bar{y}} \geq 0.$ Note this is the average budget share of good *k* for the household times the inverse of the good's mean price squared, or $\frac{\bar{q}_k}{\bar{p}_k \bar{y}} = \frac{1}{\bar{p}_k^2} \frac{\bar{p}_k \bar{q}_k}{\bar{y}_k}.$ The budget share is conceptualized as the share of the value of mean income from crop production (via returns) plus off-farm income dedicated to consumption of good *k*. The consumed quantity is valued at local consumption prices. This does not preclude consuming a crop that is grown on the households' land, as the average value of this crop would be determined by mean returns, and the value of consumption would be calculated at mean consumption prices.

A share of zero for a particular crop decouples the production and consumption decisions for that crop, and can be interpreted as a case where only production decisions matter to the household. If this is true of all crops, the household maximizes the expected utility from income, or $V(y, \mathbf{p}) = v(y),\ v_y > 0,\ v_{yy} \leq 0,$ with a strict inequality if the household exhibits risk aversion.

Taking expectations yields

$$E\left[ V_y \pi_i \right] \approx \bar{V}_y \left[ E\left[ \pi_i \right] - \left( \sum_{k=1}^{M} s_k \left( \Psi + \eta_k \right) E\left[ \pi_i \left( \frac{p_k}{\bar{p}_k} - 1 \right) \right] - \Psi \left[ E \pi_i \left( \frac{y}{\bar{y}} - 1 \right) \right] \right) \right],$$

where expectations are over random returns $\pi_i$, consumption prices $p_k$, and income $y$.

Production is separable from consumption if $\sum_{k=1}^{M} s_k \left( \Psi + \eta_k \right) E\left[ \pi_i \left( \frac{p_k}{\bar{p}_k} - 1 \right) \right] = 0,$ which is the case if the consumption shares equal zero, $-\Psi = \eta_k,$ or each $E\left[ \pi_i \left( \frac{p_k}{\bar{p}_k} - 1 \right) \right] = 0.$ A consumption share equals zero for a cash crop or if there is no relationship between the household and the local market. The relative risk aversion coefficient equaling income elasticity for good *k* is essentially a coincidence, but will determine the sign of this term given an assumed correlation between consumption prices and returns. Finally, the last term shows that in the absence of correlation between crop returns and consumer prices, production and consumption decisions are functionally independent; that is, consumption and production are separable.

We now substitute these expressions into the first-order conditions of the household model. Assume two crops 0 and 1[59], that the mean return for crop 0 is the numeraire, and let $l_i = \frac{L_i}{\bar{L}}$ be the land share for crop *i*. After dividing by the numeraire $E(\pi_0) = \bar{\pi}_0$, the first two first order conditions can be written as:

$$1 - \left( \sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0} E\left[ \pi_0 (\frac{p_k}{\bar{p}_k} - 1) \right] - \frac{\Psi}{\bar{\pi}_0} \left[ E\left[ \pi_0 (\frac{y}{\bar{y}} - 1) \right] \right] \right)$$

$$= \frac{\bar{\pi}_1}{\bar{\pi}_0} - \left( \sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0} E\left[ \pi_1 (\frac{p_k}{\bar{p}_k} - 1) \right] - \frac{\Psi}{\bar{\pi}_0} \left[ E\left[ \pi_1 (\frac{y}{\bar{y}} - 1) \right] \right] \right).$$

Let $m = \frac{\bar{\pi}_1}{\bar{\pi}_0} > 0$, $CV_x = \frac{\sigma_x}{\mu_x}$ be the coefficient of variation of random variable *x*, and $\rho_{xz} = \frac{\text{cov}(x,z)}{\sigma_x \sigma_z}$ be the correlation coefficient between random variables *x* and *z*. For convenience, let $A = \sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0} E\left[ \pi_0 (\frac{p_k}{\bar{p}_k} - 1) \right]$ and $B = \sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0} E\left[ \pi_1 (\frac{p_k}{\bar{p}_k} - 1) \right]$.

Recognizing that *A* and *B* are independent of income, the first-order condition can be written as

$$(1-m) + B - A = \frac{\Psi}{\bar{\pi}_0} \left[ E\left[ \pi_1 (\frac{y}{\bar{y}} - 1) \right] \right] - \frac{\Psi}{\bar{\pi}_0} \left[ E\left[ \pi_0 (\frac{y}{\bar{y}} - 1) \right] \right] = \frac{\Psi}{\bar{\pi}_0 \bar{y}} E\left[ (\pi_1 - \pi_0) y \right] + \Psi(1-m).$$

The term $(B - A)$ can be manipulated to obtain

$$B - A = \sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0 \bar{p}_k} \left( \text{cov}(\pi_1, p_k) - \text{cov}(\pi_0, p_k) \right).$$

This confirms the intuition presented above that separability implies no correlation between returns and consumption prices. Making this expression unit-free in terms of the coefficients of variation and correlation coefficient yields:

$$\sum_{k=1}^{M} s_k \frac{(\Psi + \eta_k)}{\bar{\pi}_0 \bar{p}_k} \left( \text{cov}(\pi_1, p_k) - \text{cov}(\pi_0, p_k) \right) = \sum_{k=1}^{M} s_k (\Psi + \eta_k) CV_{p_k} \left( CV_{\pi_1} \rho_{\pi_1, p_k} m - \rho_{\pi_0, p_k} CV_{\pi_0} \right).$$

Substituting and rearranging, the first-order condition becomes:

$$(1-m)(1-\Psi) + \sum_{k=1}^{M} s_k (\Psi + \eta_k) CV_{p_k} \left( CV_{\pi_1} \rho_{\pi_1, p_k} m - \rho_{\pi_0, p_k} CV_{\pi_0} \right) = \Psi \frac{E\left[ (\pi_1 - \pi_0) y \right]}{\bar{\pi}_0 \bar{y}}.$$

[59] We assumed two crops for convenience in exposition and because that is the situation being modeled for Afghanistan; the model completely generalizes to $N > 2$ crops.

To get a solution in terms of the choice variable $l_1$, we need to substitute for the random variable $y$ and expected income $\bar{y}$. Specifically, $y = (1-l_1)\pi_0 + l_1\pi_1 + y^*$, and let $P^* = (1-m)(1-\Psi)$ and $Q^* = \sum_{k=1}^{M} s_k(\Psi + \eta_k) CV_{p_k}\left(CV_{\pi_1}\rho_{\pi_1,p_k} m - \rho_{\pi_0,p_k} CV_{\pi_0}\right)$. The term $Q^*$ represents the link between consumption and production in the model, and is zero for separable production and consumption.

The term $P^*$ does not have a natural economic interpretation, but depends solely on the relationship between returns of the two crops and the coefficient of relative risk aversion. Under the maintained assumptions that $m > 1$ and $\Psi < 0$, this term is unambiguously negative, with absolute values that increase in the absolute value of both parameters.

Multiplying through by $(1-l_1) + l_1 m + y^*$ and isolating terms yields:

$$l_1\left[\left(P^*+Q^*\right)(m-1) - \Psi\frac{E\left(\pi_1^2 + \pi_0^2 - 2\pi_0\pi_1\right)}{\bar{\pi}_0^2}\right] = -\left(P^*+Q^*\right)\left(1+\frac{\bar{y}^*}{\bar{\pi}_0}\right) + \Psi\frac{E\left[\pi_0\pi_1 - \pi_0^2 + (\pi_1-\pi_0)y^*\right]}{\bar{\pi}_0^2},$$

noting that constant returns to scale allows for writing the problem in land shares as the land allocation cancels out.

As was the case before, the terms in the expectations operator can be manipulated further using the definitions of variance, covariance, and correlation, and the share of land in "crop 1"[60] (for an interior solution) can be written as:

$$l_1^* = \frac{-\left(P^*+Q^*\right)\left(1+\frac{\bar{y}^*}{\bar{\pi}_0}\right) + \Psi(S^*+Y^*)}{\left[\left(P^*+Q^*\right)(m-1) - \Psi T^*\right]},$$

where $S^* = mCV_{\pi_0}CV_{\pi_1}\rho_{\pi_0,\pi_1} - CV_{\pi_0}^2 + m - 1$, $T^* = CV_{\pi_0}^2 + CV_{\pi_1}^2 m^2 - 2CV_{\pi_0}CV_{\pi_1}\rho_{\pi_0,\pi_1} m + (m-1)^2$, and $Y^* = \frac{\left(\rho_{\pi_1,y^*}\sigma_{\pi_1} - \rho_{\pi_0,y^*}\sigma_{\pi_0}\right)\sigma_{y^*} + \bar{y}^*\left(\bar{\pi}_1 - \bar{\pi}_0\right)}{\bar{\pi}_0^2}$.

Except for $Q^*$, which was discussed above, there are no natural economic interpretations of these terms, though both $S^*$ and $T^*$ are related to the variances, covariances, and means of the two crops. For $S^*$, as the differential in returns or the correlation between the two crops increases, $S^*$ increases, tending to decrease the share in crop 1. For $T^*$, an increase in correlation tends to decrease the magnitude, making the denominator bigger and thus decreasing the share in

[60] We explain the designation of wheat and opium-poppy as "crop 0" and "crop 1," respectively, below.

crop 1, while increases in the variances of each crop or the differential in return tends to do the opposite. $Y^*$ is related to outside income, and its effect depends in large part on the correlation structure between returns and the income source.

Corner solutions are possible, especially in the case of separable production and consumption and risk neutrality.[61] Thus, the expression for $l_1^*$ is only valid if the household is growing both crops; an $l_1^*$ that lies outside the interval (0,1) implies monocropping. Hence, an $l_1^* < 0$ implies a zero crop 1 share and $l_1^* > 0$ implies a crop 1 share of 100 percent.

## Comparative Statics of the Model

We are interested in the signs of $\frac{\partial l_1^*}{\partial \phi}$, where $\phi$ is any model parameter. In the analysis that follows, we assume that households are risk averse $(\Psi < 0)$, that there are two crops with the mean return of crop 1 greater than mean return of crop 0 $(m > 1)$, that crop 0 is a food staple that enters the consumption bundle as the first good, that crop 1 is a cash crop and thus does not enter the household's consumption bundle, that the correlation in returns between crops is positive $\left(\rho_{\pi_0 \pi_1} > 0\right)$, and that the correlation between returns and consumption prices is positive for crop 0 $\left(\rho_{p_0 \pi_0} > 0\right)$ but the correlation between food price and cash crop returns is zero $\left(\rho_{p_0 \pi_1} = 0\right)$.

Crop 0 can be interpreted as wheat in the model, and is both a production and consumption good. Returns from wheat are denoted $\pi_0$ and the consumption price of wheat is $p_0$. Crop 1 is the opium poppy cash crop with returns $\pi_1$, which does not enter the consumption bundle (i.e., its budget share is zero, or equivalently $p_1 = 0$).

Given the maintained assumptions, $P^* < 0$, $T^* > 0$, $(m-1) > 0$, $\Psi < 0$. It can be easily shown that $-P^* + \Psi S^* > 0$, so that $S^* > 0$ for an interior solution that involves production of both crops. The sign of $Q^*$ depends on the sign of $\Psi + \eta$, the latter of which is the income elasticity of wheat and no longer carries a subscript due to the fact that there is only one crop that is both produced and consumed. If wheat is a necessity, then $0 < \eta < 1$. Thus, $Q^* \geq 0$ applies for households with relative risk aversion coefficients greater than 1 when market and producer prices are positively correlated.

To provide some additional intuition, assume an interior solution in which both crops are cultivated and production and consumption are separable ($Q^* = 0$). In this case, the denominator

[61] If production and consumption are separable and the household is sufficiently tolerant of risk, land allocation decisions will be corner solutions associated with the crop with greatest mean returns.

of the expression for opium poppy share must be positive. Looking at the terms that comprise the denominator, an interior solution is most likely when, adjusted for preferences over risk, the mean and variances of the crops are not "too different"; that is to say, neither dominates the other both in terms of expected returns and variability of those returns. Although this condition depends on the parameters, it makes intuitive sense that a risk averse producer would specialize if, for example, the differential in mean in favor of opium poppy was great enough to offset the associated risk.

In the case where production and consumption are not separable and $-\Psi > \eta$ (likely for very small to small sized landholders who are sufficiently risk averse)[62], adding the term $-Q^* < 0$ to the numerator and $Q^* > 0$ to the denominator will tend to decrease the share in opium poppy, all else equal. This implies that as the consumption share of wheat increases and relative risk aversion increases (which is generally associated with a decrease in wealth), all else equal, farmers will plant less opium poppy. Furthermore, the greater the correlation between market prices and returns from wheat, or the greater the variance in the market price of wheat, the less opium poppy will be planted. This is consistent with observations around the developing world that such conditions result in "oversupply" of the jointly produced and consumed crop, relative to maximization of the expected utility of profit (Barrett, 1993). However, $Q^*$ is decreasing in the income elasticity of wheat, so an increase in this parameter will tend to increase share in opium poppy as a result of the consumption linkage.

It should be noted that the overall relationship determining the effect of non-separability is critically related to risk preferences, income elasticities of wheat, budget shares, and the correlation between wheat returns and wheat prices. Specifically, if $-\Psi < \eta$, budget shares are positive, and correlations between returns and prices are positive, as might be the case for less risk-averse or wealthier households, the signs in the argument above are reversed and more opium poppy will be planted. Successful development efforts that tend to increase overall wealth levels, correct market failures, and lower transaction costs will tend to decouple production and consumption. This is likely to induce more opium poppy production, especially if the correlation between market wheat prices and wheat returns remains intact.

In the analysis that follows, we assume that both the numerator and denominator of the optimal land use share in opium poppy are positive, and thus if $\Delta\left[-\left(P^* + Q^*\right) + \Psi S^*\right] > \Delta\left[\left(P^* + Q^*\right)(m-1) - \Psi T^*\right]$, opium poppy land share increases.

[62] The reader is reminded that for a necessity, the income elasticity will be positive and less than one, and that the (negative) of the coefficient of relative risk aversion likely lies between 0 and 5 in most cases.

### *Mean Crop Returns* $\bar{\pi}_i$

Mean crop returns $\bar{\pi}_i$ appear in every term of the optimal land allocation expression. An increase in the mean returns of opium poppy $\bar{\pi}_1$ decreases $P^*$, increases $S^*$, and increases $T^*$. It also increases *m,* but does not affect $Q^*$. This has the effect of unambiguously increasing the share of opium poppy planted through increases in the numerator and decreases in the denominator, as expected with an increase in profitability.

The comparative static with respect to expected wheat returns, $\bar{\pi}_0$, is of opposite sign.[63] Note, however, that this calculation assumes that the consumer price of wheat $p_0$ does not change; that is, only the "production-side" incentives change.

### *Variation in Crop Returns* $\sigma_i$

The standard deviation of opium poppy returns $\sigma_{\pi_1}$ appears in the terms $S^*$ and $T^*$, increasing the former as $\bar{\pi}_0^2 \frac{\partial S^*}{\partial \sigma_{\pi_1}} = \sigma_{\pi_0}\rho_{\pi_0\pi_1} > 0,$ and thus decreasing the numerator. In the denominator, $\bar{\pi}_0^2 \frac{\partial T^*}{\partial \sigma_{\pi_1}} = 2(\sigma_{\pi_1} - \sigma_{\pi_0}\rho_{\pi_0\pi_1}),$ which is positive so long as $\sigma_1 > \sigma_0\rho_{\pi_0\pi_1}$. Because this is also the condition for the change in numerator being smaller than the change in the denominator ( $\frac{\partial S^*}{\partial \sigma_{\pi_1}} < \frac{\partial T^*}{\partial \sigma_{\pi_1}}$), an increase in the variance of opium poppy returns will unambiguously decrease the share of opium poppy for an interior solution. This conforms to intuition, as risk-averse households will always favor a less-risky gamble with the same mean over one with higher variance.

The standard deviation of wheat, $\sigma_{\pi_0}$, affects $S^*$, $T^*$, and $Q^*$, the latter due to its likely presence in the optimal consumption bundle. The effect on $Q^*$ is different than that for opium poppy, which is not a consumption good. Similar to the cash crop, $\frac{\partial T^*}{\partial \sigma_{\pi_0}} = 2(\sigma_{\pi_0} - \sigma_{\pi_1}\rho_{\pi_0\pi_1}),$ which is positive so long as $\sigma_{\pi_0} > \sigma_{\pi_1}\rho_{\pi_1\pi_2}$, and $\frac{\partial S^*}{\partial \sigma_{\pi_0}} = \sigma_{\pi_1}\rho_{\pi_1\pi_2} - 2\sigma_{\pi_1} < 0.$ These two effects combine to create an incentive to plant more opium poppy, as it becomes more attractive relative to the higher-variance wheat option given preferences over risk.

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[63] As the choice of numeraire is arbitrary, one could redefine crop 1 to be wheat and the result would immediately follow.

However, there is an opposite effect that works through the consumption term $Q^*$. If $(\Psi+\eta)<0$, the likely case for smaller, risk-averse landowners, than an increase in the variance of wheat will increase $Q^*$, which tends to *decrease* the share of opium poppy and *increase* the share of wheat. The reason for this counterintuitive result is the coupling of production and consumption decisions; that is, the positive correlation between wheat returns and wheat consumption prices. More specifically, the incentives associated with consumption tend to push the household toward more wheat cultivation precisely because the increase in variation in wheat returns is likely to be mirrored in the variation of wheat consumption prices due to the positive correlation. As such, the household responds to the increased consumption risk by planting more wheat.

This reversal in sign is more likely when shares of wheat in consumption are high, i.e., when the household is less wealthy. Households with a greater tolerance for risk, a lower income elasticity for wheat, and a smaller share of wheat in total consumption are more likely to increase opium poppy cultivation.

### *Correlation in Crop Returns* $\rho_{\pi_0\pi_1}$

The correlation in returns between crops appears in terms $S^*$ and $T^*$, with an increase in the correlation coefficient increasing $S^*$ and decreasing $T^*$. This decreases the numerator, increases the denominator, and unambiguously causes the share in opium poppy to fall.

This is due entirely to production decisions and portfolio balance in crop choice, in which production decisions are made to balance the risk-return trade-off for risk-averse households. As the correlation in returns increases between the crops, the expected variance in income increases. An optimal response against the increased variance is greater diversification, which in this case is movement toward the lower-return wheat crop.

### *Relative Risk Aversion* $\Psi$ [64]

The negative of the coefficient of relative risk aversion, $\Psi=\frac{\bar{V}_{yy}\bar{y}}{\bar{V}_y}\leq 0$, is related to the curvature of the utility function, with higher absolute values indicating more risk aversion and a greater risk premium. The coefficient of relative risk aversion appears in the expression for optimal opium poppy share explicitly and in the terms $P^*$ and $Q^*$. As $\Psi$ increases, a household becomes less risk averse. The effect of this change is to decrease $Q^*$ and $P^*$, increase the numerator by $S^*$, and decrease the denominator by $T^*$. These latter three effects tend to increase

[64] The comparative statics for relative risk aversion, the consumption shares, and income elasticity were presented explicitly in Fafchamps (1992) and did not require additional manipulation.

the share in opium poppy, and are directly related to a shift toward the higher mean-return crop as risk becomes relatively less important. However, the consumption effect due to $Q^*$ tends to work in the opposite direction.

Fafchamps (1992) explained that this effect occurs because growing wheat is a form of insurance against the consumption price risk of wheat, which is positively co-varying with returns and, thus, inducing the non-separability. Which effect is dominant depends on the parameterization of the model. A result in which an increase in risk aversion leads to planting more opium poppy would tend to occur when the correlation between returns is high, the difference in expected returns is small, the correlation between returns and market prices is high, the income elasticity of wheat is high, and the share of total consumption in wheat is high.

Unlike the other parameters of the model, which might change with market, environmental, or policy conditions, the coefficient of relative risk aversion is likely to be relatively stable for an individual household, but can vary significantly across households. In general, the literature seems to suggest that households tend to be risk averse, and there is some evidence (though not especially strong) that wealthier households (i.e., those with more land) are less risk averse (Binswanger, 1980). As such, the degree of risk aversion is most useful as a means to segment different classes of households, rather than a changing variable from season to season. We return to this point when discussing the opium poppy cultivation shares below.

### *Consumption Share of Wheat* $s_0$

The consumption share of wheat $s_0$ appears in the term $Q^*$. Its effect on the share of opium poppy planted depends on the risk preferences of the household and income elasticity of wheat. If $-\Psi > \eta$, which is likely the case for smaller, risk-averse households, then $\frac{\partial Q^*}{\partial s_0} > 0$. The increase in this term decreases the numerator and increases the denominator, which in turn decreases the share of land planted to opium poppy. All else equal, households that have a greater share of income in wheat (or more generally, food) and are "sufficiently" more risk averse are less likely to plant opium poppy than those (likely wealthier) households with a greater share of consumption in other goods.[65]

The reasoning is that the non-separability in wheat creates an incentive to overproduce wheat relative to the maximization of the utility of income. Essentially, with a large share of wheat in the consumption bundle, the "consumption side" of the incentive story, in which one would want to grow more wheat to insure against price risk as a consumer of wheat, dominates the "production side" of the incentives story, in which one would want to grow more opium poppy as a producer of opium poppy, given its greater returns (Barrett, 1993).

[65] We note the possibility of "tipping points" with respect to landholdings and other parameters below.

If, on the other hand, $= -\Psi < \eta,$ which is more likely the case for households with more wealth, then $\frac{\partial Q^*}{\partial s_0} < 0,$ and the share of opium poppy in cultivation increases with an increase in the consumption share of wheat. In this case, the household is sufficiently tolerant of risk to shift to the cash crop in order to increase income for additional wheat purchases and other good purchases. In other words, the magnitude of the relative risk aversion coefficient is such that the production-side incentives to generate more income dominate the necessity to protect against consumption-side risk.

### *Income Elasticity of Wheat* $\eta$

The income elasticity of wheat $\eta$ appears in $Q^*$, as it is a consumption parameter. An increase in the income elasticity of wheat decreases $Q^*$ for non-separable production and consumption, thereby increasing the numerator, decreasing the denominator, and increasing the share of land allocated to opium poppy. Thus, a household whose consumption of wheat (or more generally, food) is more responsive to changes in income will tend to grow more opium poppy as a consequence of the positive correlation between wheat returns and wheat market prices. It is expected that farmers closer to subsistence levels of wealth would tend to have higher income elasticities of wheat.

The reasoning behind this result is the unintuitive fact that consumers prefer price instability to pricing at the mean given the larger surplus associated with lower prices (Fafchamps, 1992; Waugh, 1944).[66] Following Waugh's (1944) argument, for any two prices associated with a given good, the consumer surplus associated with moving from the mean of the two prices to the lower price will be greater than the same movement to the higher price. This implies that consumers prefer the variation, as the larger surplus in the first case ensures higher welfare.

In terms of the indirect utility function, it turns out that a preference for price variability depends on $V_{p_k p_k}$, and that an increase in the income elasticity associated with a good tends to favor price variability (Turnovsky, Shalit, and Schmitz, 1980). Because of this preference, a household with a greater income elasticity for wheat will tend to want to use less insurance against income risk, which implies more specialization toward the crop with the greater mean, which in this case is opium poppy (Fafchamps, 1992).

[66] Waugh (1944) shows this result holds so long as demand is downward sloping.

### *Mean Consumption Price of Wheat* $\bar{p}_0$ [67]

The mean consumption price of wheat $\bar{p}_0$ appears in $Q^*$, and thus the effect of a change in this price depends on the sign of $(\Psi+\eta)$. If relative risk aversion is greater than the income elasticity of wheat, then $\frac{\partial Q^*}{\partial \bar{p}_0}<0$, resulting in an increasing share of opium poppy planted. The opposite is true if risk aversion is smaller than the income elasticity.

This is again due to the positive correlation between wheat returns and market prices for wheat, and the interplay between cropping as an income-generating activity and consumption decisions. For smaller, poorer landowners, the increase in prices requires greater income to maintain consumption shares, thus creating an incentive to shift toward opium poppy. For less risk averse households, the price increase induces a substitution toward self-supply, thus increasing wheat production.[68]

### *Variation in Consumption Price of Wheat* $\sigma_{p_0}$

The standard deviation of the consumption price of wheat $\sigma_{p_0}$ appears in $Q^*$, and as a consumption-side parameter, the effect of a change in the variance of the consumption price depends on the sign of $(\Psi+\eta)$. If $-\Psi>\eta$, then an increase in consumption price variability will positively affect $Q^*$ and thus decrease the share of land planted to opium poppy. That is, a more risk-averse household will respond to greater consumer price variation in wheat by trying to protect against consumption-side risk by growing more food and less of the cash crop. The opposite is true of those households more tolerant to risk. Just as with returns, the household responds to changes in consumption-side mean and variance prices in opposite ways. However, in the case of non-separability, the relationship between income risk and consumption risk when a crop is both grown and consumed allows for households with differing risk preferences to respond in different ways to changes in consumption prices.

### *Correlation Between Consumption Price of Wheat and Wheat Returns* $\rho_{\pi_0 p_0}$

The correlation between wheat consumption prices and wheat returns $\rho_{\pi_0 p_0}$ appears in the term $Q^*$, and like the other comparative statics related to consumption-side considerations, depends on the sign of $(\Psi+\eta)$. If this term is negative, then the effect of an increase in

[67] It is assumed that consumption shares remain unchanged as consumption prices of wheat change.

[68] Notice that these signs are opposite to those dealing with variance as a result of diversification and insurance effects—the consequences of a mean price increase with no change in variance is a pure income-type effect.

correlation on $Q^*$ is positive, and the share of opium poppy in cultivation decreases; otherwise, it increases. The reasoning is that the increase in correlation disproportionally affects the consumption side of decisionmaking for the household if sufficiently risk averse, leading to an incentive to plant more wheat as a hedge against consumption price risk. For less risk-averse households, the incentive is the opposite in an attempt to generate more income. If the correlation is zero, even with a positive consumption share of wheat, then $Q^* = 0$ and production and consumption are separable.

### *Mean Off-Farm Income* $\bar{y}^*$

The effect of mean off-farm income $\bar{y}^*$ depends on the sign of $-\left(P^* + Q^*\right)$, the correlations of outside income with crop returns, and the expected profitability of the two crops. In the case of separable consumption and production ($Q^* = 0$) and $\rho_{\pi_1, y^*}\sigma_{\pi_1} = \rho_{\pi_0, y^*}\sigma_{\pi_0} = 0$, positive outside income will tend to increase the share of opium poppy cultivated on own land, given the greater returns on opium poppy. In a non-separable case where $\left(\Psi + \eta_k\right) < 0, Q^* > 0$, relative to the previous case, there is an incentive to grow less opium poppy (with the reverse true for more risk-tolerant producers), and if the correlation-weighted standard error on opium poppy ($\rho_{\pi_1, y^*}\sigma_{\pi_1}$) is greater than the similar quantity for wheat, then there is an additional disincentive so long as $\Psi < 0$. Thus, the impact of additional outside income is ambiguous, and depends on the sign of $\left(\Psi + \eta_k\right)$, the share of wheat in the consumption bundle, and the correlations between outside income and cropping returns.[69]

Thus, the interconnectedness of consumption and production decisions has different effects on the crop choice for different types of households when there is positive correlation between consumption prices and returns of a crop. For smaller, more risk-averse households, it is likely that non-separability results in a lower share of the cash crop (opium poppy) than would be predicted by pure production models, while non-separability tends to increase the share of the cash crop for those producers who are relatively risk-tolerant relative to their income elasticity.

The comparative static results are summarized in Table C.1.

[69] We delay discussion of the comparative statics of the correlations of outside income until discussion of the cultivation factors.

**Table C.1. Comparative Statics of Opium Poppy Crop Share with Respect to Model Parameters**

| Parameter | Symbol | Sign | Condition |
|---|---|---|---|
| Mean returns to opium poppy | $\bar{\pi}_1$ | + | |
| Mean returns to wheat | $\bar{\pi}_0$ | - | |
| Variance in returns to opium poppy | $\sigma_1$ | - | |
| Variance in returns to wheat | $\sigma_0$ | + or - | More likely to be negative for poor, risk-averse households with large wheat consumption share |
| Correlation of crop returns | $\rho_{\pi_0,\pi_1}$ | - | |
| Relative Risk Aversion | $\Psi$ | + or - | More likely to be negative for highly correlated returns and market prices, small differences in mean returns, high income elasticity of wheat, and large wheat consumption shares |
| Consumption share of wheat | $s_0$ | + or - | Negative when $-\Psi > \eta$ |
| Mean consumption price of wheat | $\bar{p}_0$ | + or - | Negative when $-\Psi < \eta$ |
| Income elasticity of wheat | $\eta$ | + | |
| Variance in market price of wheat | $\sigma_{p_0}$ | + or - | Negative when $-\Psi > \eta$ |
| Correlation of market price of wheat and returns to wheat | $\rho_{\pi_0,p_0}$ | + or - | Negative when $-\Psi > \eta$ |
| Mean off-farm income | $\bar{y}^*$ | + or - | Depends on model parameterization, but positive when consumption and production are separable and $-\Psi < \eta$ |

NOTES: Comparative static signs for consumption parameters are valid if $Q^*$ does not equal zero.

We now use these comparative static results to explore the effects of changing the identified factors related to opium poppy cultivation decisions.

## Factors Related to Land Allocation Decisions

In this subsection, we use the comparative static results and model alterations to explore how changes in the identified factors translate to the opium poppy cultivation decision. In some cases, the factors may relate only to a change in one model parameter (e.g., output prices, which directly affect mean returns). In other cases, the factors may consist of multiple parameters. In these cases, the effects of a factor change are often ambiguous.

Below, we briefly discuss the use of the model to qualitatively discuss how factor changes impact cropping decisions. Table C.3 provides a summary of the effects. Additional factors may be modeled using combinations of the comparative static results in Table C.1.

*Landholding*

As in Fafchamps (1992), the effects of changes in landholding are proxied through use of model parameters.[70] In particular, the following can be used to proxy changes in the amount of land owned by a household:

- Changes in consumption shares: a poorer household, as proxied by landholdings, is likely to have a larger share of total consumption in food than a wealthier household
- Changes in risk preferences: a poorer household is likely to be more risk averse than a wealthier household
- Changes in income elasticities: a poorer household likely has a larger income elasticity for most food crops than a wealthier household.

As discussed above, it seems likely that those households with less land would be characterized by $-\Psi > \eta$, with $\eta < 1$ but (relatively) large, with large consumption shares. If representing pure production decisions (say in the case of profit-maximizing households with considerable land), consumption shares can be set equal to zero, thus resulting in $Q^* = 0$.

Table C.2 defines three types of landholding households, namely, subsistence or very small, small, and medium to large, on the basis of these parameters.

- We characterize subsistence or very small households as highly of risk averse, with high consumption shares of wheat and a high income elasticity of wheat. These households are assumed to be very poor and, consequently, to hold very small amounts of land.[71]
- We characterize small households as somewhat risk averse, with a smaller share of consumption in wheat than subsistence or very small households and modest responsiveness of wheat demand to income. However, consumption and production decisions are still linked through the positive wheat share in consumption and the positive correlation between wheat returns and wheat consumption prices.
- We characterize medium to large households (interpreted as relatively wealthy) as progressively less risk averse and operating under conditions of separable production and consumption (i.e., they maximize the expected utility of profit). We set the share of (local) wheat in total consumption equal to zero to operationalize.

In the subsections that follow, we discuss how a change in each cultivation factor affects each of the three household types. While this is convenient for exposition given the structure of the model, it should be noted that there is a continuum of household types along these three dimensions, and various "tipping points" exist where the effect of a change of a cultivation factor on the share of poppy may change sign. Furthermore, although we argue that landholdings are

[70] Recall that the model assumes constant returns to scale, so the pure scale of landholding will not impact cropping choices and must be addressed through proxies. In addition, to maintain a small degree of tractability, the model assumes that the production technology for each crop is Leontief, i.e., has fixed input shares.

[71] We note that subsistence households might plant a greater share of poppy than small households. See the discussion on the comparative statics of relative risk aversion.

generally correlated with the three behavioral parameters in Table C.2, there is likely substantial heterogeneity within each group. As such, generalizations should be made with caution.

**Table C.2. Farmer Typologies**

| Household Type in Relation to Landholding | Risk Aversion ($\Psi$) | Consumption Share of Wheat ($s_0$) | Income Elasticity ($\eta$) |
|---|---|---|---|
| Very small (Subsistence) | Very risk averse ($\Psi << -1$) | High ($0 < s_0 < 1$, near 1) | High ($0 < \eta \leq 1$, near 1) |
| Small | Moderately risk averse ($\Psi < -1$) | Moderate ($0 < s_0 < 1$, near 0.5, less than Subsistence type) | Moderate ($0 < \eta < 1$, near 0.5, less than Subsistence type) |
| Medium to large | Slightly risk averse ($-1 < \Psi < 0$) | $s_0 = 0$, separable consumption and production | n/a, separable consumption and production |

SOURCE: RAND analysis.
NOTES: The notation "<<" means "much less than." Wheat is assumed to be a normal necessity good. Subsistence and large household types are conceptualized as extreme cases—or "bookends"—in the model. Descriptions of parameter values (e.g., "very", "high", "moderate", slightly") are defined relative to the other household types, with values chosen to aid interpretation and illustrate potential differences in the effects of a change in cultivation factors (i.e., to span "tipping points," points below which the household does not have enough land to meet its food consumption needs). Risk neutral producers with separable consumption and production would allocate 100 percent of their land to the higher mean return crop and, as such, their crop shares would switch between 0 and 1 on the basis of relative mean returns when factors change. All else equal, a very risk averse household with high consumption share and high income elasticity could plant a greater share of opium poppy than a moderately risk averse household. See comparative statics with respect to relative risk aversion for more details.

One additional note about landholdings merits consideration at this point. The household model assumes that observed returns on opium poppy and wheat are the proper "decision prices" per unit land used by the household to make their copping decisions. Put another way, there are no additional constraints in the maximization problem that suggest, for example, that incomes that fall below a certain subsistence level could result in illness or starvation, and we assume that utility is strictly increasing in income.

In the case of binding constraints, however, this may not be the case, and the "decision prices" related to consumption might actually be the shadow prices associated with the constraint. If applicable, say in the case of subsistence constraints where a household did not own enough land to feed the household (e.g., subsistence farm types), then a wedge would be driven between the observable returns and shadow returns, and the differential in returns on the margin would widen. Since opium poppy returns are greater than wheat returns, this incents cash crop production, as this would be the only way for the household to survive.

Specifically, suppose there was some minimum income level necessary to ensure survival, denoted $y_{\min} > 0$. Rewriting the optimization problem to incorporate this constraint yields:

$$\max_{L_i} \ \mathrm{E}\left[V(y,\mathbf{p})\right]$$
$$s.t. \ \ y = \sum_i \pi_i L_i + y^*$$
$$y \geq y_{\min}$$
$$\sum_i L_i = \bar{L},$$

with first-order conditions of the form $E\left[V_y \pi_i\right] + \lambda \pi_i = 0 \ \forall i,$ where $\lambda$ is the Lagrange multiplier associated with the subsistence constraint. Note that the term associated with the multiplier essentially distorts the perceived crop returns as a result of the subsistence constraint. If this constraint is binding, then $E\left[V_y \pi_i\right] < 0,$ and with $\pi_1 > \pi_0$, this implies that the expected marginal utility of opium poppy $E\left[V_y \pi_1\right]$ should be greater than the expected marginal utility of wheat $E\left[V_y \pi_0\right]$.[72] Compared to the no-constraint case, and because indirect utility is increasing in income, this implies a shift toward the higher mean crop, which increases the share of opium poppy in cultivation.[73] Thus, if subsistence constraints are binding, the household will choose to plant more opium poppy.[74]

### *Household Size*

There is no explicit conceptualization of household size in the theoretical model. However, like landholdings, differentials in the size of a household may be represented by different parameter combinations, especially in terms of the consumption parameters that appear in $Q^*$ and perhaps the amount of off-own-farm income $y^*$ earned by the household and the returns from cultivation of each crop.

Unlike the parameterization describing landholdings, however, the correlation between household size and each key parameter is not particularly clear, and may be subject to considerable differences across households of the same size. This is because individuals in a household can provide labor (leading to "production-side" concerns) and potentially provide off-farm income, as well as consume various goods and services. On the production side, the value of each individual for the generation of income is likely specific to that person, who is endowed with particular skills and opportunities, while consumption preferences are also individual-specific. Given the conflicting incentives related to production of each crop and the consumption of wheat, the effect of a change in household size on the cultivation of opium poppy is

[72] The ratio of these two terms should equal the ratio of returns, *m*.

[73] The only way to increase expected income given the model structure is to cultivate more of the higher-mean crop.

[74] Other constraints (e.g., constraints on family labor, etc…) can be modeled in a similar manner.

ambiguous. However, if one were willing to make explicit assumptions about the relationship between household size and model parameters, the effects in Table C.1 could be used to describe the effects.

### *Environmental (Yield) Risk*

Environmental risk is conceptualized in the model through changes in the standard deviation of crop returns (namely, $\sigma_{\pi_0}$ and $\sigma_{\pi_1}$). This interpretation assumes that mean returns do not change, but the dispersion around the mean increases. Increases in the variance of returns were discussed in the previous section, with comparative statics given in Table C.1. Briefly, an increase in the environmental risk of opium poppy unambiguously decreases the share of opium poppy, as it does not enter the demand-side of the model and households are assumed to be risk averse. However, due to non-separability, an increase in the variance of wheat returns may increase or decrease the share of land dedicated to opium poppy, with subsistence households the most likely to decrease the share, and large households most likely to increase.

Heterogeneity in farmer's response to environmental risk can be handled using existing model parameters. For example, landowners with access to irrigation may face higher mean returns and lower variances than other farmers, and cropping decisions will reflect these differences. In cases where the comparative statics are of indeterminate sign, it is possible that these changes will affect the qualitative direction of the effect.

### *Eradication Risk*

Eradication is conceptualized as an additional probability that the entire opium poppy crop for a household will not generate income.[75] We incorporate eradication risk through a change in both the mean and the variance of opium poppy returns in the household model. We start by developing the distribution of opium poppy returns when incorporating eradication risk. We then discuss the effects of a change in that risk on opium poppy production.

#### Distribution of Opium Poppy Returns with Eradication Risk

If the environmental risk remains unchanged, and there is a given probability $0 \leq \gamma \leq 1$ each growing season that eradication will result in zero returns per hectare for opium poppy growers, then the overall distribution of opium poppy returns can be modeled with a "mixture distribution."[76] We derive the first two moments, i.e., the mean and variance, of this distribution below.

Redefine $\bar{\pi}_{env}$ and $\sigma^2_{env}$ to be the mean and variance of returns to opium poppy under environmental risk only. Under eradication risk, the new mean of the opium poppy return

[75] We note that this is a simplification in that a household could lose only part of its crop to eradication.

[76] A mixture distribution is a convex combination of probability distributions.

distribution will be $E[\pi_1] = (1-\gamma)\bar{\pi}_{env}$, since the expected return under eradication equals zero. Clearly, an increase in eradication risk will reduce expected returns to opium poppy.

The variance of $\pi_1$ under both eradication risk and environmental risk is:

$$\text{var}[\pi_1] = E[\pi_1^2] - E[\pi_1]^2 = E[\text{var}(\pi_1 \mid \theta)] + \text{var}[E(\pi_1 \mid \theta)].$$

where $\theta$ is the random variable denoting the state of the world (eradicated or not). The first term in this expression is just a weighted average of variances in each state and equals $(1-\gamma)\sigma_{env}^2$, as the variance of the eradication state is zero. The second term is $\text{var}[E(\pi_1 \mid \theta)] = E[E(\pi_1 \mid \theta)^2] - E[E(\pi_1 \mid \theta)]^2 = \gamma(1-\gamma)\bar{\pi}_{env}^2$. Thus, under the mixture distribution, the overall variance of opium poppy returns is $(1-\gamma)(\sigma_{env}^2 + \gamma\bar{\pi}_{env}^2)$.

Given the new mean and variance of opium poppy returns, it is of interest for comparative static purposes to investigate how a change in eradication risk $\gamma$ affects each. Letting $\bar{\pi}_1(\gamma)$ and $\sigma_{\pi_1}^2(\gamma)$ denote these moments, we calculate

$$\frac{\partial \bar{\pi}_1(\gamma)}{\partial \gamma} = -\bar{\pi}_1 < 0$$

$$\frac{\partial \sigma_{\pi_1}^2(\gamma)}{\partial \gamma} = -(\sigma_{env}^2 + \gamma\bar{\pi}_{env}^2) + (1-\gamma)\bar{\pi}_{env}^2.$$

While the change in mean returns is clearly negative, the change in variance given an increase in eradication risk depends on the magnitudes of $\gamma$ and $\sigma_{env}^2$. If $\gamma > 0.5$, then variance will always decrease with an increase in eradication risk. Even if this condition is not met, this term might be negative if the environmental variance $\sigma_{env}^2$ of opium poppy is sufficiently large or mean returns are sufficiently large (more specifically, if $\gamma > \frac{1}{2} - \frac{\sigma_{env}}{\bar{\pi}_{env}}$). The intuition is that the eradication risk both shifts the mean and "compacts" the distribution, making tail event less likely overall.

### Effect of a Change in Eradication Risk on Opium Poppy Cultivation

Given that change in eradication risk changes decreases the mean and increases the variance of opium poppy returns, the comparative statics must incorporate changes in both parameters. In the case where a change in eradication risk decreases the mean and increases the variance of opium poppy production, Table C.1 shows that the share of cultivation in opium poppy will unambiguously decrease, as might be expected.

If, however, the change in eradication risk decreases mean returns but also decreases the variance, the effect is ambiguous in the model. It is possible that, especially for extremely risk-averse producers, the incentive to increase opium poppy production given the decrease in

variance will dominate the incentive to decrease opium poppy due to decreased mean returns. Empirical evidence neither "proves" nor "disproves" the possibility.

Although counterintuitive, the result that the share of opium poppy could increase is a complement to that of Andersson (2013), which showed that, in the presence of imperfect credit markets, an increase in eradication risk could increase the share of opium poppy planted.[77] Here, in our household model, imperfect credit is not a necessary condition.

To demonstrate the mathematical conditions under which this could occur, let $\frac{\partial \sigma_1}{\partial \gamma}$ denote the change in opium poppy return variance given a change in eradication risk. The overall effects of the mean and variance change on the numerator of the share equation is $-m + \frac{\partial \sigma_{\pi_1}}{\partial \gamma}\left( \Psi \frac{\sigma_{\pi_0}\rho_{\pi_0\pi_1}}{\bar{\pi}_0^2} \right)$, while the total effect on the denominator is $-2m(1-m) + \frac{\partial \sigma_{\pi_1}}{\partial \gamma}\left(2\Psi(\sigma_{\pi_1} - \sigma_{\pi_0}\rho_{\pi_0\pi_1}\right)$. Note that the numerator will decrease and the denominator will increase in the case of risk neutrality $(\Psi = 0)$ and when $\frac{\partial \sigma_1}{\partial \gamma} > 0,$ but this may not be the case if the effect of eradication risk on opium poppy return variance is negative, risk aversion is large, and certain other conditions hold. If this is true, the share of opium poppy will increase, somewhat counterintuitively.

### *Security Risk*

Factors other than those related to agronomics or prices can affect cropping behaviors, especially if the overall security environment is uncertain. The model can conceptualize "security risks" by considering changes in groups of parameters in the model.

Possible effects include[78]

- difficulty in obtaining inputs, including labor, which may increase input costs and decrease the net returns per hectare for those crops which use the inputs, and also may increase the variance of those returns
- changes in the per-unit means of or variances in agricultural outputs, affecting the means and variances of the returns to those outputs
- changes in the difference between producer prices and market prices due to changes in transaction costs, such as those relating to transportation, which can translate into changes in the correlation between returns and market prices.

[77] Andersson (2013) frames her analysis in terms of imperfect credit markets, but the treatment of the distribution of risk between lenders and borrowers results in random second-period prices.

[78] Although we discuss these as negatives, symmetrical positive effects can also be examined.

Changes in input costs can affect both the mean and the variance of crop returns. If the security environment degrades such that inputs are difficult to obtain, then input prices will increase and net cropping returns will decrease, all else equal. In the case of labor, this might seem to favor wheat cultivation, which is less labor intensive, but not necessarily under all circumstances and for all household types.[79] Output prices may also be affected. Functionally, due to decreases in the ability to transport (bulky) wheat to and from market as the security environment degrades, the ratio of opium poppy prices to wheat output prices is likely to increase.[80] As only relative prices matter in the model, this increase tends to increase the share of opium poppy cultivated, regardless of household type.

Variances in returns may also increase. If the variance of opium poppy returns increases, there is an unambiguous disincentive to plant opium poppy, and the share will decline. However, this might be fully or partially offset by a change in the variance of returns to wheat, especially for relatively risk-tolerant producers with a relatively small consumption share in wheat.

Finally, a degraded security environment may increase the differential between producer prices (returns) and consumer prices for wheat as market failures increase as a result of the change. This particular parametric change would only affect households with non-separable consumption and production decisions and, on that basis, would tend to be less relevant for medium to large landholders than for small and subsistence landholders.

Until this point, the relationship between consumption prices for wheat $p_0$ and returns to wheat $\pi_0$ was summarized by the correlation coefficient $\rho_{\pi_0 p_0}$, which was assumed to be positive. However, in accordance with recent development literature (see, e.g., de Janvry and Sadouolet, 2006), a more structural interpretation can be derived that explicitly models the differential in price.

Let $\pi_k = (p_k - \tau_k)x_k$, where $x_k$ are (random) yields assuming no eradication, and $\tau \geq 0$ is represents the gap between producer and consumer prices that might proxy transportation costs, political risk, etc… Assume that the relationship between $p_k$ and $x_k$ is such that $\rho_{p_k,x} < 0$; that is, yields and consumption prices are negatively correlated, as a better than average year for farmers due to (similar) environmental or other shocks leads to increased supply in the market, lowering prices. Then we can derive the correlation between returns and market prices as follows:

$$\begin{aligned}\operatorname{cov}(p_1, \pi_0) &= E[p_0\pi_0] - \bar{p}_0\bar{\pi}_0 = E\left[p_0(p_0 - \tau)x_k\right] - \bar{p}_0 E\left[(p_0 - \tau)x_0\right] \\ &\approx (2 - \tau - \bar{p}_0)\rho_{p_0,x_0}\sigma_{p_0}\sigma_{\pi_0}.\end{aligned}$$

[79] For a more detailed discussion of the implications of changes in the costs of labor and other inputs, see the discussion of "agricultural input and technology," below.

[80] This can be conceptualized as an increase in the transaction costs of buying or selling wheat. For a more detailed discussion of such transactions costs, see the discussion of "remoteness," below.

Unless the gap and prices are very low, the correlation will be the opposite sign of $\rho_{p_k,x_k}$ (i.e., the correlation between prices and returns is positive), and an increase in the divergence between producer and market prices will increase the covariance of consumer prices and farm returns. Similarly, the impact of a change in the differential term $\tau$ on the variance of wheat returns shows that the variance in returns tends to decrease as the gap increases, as the lowering of the price at each possible level tends to compact the distribution.

Mapping these to the comparative statics in Table C.1, there are three major effects that occur when the differential in consumer and producer prices increase. First, the mean effect is $\frac{\partial \bar{\pi}_0}{\partial \tau} = -\bar{x}_0 < 0,$ and thus the reduction in the overall mean of wheat production tends to increase the share in opium poppy. Second, an increase in the price gap will decrease the variance in wheat returns, thus providing an incentive to plant more wheat for all but poorer, very risk-averse households (such as in the subsistence category). This follows directly from the analysis of the comparative statics with respect to $\sigma_{\pi_0}$ in the previous subsection. Finally, the increase in correlation between wheat consumption prices and wheat returns can result in positive or negative effects on the share of opium poppy grown, with the effect more likely to incent opium poppy production for the large household typology.

In sum, the effects of a degradation of the security environment on the share of opium poppy grown by an individual household are ambiguous, and quite sensitive to the assumptions about the specific market effects of the disruption, their relative magnitudes, and the type of household under consideration.

### *Remoteness*

Remoteness is related to the notion that in developing countries, for many commodities which can be both produced and consumed, "their sales price is a fraction of the purchase price" (de Janvry, Fafchamps, and Sadoulet, 1991). Explanations for this phenomenon include transportation costs, mark-ups by merchants, search costs, risk associated with uncertain prices, other household-specific transaction costs, and negative correlations between yields and prices (de Janvry, Fafchamps, and Sadoulet, 1991). Remoteness will typically increase transportation and search costs, at the very least. The mechanism by which this enters the model is through the correlation between returns and consumption prices, which makes consumption and production essentially non-separable.

In Afghanistan, the willingness of traders to collect opium at the farm gate, even under adverse conditions, essentially implies that while remoteness will affect the profitability of opium poppy, traders and farmers will share the burden of the costs of transit.[81] However, this

[81] The relative distribution of cost would depend on the market power of the trader and the farmer. We might expect a trader to exert more power than a farmer, but not to have absolute control over the transaction. Only under very limited circumstances would the trader pass on the entire cost to the farmer.

might not be the case for wheat, for which the supply of traders could be much more limited, thus implying that the burden of transit would fall largely, if not entirely, to the farmer.[82] Even if opium poppy and wheat farmers were to bear the cost of remoteness identically across the two commodities, the relative bulkiness of wheat, coupled with its somewhat greater perishability and susceptibility to infestation, would tend to heighten the relative transaction costs. Thus, an increase in remoteness will tend to widen the gap between consumer and producer prices for wheat to a greater extent than for opium poppy.[83]

On that basis, as remoteness—and the effective gap between producer and consumer prices—increases, we would anticipate a decrease in the returns to wheat, a decrease in the variance in wheat returns, and an increase the correlation between wheat returns and the consumer price of wheat. It seems likely that the mean effect would tend to dominate for larger households, and as relative profitability of wheat declines, the share in opium poppy should increase. For other household types, an increase in the gap may increase or decrease the share in opium poppy, depending on the relative magnitudes of the effect of lower mean wheat returns (tending to increase opium poppy share), lower variance of wheat returns (tending to decrease opium poppy share unless the farm is of the subsistence type), and higher correlation between consumer prices and wheat returns (tending to increase opium poppy share for the more risk-tolerant, and decrease it otherwise).

### *Landholding Arrangement*

As discussed in Chapter 2, some of the most common land tenure arrangements in Afghanistan involve landowners serving as owner-operators, which the household model was originally intended to describe (Fafchamps, 1992), and landowners who "let" at least some of their land to sharecroppers. In our framing of sharecropping arrangements, sharecroppers provide their labor to landowners in exchange for a pre-specified share of the eventual harvest,[84] but have little or no control over the cropping decision. In effect, this "land tenure arrangement" might be more appropriately termed a "labor arrangement."

This conceptualization suggests a substantial departure from the specification found in Andersson (2013), which gives such "tenants" complete control over the cropping decision. The suggested departure would, however, be consistent with the notion that those who engage sharecroppers are likely to have greater-than-subsistence landholdings; are likely to maximize

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[82] Kuhn (2010, pp. 6-7) reports farm gate prices for several commodities, including wheat, thus suggesting the availability of farm gate collection; however, it is our understanding that farm gate traders are in relatively ample supply vis-à-vis opium, but not for other commodities.

[83] This discussion extrapolates away from additional incentive for planting opium poppy that may be present at the extensive margin. For example, there may be self-selection of cash-crop opium poppy production into remote areas where land is reasonably available and eradication is low, such as in the shift to the *dasht*. These dynamics are not captured by the model presented here.

[84] Sharecroppers might also obtain room and board and pay a proportional share of some in-kind taxes.

the utility of profit, implying separable consumption and production decisions; have a relatively low share of consumption in food overall, and have a relatively low income elasticity of wheat. Coupled with an almost perfectly elastic supply of individuals willing to serve as sharecroppers, the greater returns to opium poppy would ensure that such a landholding household would favor opium poppy cultivation within the sharecropping contract.

Another way to look at the sharecropping arrangement is to conceptualize it as a means by which the "landlord" can earn income from land without applying family labor, which may be scarce relative to landholdings, particularly in the case of a household with large landholdings and a moderate household size.[85] As such, the sharecropped land is not part of "on-farm" income in the sense that it is a capital good earning a return on the basis of non-family labor. We can thus model the sharecropping arrangement as an increase in expected "off-farm" income $\overline{y}^*$, with a positive correlation between this income and the returns to opium poppy. The correlation does not matter for a risk-neutral producer, but tends to decrease the incentive to grow opium poppy on the *rest* of the landlords' property as a diversification response to the correlation. Although not certain, it appears that the most likely outcome of sharecropping arrangements on opium poppy production is to increase the share of it.

### *Accumulated Debt*

Accumulation of debt is a dynamic process which is difficult to replicate using a simplified static model. However, proxies for the process can provide some insight. In particular, the process of borrowing and the accumulation of debt generally have the following effects:

- Borrowing allows for consumption smoothing across time periods that would otherwise not be possible (e.g., borrowing against returns in the harvest period to allow for consumption in the decision period).
- Borrowing also might reduce the variance of income, especially if the loan is used to purchase productive inputs.[86]
- In return for the increased income and consumption in the period of borrowing, the household pays back the loan plus interest in the payback period. This tends to reduce income and consumption in this period.
- In a stochastic environment, inability to repay the loan may occur due to random factors. As a result, debts may roll over to subsequent periods, with corresponding interest based on "market" conditions.[87]

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[85] We assume that a landowner would seek sharecroppers if the expected utility from doing so is greater than the next best alternative. This seems most likely when family labor is scarce relative to landholdings and when hired labor requires additional supervision, i.e., when hired and family labor are not perfect substitutes.

[86] We address this possibility in the crop budget appendix.

[87] This is not to imply perfectly function markets, but rather that the interest rate charged on such rollover depends on the environment in which lenders and borrows are operating.

Conceptually, a rational agent will attempt to set the discounted marginal utilities of any behavior equal across time periods. Thus, the household will borrow such that the expected marginal benefit of that borrowing (typically in period 1 for consumption smoothing) will equal the expected marginal opportunity cost of that borrowing (borne in period 2 through the reduction in consumption/income). Furthermore, the agent will borrow if the utility from doing so is greater than the utility from not doing so. Andersson (2013) provides a simplified two-period model of consumption smoothing and crop choice in Afghanistan.[88]

We do not attempt to model the decision to borrow, but note that for smaller landowners with a large share of food in the consumption bundle, borrowing may be a necessity for consumption smoothing (if, for example, the marginal utility associated with an income level lower than subsistence is essentially infinite). The conceptual basis for the household model presented herein is a two-period model; however, it does not deal explicitly with consumption smoothing or borrowing for productive inputs, as utility depends only on second-period income and prices.

In our specification, we implicitly assume that the landowner enters into whatever agreement will maximize household utility, with borrowing behavior implied by the level of income realized after cropping decisions. The level of debt is a result of this implicit behavior and is affected by the circumstances of the household and the randomness inherent in production. An increase in debt, all else equal, will tend to lower income through repayment, but the level of this repayment likely covaries negatively with returns—as returns increase, the level of debt decreases and income increases.

As such, we assume that the effects of debt accumulation can be proxied via the off-farm income term with a negative correlation in returns. As debt is typically denominated in opium poppy in Afghanistan, we assume $\rho_{\pi_1,y^*}\sigma_{\pi_1} < \rho_{\pi_0,y^*}\sigma_{\pi_0} < 0$. An increase in debt is assumed to be a decrease in $\bar{y}^*$, which absent correlations and with separable production, would provide an incentive to grow less opium poppy. However, when $Q^*$ is large (likely the case of high risk aversion and high wheat consumption shares) and the correlation structure is as assumed, it is entirely possible that increased debt leads to the planting of more opium poppy. See the discussion on off-farm income for additional details.

Note that this effect is solely due to the level of the income expected over the course of a growing season, or the *stock* of debt. It does not include the decisions on land use due to, for example, consumption smoothing, or other decisions related to the *flow* of debt. For example, it may be rational for a household to enter a forward-contracting arrangement in which a loan is made prior to harvest in order to gain income, and is paid back after harvest. If that loan is denominated in opium poppy (i.e., the agreement is to pay forward for a portion of opium poppy production or equivalent cash at a lower than market price), then the contract effectively would bind the agent to plant at least some portion of opium poppy (or obtain it via the market, thus

[88] Andersson, 2013, pp. 917–931.

decreasing expected income), and may also change the mean and variance of returns for opium poppy overall. In fact, if risk sharing took the form as in Andersson (2013), in which the risk of opium poppy was completely capitalized into the producer price of opium poppy, then the variance of returns to opium poppy could shrink to zero, with mean returns decreasing.[89] As these two forces create conflicting incentives toward opium poppy cultivation, the net result is parameter-specific, as in the case of eradication risk.

Regardless of this effect, however, the need to borrow (in opium poppy-denominated debt) to smooth income may be a contributor to the observation that some smaller landholders who are unable to grow enough wheat for household consumption tend to monocrop opium poppy. This result serves as a complement to the argument about subsistence constraints made in the earlier subsection. Ultimately, however, the effect of increased debt levels on cropping decisions is indeterminate using the static household model. Future research incorporating the dynamics of the debt accumulation process could help to clarify the various incentives at play.

### *Outside Income*

Outside income enters the model through the off-farm income term. The decision to allocate labor to on-farm activities, off-farm activities, or leisure is not explicitly modeled, though conceptually it is endogenous (see Barrett, 1993, for an example). This is typically modeled via leisure entering the (direct) utility function as an argument, with decisions about labor occurring in the first model period (conditional on second-period optimal consumption). As such, labor decisions affect income, which are modeled here via the land allocation decision.

In the model, additional income opportunities are proxied by an increase in $\overline{y}^*$, which may either increase or decrease the share planted to opium poppy depending on the coefficient of relative risk aversion, the share of consumption in wheat, and the correlation structure of outside income with crop returns. If the outside income source is uncorrelated with crop returns, a larger landowner with more separable production and consumption decisions and relatively low risk aversion will increase the share of opium poppy cultivated, taking advantage of the higher returns for opium poppy.

The intuitive explanation for this result is that the increase in non-crop income serves to sever the ties between production and consumption decisions, thus moving the household to act more like profit maximizers in production. Recall that given the maintained assumptions in the model, all else equal, a household has a strong incentive to grow opium poppy due to the greater returns, and it is only the links between consumption and production decisions (coupled with the risk of food scarcity) that drives any wheat production.[90] An increase in non-correlated off-farm income, which is not costly, thus provides the same incentive as a reduction in relative risk

[89] Andersson, 2013, pp. 917–931.

[90] Note that outside income is, in this model, independent of the resource base of the household.

aversion, pushing the household toward income maximization. In other words, it serves the same "insurance" purposes as does growing wheat for a non-separable household, but does so without the use of scarce resources (by assumption). Note that this argument depends on opium poppy being more profitable in expectations than wheat; in the presence of eradication, which might reverse their ranking, the opposite could be true.

For a more risk-averse individual with non-separable consumption and production decisions, this might not be the case, as the outside income opportunity could provide an opportunity to shift into more wheat to account for consumption risk.

If there is positive correlation between opium poppy returns and the outside income source, then the tendency would be to decrease the share in opium poppy (relative to the uncorrelated case) in order to diversify. The reverse is true if the outside opportunity is positively correlated with wheat returns. However, the overall sign is ambiguous.

Finally, it should be noted that the off-farm income term introduced into the model is exogenous to the cropping decision. That is, we assume that there is no opportunity cost of farming for the household in terms of obtaining this outside income. If this is not the case, then the analysis may not hold, as multiple additional parameters might change in the model. Similarly, the introduction of new cash crops or other growing options would be represented by expanding the number of crops in the model, rather than increasing outside income opportunities. The effects of such an introduction would depend on the agronomic and market characteristics of the new options, as well as the transaction costs involved in learning to grow them.

### *Agricultural Inputs and Technology*

While input decisions are not explicitly modeled, the effects of changes in input prices, technologies, and investments are implicit in the returns to agricultural activities and, perhaps, in the additional terms determining income. In considering a change in these conditions, the effect on both the means and variances of returns (and outside income), as well as any potential change in the correlations between returns/outside income and prices, should be considered. The following documents potential categories of changes and their likely effects:

- Labor: An increase in labor costs has two effects in a household model. First, on the production side, an increase in the prevailing wage rate will decrease net returns to agricultural activities, with the impacts disproportionally affecting crops with higher labor intensity. We assume this to be the case for opium poppy, and thus this will tend to decrease the share in opium poppy. On the consumption side, an increase in the wage rate will tend to increase income if there are off-farm income opportunities, assuming an upward sloping labor supply curve. As discussed earlier, the correlation structure between the outside income and returns are likely to affect the results, though the initial effect would be to increase the share in opium poppy. The results are thus ambiguous, but, on balance we might expect a diminution in poppy production relative to other options, at least among wealthier households.

- Credit: If credit is used to obtain inputs into cultivation activity, an increase in the cost of credit will likely decrease the returns to agricultural activity and increase variability of those returns (if less credit is associated with using less inputs, the use of which tend to reduce the variance of returns). The effect on opium poppy shares depends on which crop is impacted the most, and on the relative magnitudes between the changes in returns and the changes in variances, as well as separability and risk preferences. Opium poppy shares could either increase or decrease. In addition, an increase in the cost of credit will tend to decrease the quantity demanded of credit (if that demand is not perfectly inelastic) for credit flows, but likely intensify the effects of holding any given stock of debt. These effects are landowner- and parameter- specific, and may either increase or decrease the share of opium poppy cultivated.
- Other variable inputs: Changes in these costs will impact returns (and possibly the variability of returns) in accordance with the input shares of the particular crops being modeled. Any increase in the relative profitability of opium poppy or decrease in the variance of opium poppy will tend to increase the share of opium poppy planted. As discussed earlier, however, when the variance of wheat increases, there is not necessarily an incentive to plant more opium poppy, depending on the strength of the linkage between production and consumption.
- Investment: We do not explicitly model investment decisions, but investments will tend to impact both the returns to agricultural activities and their relative variances and, depending on how they are financed, may affect debt levels. [91]

### *Output Prices*

Changes in mean output prices enter the model directly through returns. Unambiguously, and all else equal, an increase in the relative profitability of opium poppy will increase the share of opium poppy planted, while an increase in the relative expected profitability of wheat will decrease this share. (See prior discussion of consumption price of wheat.)

Table C.3 summarizes this discussion.

[91] The comparative statics in Table A1 can be used to explore the implications of any particular investment scenario.

**Table C.3. Mapping Cultivation Factors to Model Parameters and Opium Poppy Share by Household Type**

| Factor | Change in Model Parameters (likely sign) | Likely Impact on Opium poppy Share by Household Type $(\Delta l_1)$ | | | Comments |
|---|---|---|---|---|---|
| | | Very small (Subsistence) | Small | Medium to large | |
| Household Size | $\bar{\pi}_1, \bar{\pi}_0, s_0, \eta, \Omega, y^*$ | Decrease or Increase | Decrease or Increase | Decrease or Increase | The interplay of production and consumption incentives of each individual household determine the effects of household size. |
| Environmental (Yield) Risk | | | | | |
| Opium Poppy Risk Increases | $\sigma_{\pi_1}$ (+) | Decrease | Decrease | Decrease | |
| Wheat Risk Increases | $\sigma_{\pi_0}$ (+) | Decrease | Decrease or Increase | Increase | For smaller households, the positive correlation between prices and returns can induce consumption risk for wheat, thus increasing its on-farm production |
| Eradication Risk Increases for Opium Poppy | $\gamma$ (+) | Decrease or Increase | Decrease or Increase | Decrease (if sufficiently risk-tolerant) | For risk averse households, depends on level of eradication risk, environmental risk, mean returns, and correlation of returns |
| Security Risk Increases | $\bar{\pi}_1$ (+), $\bar{\pi}_0$ (+), $\bar{\pi}_1 / \bar{\pi}_0$ (+)<br>$\sigma_{\pi_1}$ (+), $\sigma_{\pi_0}$ (+), $\sigma_{\pi_1} / \sigma_{\pi_0}$ (+)<br>$\tau$ (+), or eq., $\bar{\pi}_0$ (-), $\bar{p}_1$ (+), $\sigma_{\pi_0}$ (-) and $\rho_{p_1,\pi_0}$ (+) | Decrease or Increase | Decrease or Increase | Increase (if sufficiently risk-tolerant) | Mean return effects tend to increase opium poppy share. Market price of wheat effect tends to decrease share of opium poppy when risk aversion is relatively high. Correlation effect increases share in opium poppy when risk aversion high, but may decrease it otherwise. Variance in opium poppy effect decreases share in opium poppy; variance in wheat effect increases or decreases share in opium poppy depending on consumption risk, risk aversion, and correlation between market and producer returns and total effect |

| Factor | Change in Model Parameters (likely sign) | Likely Impact on Opium poppy Share by Household Type ($\Delta l_1$) | | | Comments |
|---|---|---|---|---|---|
| | | Very small (Subsistence) | Small | Medium to large | |
| Remoteness Increases | $\tau$ (+), or eq., $\bar{\pi}_0$ (-), $\bar{p}_0$ (+), $\sigma_{\pi_0}$ (-) and $\rho_{p_1,\pi_0}$ (+) | Decrease or Increase | Decrease or Increase | Increase (if sufficiently risk-tolerant) | Assume remoteness creates a gap in production and consumption prices due to transaction costs in the wheat market. Opium poppy is unaffected due to buying at farm gate. Wheat return effect increases share in opium poppy, wheat market price effect decreases share in opium poppy if risk aversion high, variance of wheat effect increases share in opium poppy for subsistence, decreases share otherwise, and correlation effect decreases share in opium poppy if risk aversion high |
| Landholding Arrangement | | | | | |
| Sharecropping Land (impact on landowner) | $\bar{y}^*$ (+), $\rho_{\pi_1,y^*} > 0$ | n/a | Decrease or Increase | Increase (if sufficiently risk tolerant) | Assumes positive correlation between "outside income" from sharecropping activity and opium poppy returns. Income effect tends to increase share of opium poppy; correlation structure and risk aversion tend to decrease share of opium poppy. |
| Accumulated Debt | | | | | |
| Stock of Debt Increases | $\bar{y}^*$ (-), $\rho_{\pi_1,y^*} < 0$ | Decrease or Increase | Decrease or Increase | Decrease (if sufficiently risk tolerant), but requiring further investigation | Assumes outside income with negative correlation with opium poppy returns. Income effect tends to decrease share of opium poppy; correlation structure tends to increase share of opium poppy. |
| Flow of Debt (Borrowing) | $\bar{\pi}_1$ (-) $\sigma_{\pi_1}$ (-) | Decrease or Increase | Decrease or Increase | Decrease (if sufficiently risk tolerant), but requiring further investigation | Assumes consumption smoothing denominated in opium poppy, lender assumes risk. Borrower will allocate agreed-to share of land to opium poppy. *Results shown for remaining land not part of agreement.* |

| Factor | Change in Model Parameters (likely sign) | Likely Impact on Opium poppy Share by Household Type ($\Delta l_1$) | | | Comments |
|---|---|---|---|---|---|
| | | Very small (Subsistence) | Small | Medium to large | |
| Outside Income | | | | | |
| Opportunities increase, uncorrelated with returns | $\bar{y}^*$ (+) $\rho_{\pi_0,y^*}=0,\ \rho_{\pi_1,y^*}=0$ | Decrease or Increase | Decrease or Increase | Increase (if sufficiently risk tolerant) | Sign depends on strength of consumption/production linkage; share in opium poppy more likely to decrease if risk aversion is high and share of consumption in wheat is high |
| Opportunities increase, positive correlation with opium poppy returns | $\bar{y}^*$ (+), $\rho_{\pi_1,y^*}>0$ | Decrease or Increase | Decrease or Increase | Increase (if sufficiently risk tolerant) | Correlation provides additional incentive in each case to decrease share in opium poppy relative to uncorrelated case |
| Opportunities increase, positive correlation with wheat returns | $\bar{y}^*$ (+) $\rho_{\pi_0,y^*}>0$ | Decrease or Increase | Decrease or Increase | Increase (if sufficiently risk tolerant) | Correlation provides additional incentive in each case to increase share in opium poppy relative to uncorrelated case |
| Agricultural Inputs and Technology | | | | | |
| Labor wage costs increase | $\bar{\pi}_1$ (-) $\bar{y}^*$ (+) | Decrease or Increase | Decrease or Increase | Decrease | Assumes opium poppy more labor intensive. Production-side effect (returns) decrease share in opium poppy. Income effects, if they exist, can increase or decrease share in opium poppy depending on correlation structures and consumption behavior. |
| Credit costs Increase | $\bar{\pi}_0$ (-) $\bar{\pi}_1$ (-) $\sigma_{\pi_1}$ (+) $\sigma_{\pi_1}$ (+) $\bar{y}^*$ (-) | Decrease or Increase | Decrease or Increase | Decrease or Increase | Can impact returns on each crop using financing. If only opium poppy finances, provides incentive for less opium poppy. If credit used for productive purposes, variances may increase as well. Overall incentive change depends upon relative size of change for each crop, consumption, and risk aversion (see environmental risk). Availability of credit may also impact debt levels or ability to smooth consumption. |
| Other variable input costs increase | $\bar{\pi}_0$ (-) $\bar{\pi}_1$ (-) | Decrease or Increase | Decrease or Increase | Decrease or Increase | Sign of effect depends on relative changes in all variables. On mean return effect, the more intensive user of the input in crop |

| Factor | Change in Model Parameters (likely sign) | Likely Impact on Opium poppy Share by Household Type ($\Delta l_1$) | | | Comments |
|---|---|---|---|---|---|
| | | Very small (Subsistence) | Small | Medium to large | |
| | $\sigma_{\pi_1}$ (+) | | | | budget will see biggest decrease in returns, providing an incentive to plant less of that crop. If input affects risk, variance effect may augment or reverse this effect (see environmental risk above). |
| | $\sigma_{\pi_1}$ (+) | | | | |
| Increased Investment | $\bar{\pi}_0$ (+) | Decrease or Increase | Decrease or Increase | Decrease or Increase | Opposite case to other variable input costs. Need for investment may also change debt structure. |
| | $\bar{\pi}_1$ (+) | | | | |
| | $\sigma_{\pi_1}$ (-) | | | | |
| | $\sigma_{\pi_1}$ (-) | | | | |
| | $\bar{y}^*$ (-) | | | | |
| Opium poppy output price increase | $\bar{\pi}_1$ (+) | Increase | Increase | Increase | Magnitude depends on linkages between production and consumption. |
| Wheat output price increase | $\bar{\pi}_0$ (+) | Decrease | Decrease | Decrease | Magnitude depends on linkages between production and consumption. |

NOTE: For security risk increases and remoteness, $\tau$ (+) implies $\bar{\pi}_0$ (-), $\bar{p}_1$ (+), $\sigma_{\pi_0}$ (-) and $\rho_{p_1,\pi_0}$ (+).

# Appendix D: Annotated List of Programs

**Table D.1. Eradication, Agricultural Development, and Alternative Livelihood Programs in Afghanistan**

| Program | Funder | Implementer | Dates |
|---|---|---|---|
| **Eradication** | | | |
| Governor Led Eradication (GLE) | STATE -- INL | | |
| Good Performers Initiative (GPI) | STATE -- INL | | |
| **Agricultural Development** | | | |
| Accelerating Sustainable Agriculture Project (ASAP) | USAID | | 11/2006-9/2011 |
| Afghan Agricultural Research and Extension Development (AGRED) Program | USAID | Roots of Peace | 7/2012-7/2017 |
| Afghanistan Farm Service Alliance (AFSA) | USAID | CNFA | 3/2008-6/2012 |
| Afghanistan Immediate Needs Program | USAID | | 12/2004-1/2006 |
| Afghanistan Vouchers for Increased Production in Agriculture (AVIPA) | USAID | | 9/2008-9/2009 |
| Afghanistan Vouchers for Increased Production in Agriculture – Plus (AVIPA Plus) | USAID | | 9/2009-11/2012 |
| Afghanistan Water, Agriculture and Technology Transfer (AWATT) Project | USAID | | 3/2008-6/2011 |
| Agricultural Development Fund (ADF) and Agricultural Credit Enhancement (ACE) | USAID | DAI | 8/2010-12/2014 |
| Commercial Horticulture and Agricultural Marketing Project (CHAMP) | USAID | Roots of Peace | 2/2010-12/2014 |
| Cotton & Alternative Crops Pilot Project in Helmand Province | USAID | | 7/2002-12/2006 |
| Fund to IFDC For Seed/Fertilizer | USAID | | 8/2005-12/2006 |
| Global Development Alliance for Strengthening Market Chains for Afghan Raisins and Pomegranates (GDA) | USAID | | 5/2008-11/2011 |
| Helmand Food Zone Program (HFZP) | USAID | Helmand PRT | 9/2009-12/2011 |
| Irrigation and Watershed Management Program | USAID | | |
| Rebuild Agriculture Markets Program (RAMP) | USAID | | 7/2003-9/2006 |
| Southern Regional Agricultural Development in Afghanistan (S-RAD) | USAID | IRD | 8/2011-8/2012 |
| USAID/Washington DCHA Office of Food for Peace (MYAP) | USAID | World Vision | |
| USAID/Washington DCHA Office of Food for Peace (PRRO) | USAID | World Food Programme | |
| On Farm Water Management Project | World Bank | | 1/2011-6/2014 |
| Irrigation Rehabilitation and Development Project | World Bank | | 2/2012-12/2017 |

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| Program | Funder | Implementer | Dates |
|---|---|---|---|
| National Horticulture and Livestock Project | World Bank | | 12/2012-12/2018 |
| Afghanistan Agriculture Inputs Project | World Bank | | 6/2013-6/2018 |
| Helmand Agricultural and Rural Development Programme (HARDP) | DfID | | 11/2006-3/2011 |
| Strengthening the Agriculture Sector in Afghanistan (SASA) | DfID | | 6/2012-4/2015 |
| Horticulture & Livestock Programme | DfID | | 3/2007-12/2009 |
| Increasing Food Production for Afghanistan (IFPA) | DfID | | 9/2008-3/2010 |
| Increasing Agricultural Potential in Afghanistan | DfID | | 4/2010-8/2012 |
| Helmand River Basin Master Plan (HRBMP) | DfID | | 2/2010-2/2014 |
| Agriculture Market Infrastructure Project (formerly Commercial Agriculture Development Project) | ADB | | |
| Agriculture Sector Program Loan | ADB | | |
| Community-Based Irrigation Rehabilitation and Development | ADB | | |
| Rural Finance Expansion | ADB | | |
| Rural Recovery through Community Based Irrigation Rehabilitation | ADB | | |
| Water Resources Development Investment Program | ADB | | |
| **Alternative Livelihoods** | | | |
| Afghan Growth Finance (AGF) | USAID | Small Enterprise Assistance Funds | 5/2010-5/2015 |
| Afghanistan Credit Support Program (ACSP) | USAID | | 2/2005-2/2008 |
| Agriculture, Rural Investment, and Enterprise Strengthening (ARIES) | USAID | | 9/2006-12/2009 |
| Alternative Development Program/Southern Region (ADP South) | USAID | | 2/2005-9/2009 |
| Alternative Development Program/Southwestern Region (ADP/SW) | USAID | | 3/2008-3/2011 |
| Alternative Licit Livelihoods Initiative (ALLI) (formerly Agro-enterprise Development Alliance) | USAID | | 9/2009-9/2011 |
| Cash for Work Hilmand Program | USAID | | 7/2002-9/2003 |
| Community Development Program – South, East & West (CDP-SEW) | USAID | Central Asia Development Group | 3/2009-11/2011 |
| Development Credit Authority (DCA) | USAID | | 9/2008-6/2011 |
| Financial Access for Investing in the Development of Afghanistan (FAIDA) | USAID | Chemonics International | |
| Incentives Driving Economic Alternatives for the North, East, West (IDEA-NEW) | USAID | DAI | 3/2009-3/2014 |
| Incentives to Reduce Poppy Cultivation in Afghanistan | USAID | | 7/2002-11/2003 |
| Kandahar Commercialization Support | USAID | Louis Berger Group/Black & Veach | 5/2009-12/2011 |

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| Program | Funder | Implementer | Dates |
|---|---|---|---|
| Land Reform in Afghanistan (LARA) | USAID | Tetra Tech | 2/2011-1/2014 |
| Land Titling and Economic Restructuring Activity (LTERA) | USAID | | 9/2004-10/2009 |
| Rural Finance and Cooperative Development (RUFCOD) | USAID | World Council of Credit Unions | 12/2009-12/2012 |
| Afghanistan Access to Finance | World Bank | | 11/2013-12/2018 |
| Afghanistan New Market Development | World Bank | | 5/2011-2/2016 |
| Afghanistan Rural Access Project | World Bank | | 7/2012-3/2018 |
| Expanding Microfinance Outreach and Improving Sustainability | World Bank | | 6/2008-6/2012 |
| Microfinance for Poverty Reduction | World Bank | | 6/2003-6/2010 |
| National Emergency Rural Access Project | World Bank | | 12/2007-12/2013 |
| National Solidarity Program I | World Bank | | 12/2003-3/2007 |
| Rural Enterprise Development Program | World Bank | | 3/2010-1/2015 |
| Skills Development Project | World Bank | | 4/2009-1/2014 |
| Afghanistan Market Place Expansion | DfID | | 1/2009-7/2012 |
| Bost Airport and Agricultural Business Park | DfID | | 9/2009-1/2014 |
| Helmand Alternative Livelihoods Program (HALP) | DfID | | 8/2009-12/2010 |
| Helmand Area Based Stabilization | DfID | | 8/2008-3/2012 |
| Helmand Growth Programme | DfID | | 5/2010-9/2014 |
| Microfinance Investment Support Program | DfID | | 3/2004-3/2010 |
| Road Improvement in Central Helmand | DfID | | 11/2010-4/2013 |
| Road Rehabilitation and Maintenance Programme (RRMP) | DfID | | 5/2012-1/2016 |
| Supporting Employment and Enterprise Development | DfID | | 3/2010-2/2015 |
| Afghanistan Rural Business Support Project | ADB | | |
| Enhanced Value Chains | ADB | | |
| Resilience of Rural Livelihood | UNDP-AFGHANISTAN | | |

SOURCE: Based on RAND staff analysis.

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# Appendix E: Other Less-Developed Countries' Experiences with Counternarcotics and Related Programs

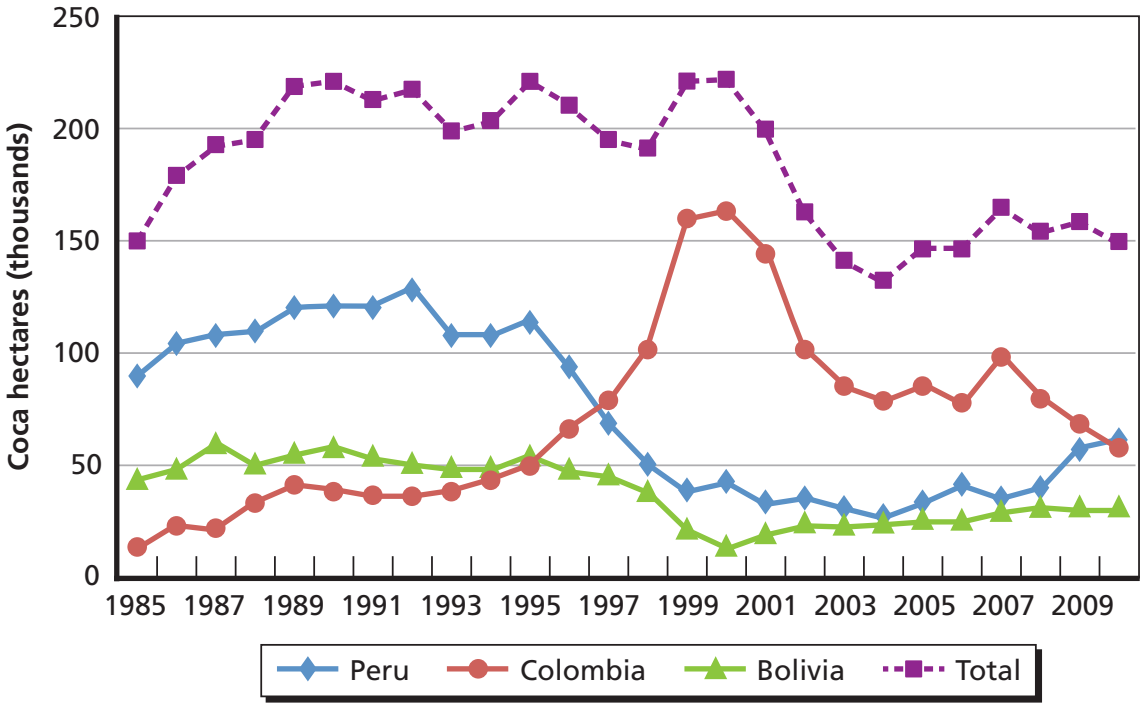
In this appendix, we review the experiences of other countries with policies to reduce the cultivation of coca and opium poppy, either directly or indirectly, through eradication, rural development programs, and interdiction. We consider these types of policies both separately and in combination, as "mixed strategies."

## Introduction

A variety of supply-oriented policies and interventions have been designed and implemented in drug-producing countries over the past decades to discourage production of illegal crops, primarily coca and opium poppy. Three forms that such interventions take include eradication, rural development programs that aim to bring farmers into the legal economy, and interdiction campaigns against traffickers and refiners of drugs.

Drug market researchers largely agree that such supply-oriented policies can have unintended negative consequences (Chouvy, 2013), and are often unsuccessful in achieving their primary aims, at least globally (Costa Storti and De Grauwe, 2009; Greenfield and Paoli, 2012; Paoli, Greenfield, and Reuter, 2009; Werb et al., 2008). Global aggregate production volumes of cocaine and opium poppy have remained steady or increased over the past few decades despite a stark increase in funding for supply-oriented drug reduction policies and programs worldwide (Costa Storti and De Grauwe, 2009; Mejía and Restrepo, 2008). Figure E.1 shows that, notwithstanding a substantial rise in global production in the late 1980s and a change in relative positions among Peru, Colombia, and Bolivia, 2010 global production of coca is effectively identical to that in 1985 in terms of hectares under cultivation. Moreover, during this time, coca yields per hectare have improved as a result of improved production techniques (Mejía and Restrepo, 2008; Davalos, Bejarano, and Correa, 2009), so the global supply has increased (Costa Storti and De Grauwe, 2009).

**Figure E.1. Hectares of Coca Cultivation in the Andean Region, 1985–2010**




SOURCE: Jaen and Dyner, 2014, p. 227, citing UNODC.

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Nonetheless, there are examples of individual countries or regions that have seen reductions in local production (Paoli, Greenfield, and Reuter, 2009). In Figure E.1, Peru might view itself as having enjoyed some degree of success in reducing local production of coca in the past 25 years—even if such production relocated to Colombia[1].

Yet whether such reductions are the result of one or more supply-oriented policy interventions or not is largely unknown. Each country and region's experience with illegal crops is context-specific, and very few rigorous assessments of any supply-reduction policy's effectiveness exist (Strang et al., 2012; Chouvy, 2013; Ibanez and Carlsson, 2010). Those empirical studies that have attempted to evaluate the effectiveness of supply-control interventions face many challenges, such as incomplete data (aggregated information does not allow identification of behavioral factors affecting the farmer decision to plant an illegal crop) and endogenous policy choice (Ibanez and Carlsson, 2010).[2] The evidence base for the success or lack thereof of particular supply-oriented policies or interventions in particular countries or

[1] Windle and Farrell (2012) argue that the "balloon effect" has been over-subscribed as a consequence of any drug policy and neglects to consider some spillover benefits that also result from drug law enforcement.

[2] Examples of attempts to evaluate the effectiveness of different supply-control policies include Moreno-Sanchez, Kraybill, and Thompson, 2003; Carvajal, 2002; and Tabares and Rosales, 2004. See Ibanez and Carlsson, 2010.

regions is weak. As a result, policies tend to be chosen based on politics or moral values instead of evidence of effectiveness or cost-effectiveness (Strang et al., 2012).

Nevertheless, a brief historical review of the various supply-oriented policy interventions can shed light on what has not worked and what might work, under the right circumstances. Here we consider rural development, eradication, and interdiction efforts, both separately and in combination, in terms of the mechanisms by which they operate and any evidence of their effectiveness or unintended consequences. In some instances countries or regions have implemented one policy in isolation, while other policy interventions have combined two or more supply-reduction policies as part of a mixed strategy. There are also examples of staggered approaches, such as an alternative development intervention following or preceding an eradication campaign. We try to synthesize the lessons learned across types and timing of intervention policies, the drugs addressed, and individual country experiences in order to draw general conclusions about what has worked and what has not to discourage local illicit crop production on a sustainable basis.

## Rural Development

In conceptualizing rural development programs, the literature uses a number of terms of art—with more or less precision—to focus on different dimensions of development and cultivation incentives. Common among those terms is *alternative development* (AD), which generally aims to bring farmers who currently plant illegal crops into the legal economy by making other economic opportunities more attractive than the illegal crop.

A common element of alternative development is crop substitution, which seeks to encourage planting of competing, legal crops through various measures, potentially including price guarantees for the legal crop, help in bringing the legal crop to market (such as assistance with marketing, financial credits or improved transportation), subsidies for planting the legal crop, or other new techniques or tools to encourage cultivation. However, alternative development programs can encourage non-agricultural activities too, e.g., by improving market access for all crops. Some more recent AD designs have featured holistic and multipronged approaches to encourage participation in the licit economy (Chouvy, 2013; Farthing and Kohl, 2005).

UNODC (undated) describes AD in broad terms:

> Alternative Development programmes now aim at elimination or prevention of the production of illicit crops through a methodology encompassing a broader conception of rural development aimed at improving the overall quality of life of the target population by addressing not only income but also education, health, infrastructure and social services.

No matter the design, the general goal of AD is to adjust farmers' underlying incentives sufficiently to cause them to voluntarily stop growing illegal drugs. However, because AD projects necessarily encourage legal alternatives—oftentimes produced under competitive and uncertain market conditions—lasting, stable profitability can be elusive. Thus, Thoumi (2005),

speaking largely from Colombia's example, argues that AD projects do not really end and must be monitored constantly to ensure no reversion back to the illegal crop.

Finally, because AD schemes rely on individual-level behavioral changes—in the midst of a complex web of competing factors— intended to result in an eventual market impact, one can readily envision multiple potential points of failure along the causal chain. One coca grower from the Monzon Valley in Peru concluded about alternative development:

> Alternative Development projects are sown at a table, cultivated on a blackboard, harvested on a computer and sold in publicity campaigns on radio and television. (Azucena Vermandi, Notcias Aliadas, 2004, as quoted in Farthing and Kohl [2005], p. 183).

The general consensus is that, in their history, alternative development programs have registered more failures than successes (Paoli, Greenfield, and Reuter, 2009; Werb et al., 2008; Farthing and Kohl, 2005; Lupu, 2004; Thoumi, 2005). Chouvy (2013) argues that because AD programs often start as small-scale local pilot projects (supported by Western governments), perverse incentives can be created for nearby areas to plant more of the illegal crop to attract their own international aid—a possible internal displacement effect. The short time horizon of most AD programs also means that failure or cancellation can lead to a quick resurgence of the production of the illegal crop and, in some instances, can leave intended beneficiaries in debt and, perhaps, more likely to plant the illegal crop than before. Lupu (2004); Thoumi (2012); Paoli, Greenfield, and Reuter (2009); and many others argue that AD programs must have a credible long-term commitment, or risk that farmers will not be willing to shift to the new alternative. Political stability and trust in the government are also necessary or farmers may doubt the credibility of any AD program and fail to buy in (Thoumi, 2012).

A recent *Lancet* review of drug policy measures concludes, "very little evidence exists for the effectiveness of alternative development programmes in source countries, and no evidence exists that they affect the availability or price of drugs in final-market countries (although they can possibly trigger a shift in location of production)" (Strang et al., 2012). However, the evaluation of AD programs has not always been strong. Many programs have been assessed qualitatively on the exercise of professional judgment, absent robust methodologies. Moreover, countries that wish to attribute success to a particular AD program are hampered by the difficulty of disentangling the effects of the program from other factors. Mansfield (1999) recognized this challenge early on when he wrote:

> local successes in such [drug crop cultivation] reductions cannot be directly attributed to alternative development interventions because the motivations and circumstances that determine household drug crop cultivation remain largely unexplored…. the failure to recognize the dynamics of household decision-making has implications for the cost-effectiveness of the current [alternative development] strategy...

A UNODC report (2005) acknowledges that:

> in those areas where lasting reductions in production have been seen, other possible influences on farmer decisions not to cultivate drug crops can be put forward as being equally likely causes for change. These include: overall economic growth (Thailand and Viet Nam), political change (Myanmar), increasing government access to formerly remote areas (Pakistan), social pressure (Lao PDR, Bolivia), subsidies (Thailand), and booming prices for alternative crops (coffee and cacao growing areas). (UNODC, 2005, pp. 9–10).

Lupu (2004) and Farthing and Kohl (2005) reviewed Bolivia's experience with major U.S.-supported AD programs that were implemented in the 1980s and early 1990s, prior to the mixed strategy that combined AD with eradication. They found a number of common problems in the original designs of the programs and with patterns of implementation:

- Conditionality terms for eradication to accompany any AD program benefits that were often counterproductive in practice
- Narrow and short-term definition of success
- Inadequate market appraisal of the alternative crops encouraged by the various AD programs
- Lack of necessary infrastructure development to help bring alternative crops to market
- Lack of contingency planning and technical assistance
- Poor targeting of programs
- Bureaucratic conflicts between implementing agencies
- Poor and culturally insensitive implementation approaches that fail to involve coca growers and their leaders in program design and implementation.

Even the relative success story of Thailand, which has largely abandoned opium production over the past 30 years, provides instructive lessons on the pitfalls of crop substitution as an AD strategy. For instance, Renard (2001) reviewed an AD program from the 1970s in which peaches were promoted as an alternative crop to opium poppy. At the time of program initiation, the price of peaches was 8 baht per kilogram, sufficiently high to encourage some farmers to abandon opium poppy in favor of peaches even before any official AD program was introduced. However, when the peach became the official strategy of an AD program supported by the King of Thailand and the UN, the price dropped to 2 baht per kilogram and many growers simply let their harvest rot because they could not cover transportation costs (Renard, 2001, p. 57).

The UN and other agencies have also promoted coffee growing to discourage Thai farmers from planting opium poppy. Coffee was considered a safe crop due to the seemingly strong world demand and high potential earnings. By 1974 the Thai government had distributed thousands of seedlings to encourage cultivation of coffee in poppy producing regions. However, like many other perennials, coffee does not yield a harvest immediately. The coffee bush requires about three years of maturation to generate

a harvestable bean, which meant that poorer farmers with small landholdings were discouraged from switching out of poppy. Furthermore, to obtain premium prices, the processed coffee needed to meet strict grading requirements. Thus, poppy farmers had to learn how to grade coffee as well as how to cultivate the crop. Many abandoned the crop in the face of these challenges and the effort largely ended.

Thailand had more success in the 1970s with an AD strategy for crop substitution focused on red kidney beans. These beans are can be easily stored, are high-yielding, are adaptable to a variety of climates, and require little in the way of special care. However, kidney beans were initially unfamiliar to Thai diets. As a result, this AD strategy included television marketing efforts to introduce the Thais to red kidney beans, including instructions how to cook them. The UN offered a price guarantee to farmers of 3 baht per kilogram for switching to this crop. Although there were instances of local failures, kidney beans slowly became integrated into Thai diets and continue to be grown today.

Despite the apparent success of the red kidney bean, the overall history of Thailand's experience with crop substitution suggests more limitations than promise. By 1979, nineteen research projects on crop substitution had been conducted. Although a few viable options, such as the red kidney bean, were found, even the best were only partially successful and none was sufficient to drive out opium production on any large scale (Renard, 2001). By the 1980s, critics of the programs in Thailand pointed to many of the same shortcomings that Lupu (2004) and Farthing and Kohl (2005) identified in Bolivia: errors in implementation, a lack of participation on the part of local peoples, and inadequate market appraisals of competing crops (Renard, 2001).

The 1980s saw the emergence of more-integrated approaches to AD in places like Peru and Thailand that focused on improving growers' living standards rather than narrowly focusing on crop substitution. By the 1990s, participatory approaches that increased the involvement of locals in the planning and design of AD programs came into favor in places such as Thailand (Renard, 2001) and Bolivia (Farthing and Kohl 2005). By the 2000s, AD programs evolved to become increasingly complex in their aims to address the multiple underlying forces leading to the growth of opium and coca production (Mansfield and Pain, 2005; Chouvy, 2013; Thoumi, 2012).

In light of the Bolivian experience with AD programs, Lupu (2004) suggested five broad policy implications:

- Enact a more participatory approach to alternative development and soften rules of conditionality for being a program beneficiary.
- Encourage a strategy of diverse alternatives that combine high-yield crops with diverse growing cycles to provide income throughout the year, and have contingency plans in case of the failure of one crop or market.
- Work with farmer groups to create economies of scale to reduce transaction costs and thereby make their crops competitive to bring to market.

- Invest in complementary infrastructure development that is free of conditionality, even if such projects (e.g., road construction) can potentially also benefit the drug producing industry in the short term.
- Take a long-term approach to any AD strategy.

These policy recommendations match recent thinking by many other drug policy researchers. They are also in accordance with drug policies that have been adopted by Western donors and nations that grow illegal drugs. Farthing and Kohl (2005) argue in the case of Bolivia that the European Union's support of AD programs was more successful at reducing cultivation than U.S.-sponsored programs that had been pursued in Bolivia since the 1980s. The EU-supported programs were free of conditionality, engaged directly with local coca growers and their unions, and were decoupled from eradication. A 2009 UNODC report on a recent alternative development program in Peru that was deemed a success in decreasing coca cultivation in the San Martín region made many similar recommendations. It emphasized the importance of local buy-in and an integrated focus, "which systematically incorporates economic, social, political, and environmental factors" (UNODC, 2009, p. 25). Similar lessons are offered in a recent UNODC publication that synthesizes lessons learned from many decades of AD projects throughout Southeast Asia (Renard, 2010).

However, it is precisely this complex and integrative approach to AD that makes these programs difficult and expensive to implement. Because of their complexity, evaluators find it difficult to determine the effects of the programs, which, in turn, complicates the ability of drug policy researchers to identify generalizable results. In many instances, cultivating opium poppy and coca remains attractive even while growing the newly introduced crops (Clemens, 2008; Ibanez and Carlsson, 2010). A recent hypothetical choice experiment conducted among Colombian coca farmers found coca cultivation to be relatively inelastic to increases in the relative profits of competing crops and perceived risks,[3] suggesting that AD programs are unlikely to induce substantial reductions in coca cultivation (Ibanez and Carlson 2010).

## Eradication

A variety of eradication campaigns have been launched over the past few decades in drug-producing countries to combat both coca and opium poppy production. These can take the form of aerial fumigation campaigns (as in Colombia) or manual eradication campaigns (as more recently done in Afghanistan or in Bolivia in the 1990s). Eradication campaigns can be "voluntary," in which case farmers might agree to eradicate crops in exchange for some sort of compensation, or "forced," in which case farmers' crops are destroyed regardless of their

[3] Ibanez and Carlsson (2010) found that other factors, including religion, remoteness, and poverty were more important to farmers' decisionmaking.

preferences, but the line between voluntary and forced eradication is blurry. A farmer might acquiesce to eradication because, de facto, he has no choice. On that basis, the distinction between voluntary and forced eradication could be framed as a matter of degree along a continuum of coercion. Recognizing the difficulty of distinguishing between voluntary and forced eradication, we use these terms cautiously, with reference to actions at the ends of the spectrum, but we also try to maintain consistency with the cited literature. Eradication campaigns aim to reduce supply either by increasing the risk of crop loss, if forced to some degree and uncompensated, or by destroying the crop in situ—both with the potential to affect availability and pricing further down the supply chain.

The United States and other wealthy drug-consuming countries have sometimes financed these operations in the context of other foreign assistance or counter-narcotics efforts, at times linking assistance to reduction. In Colombia, as of 2006, U.S. expenditures on alternative development in coca-growing regions were $72 million and military assistance focused on aerial fumigation, amounted to $205 million (Davalos, Bejarano, and Correa, 2009).

While some of the immediate effects of eradication are measurable, e.g., in terms of hectares of illegal crops destroyed, Chouvy (2013), Ibanez and Carlsson (2010), and Thoumi (2005) argue that eradication fails to address the underlying incentives that lead to cultivation and could reinforce them or yield unintended negative consequences.[4] Absent alternative economic opportunities, eradication campaigns can create perverse incentives for farmers to grow more drugs in subsequent growing cycles as a coping mechanism (Davalos, Bejarano, and Correa, 2009, Chouvy, 2013, etc.), e.g., in the face of accumulating debt.[5] The experiment described above, which found coca cultivation to be relatively inelastic to increases in perceived risk and relative profit (Ibanez and Carlsson, 2010), also suggests a limited role for eradication.

Colombia's experience, albeit including a substantial reduction in cultivation from peak levels in 1999-2000, suggests that farmers can adapt to eradication, for example, by shifting production to new locales in remote and inaccessible areas with low state presence. In 2005, 8 percent of new coca fields in Colombia were in National Parks (Davalos, Bejarano, and Correa, 2009). Farmers also found other means of combating the effects of fumigation, including the adoption of more potent crops and more efficient production methods. In 1999, the average yield was 0.11 percent of the weight of cocaine from fresh leaves and, by 2006, it was 0.15 percent. In addition, farmers have responded by planting smaller plots that can be overlooked from the air and switching to agroforestry, i.e., mixing coca plants with native trees or legal crops that hide them or reduces the efficacy of fumigation (Davalos, Bejarano, and Correa, 2009; Mejia and Restrepo, 2008).

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[4] Chouvy (2013) concludes, "forced eradication is highly likely to be counterproductive…..Worse, forced eradication also generates many harmful unintended consequences" (p. 223).

[5] We discuss this possibility in Chapter 3 and Appendix C.

Thailand's eradication campaign, begun in the mid-1980s, might have contributed to that country's exit from cultivation, but, as noted previously, it can be difficult to disentangle the effects of concurrent policies and strategies. The eradication efforts were largely preceded by crop replacement and other alternative development projects and major infrastructure development projects, some of which were unrelated to counter-narcotics efforts. Furthermore, eradication was only undertaken in areas "where it was thought that the people could make a satisfactory living without relying on opium" (Renard, 2001, p. 102). When one examines Thailand's successful history of reducing production of opium since the 1970s, an important general point to keep in mind was that this was a 30-year effort with strong support from the monarchy and was accompanied by intense economic growth in general.

Other governments have periodically pursued national bans on the production of illegal drugs through forced eradication and coupled with stiff penalties for growers. Pakistan's ban on illegal opium production in 1980 and the more recent Kokang and Wa opium bans in Burma in 2003 and 2005, respectively, are examples of forced eradications pursued to enforce bans on production (Chouvy, 2013; Farrell and Thome, 2005; Windle, 2012). Although such bans did result in significant short-term reductions in local production of opium poppy where the bans were actively enforced, production tended to rebound in those areas or in nearby areas, when and where forced eradication was not pursued. In each case poor local growers were found to be worse off following the bans, in many cases the bans drove them deeper into debt increasing their reliance on the cultivation of the illegal crop in subsequent years (Chouvy, 2011; Chouvy, 2013; Farrell and Thome, 2005; Windle, 2012).

## Interdiction

Drug interdiction – the interception of illegal drugs during transport by air, land or sea – is a measure intended to disrupt the drug market by reducing supply or increasing the costs (risks) of production. This policy is not aimed at farmers directly, but we review its recent history as a common tactic in anti-coca-cocaine strategies in the Andes (Dammert, 2008). It is also used in the opiate market, with most large seizures occurring in Asia close to production centers (Paoli, Greenfield, and Reuter, 2009). In 2009, there was between a 2 and 16 percent interdiction rate for global heroin flows (depending on the purity of the heroin seized) (UNODC, 2011, p. 5).

Perhaps the most well-known interdiction policy was the "Air Bridge Denial Program" implemented by Peru in the mid-1990s with financial support from the United States. The goal of this program was to interrupt the transport of coca by airplane and boat between Peru and Colombia and, to a lesser extent, between Bolivia and Colombia. During the 1980s and early 1990s (as shown in Figure E.1 above), Peru and Bolivia were the largest producers of coca leaves in the world; Colombia was the main producer and exporter of refined coca paste and cocaine (Dammert, 2008). Local militaries took control of airports and ports in coca regions to disrupt the traffic of coca and derivatives from the growing regions of Peru and Bolivia to the

processing centers in Colombia. In early 1995, the Peruvian government implemented a "shoot down" policy against suspicious aircraft, and, by April of that year, the governments of Peru and Colombia, with the assistance of tracking data from various U.S. agencies, shot down or otherwise destroyed dozens of trafficker aircraft (Crane, Rivolo, and Comfort, 1997).

The interdiction operations might have contributed to the subsequent decrease in Peruvian cultivation in the late 1990s and simultaneous increase in Colombian production. Although traffickers adapted to this new source of risk, such as by relying on land and river routes (Crane, Rivolo, and Comfort, 1997), farmers in Peru started to abandon their coca fields as prices declined below production costs. Meanwhile, Colombian drug traffickers turned to homegrown crops to mitigate this new source of risk (Dammert, 2008).

However, Jaen and Dyner (2014) estimate only modest market disruptions from these operations and they—and others—suggest the influence of concurrent events. At the time of implementation, the powerful Cali and Medellín cartels in Colombia were dismantled as several high-level members were arrested or killed. Jaen and Dyner (2014) argue this changed the structure of the industry. A few large organizations no longer dominated the market; rather, many smaller "cartelitos" were competing against each other, driving prices down in a more-fragmented market. The cartelitos encouraged local farmers to grow their own coca, whether by coercion, force, or financial incentives.

The overall evidence for the effectiveness of interdiction is thus mixed. Notwithstanding claims of success, a 2005 GAO report concluded that the Colombian program, begun in 2003,[6] had an unclear overall effect on drug trafficking in Colombia (GAO, 2005).[7] A 1997 Institute for Defense Analyses report on the effectiveness of interdiction policies concluded that "source-zone operations . . . that significantly and unexpectedly disrupt the normal drug trafficker processes for producing and transporting coca products from the source zone, cause discernible increases in the street prices of cocaine in the U.S., and . . . thereby reduce cocaine consumption" (Crane, Rivolo, and Comfort, 1997, p. VI-1). However, a more recent summary of the evidence for both cocaine and opiate markets suggest that interdiction can disrupt drug markets and supply chains, but there is little evidence that increased efforts lead to increased effectiveness (i.e., no "dose response effect") and they can be costly to implement (Strang et al., 2012).

## Mixed Strategies

A mixed strategy for reducing illegal production of drugs combines various strategies, e.g., alternative development and eradication, whether in parallel or in a staggered approach over

[6] The Peruvian Air Bridge Denial Program was suspended in April 2001 after an innocent civilian aircraft was accidentally shot down in Peru and two U.S. citizens were killed (GAO, 2005). It was restarted in Colombia in August 2003 with additional safeguards.

[7] Specifically, between October 2003 and July 2005, the Colombian Air Force located just 48 aircraft out of 390 "suspicious tracks" pursued, and took control of just 14. One resulted in a drug seizure.

time. "Carrot and stick" approaches have been employed in Bolivia in the 1980s and 1990s, Colombia in the 1990s and 2000s, and Thailand in the 1980s (Lupu, 2004; Mejia and Restrepo, 2008; Renard, 2001). Such, mixed strategies have a mixed record of success. A common theme in discussions of failures relates to the timing of implementation of the various components and the relative funding and support allocated among the two strategies.

In the Andean region, the "carrots" and "sticks," taken in combination, have suffered some of the same deficits as noted previously, when treated in isolation.[8] For example, alternative development programs have been hampered by poor implementation, insufficient funding, and attenuated timelines and by ignoring the needs and motives of the poor farmers whose decisions they aim to affect (Lupu, 2004; Farthing and Kohl, 2005; Sanabria, 1997). Meanwhile, the "stick" of eradication often receives significantly more funding than alternative development. Mejia and Restrepo (2008) observe that about three quarters of the $3.8 billion in U.S. funds dedicated to Colombia's War on Drugs between 2000 and 2005 were devoted to military operations focused predominantly on eradication and related efforts. When alternative development programs cannot keep pace with eradication, local farmers learn to mistrust AD programs and to see them as tied to eradication efforts (Lupu, 2004; Farthing and Kohl 2005), potentially leading to resentment of development efforts.

Thailand experimented with both eradication and alternative development strategies and has enjoyed much greater success in reducing the cultivation of opium poppies than most other countries, discussed above. Thailand's eradication programs were introduced *following* the implementation of alternative development strategies, which included crop replacement and general development projects, and only in areas where farmers were thought to have viable alternatives (Renard, 2001). Whether intentional or not, Thailand's mixed strategy might have accounted for the difference in time it takes for eradication and alternative development efforts to take hold. Although it is, as noted elsewhere, difficult to ascribe a single causal factor or policy to the decline in opium poppy cultivation, particularly given the climate of economic growth, the timing of the respective efforts appears to have better considered the needs and motives of poor farmers. However, some ascribe the success of the Thai approach expressly to this combination strategy and emphasize the crucial role played by eradication:

> With the threat of eradication or legal punishment, farmers were much more willing to stop growing the poppy. After thirteen years of an increasing amount of development initiatives in the hills, no appreciable decline in opium had been observed. The government realized that AD by itself would not be able to reduce cultivation effectively. Given the opium poppy's many advantages as a cash crop, creating economic alternatives that poppy growers will accept voluntarily is a challenging task. It is possible but it takes decades. (Renard, 2010, p. 56)

[8] In the foregoing sections of this appendix, we addressed the use of "carrots" and "sticks" separately and attempted to explore their effects as independent agents, but, in large part, the occurred in tandem.

## Summary and Concluding Thoughts

The general consensus among drug policy researchers is that supply-reduction policies aimed at reducing drug cultivation and trafficking have been largely unsuccessful (Greenfield and Paoli, 2012; Chouvy, 2013; Strang et al., 2012). Despite the substantial sums of money dedicated to supply reduction by governments and donors, little systematic evidence exists about the effectiveness or cost-effectiveness of the various programs and policies that have been implemented in the Andes, Southeast Asia, and elsewhere over the years (Mejia and Restrepo, 2008; Reuter, 2008). Although isolated instances of local successes to drive out cultivation of illegal crops can be found (e.g., in Thailand), these successes tend to be highly context-specific. Nevertheless, past experience provides some, limited bases for generalization. For example, when implemented alone, e.g., without means to address the underlying causes of production, eradication has generally failed to achieve permanent reductions.

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