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Aid Under Fire: How Development Projects Can Increase Civil Conflict

Benjamin Crost

Donors and governments are increasingly targeting development aid to conflict-affected areas, in the hope that aid will reduce conflict by "winning the hearts and minds" of the population. But this strategy can backfire. If insurgents expect that development projects will weaken their position in the long run, they will try to derail them,* which can exacerbate conflict.

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In recent years, donors and governments have increasingly targeted development aid to conflict-affected areas, often in the hope that aid will reduce conflict by "winning the hearts and minds" of the population. The idea is that by implementing development projects, for example by building roads, schools and hospitals, or by extending technology, cash transfers or insurance to poor people, we can increase popular support for the government and reduce support for insurgent movements. Facing a more hostile population, insurgents will find it harder to recruit fighters, acquire supplies and carry out attacks, leading to an overall reduction in violence.

This idea—that development aid can be used to win hearts and minds—is widespread and forms the basis of much of the U.S. Armed Forces' counterinsurgency strategy. Yet, there is no conclusive empirical evidence that development projects reduce violence. In fact, there is anecdotal evidence for the opposite.

Insurgents in many countries have ramped up attacks on aid workers and infrastructure projects. A recent report on civil counterinsurgency strategies by the RAND Corporation warns that "insurgents strategically target government efforts to win over the population. Indeed, the frequency with which insurgents attack schools, government offices, courthouses, pipelines, electric grids, and the like is evidence that civil [counterinsurgency] threatens them."

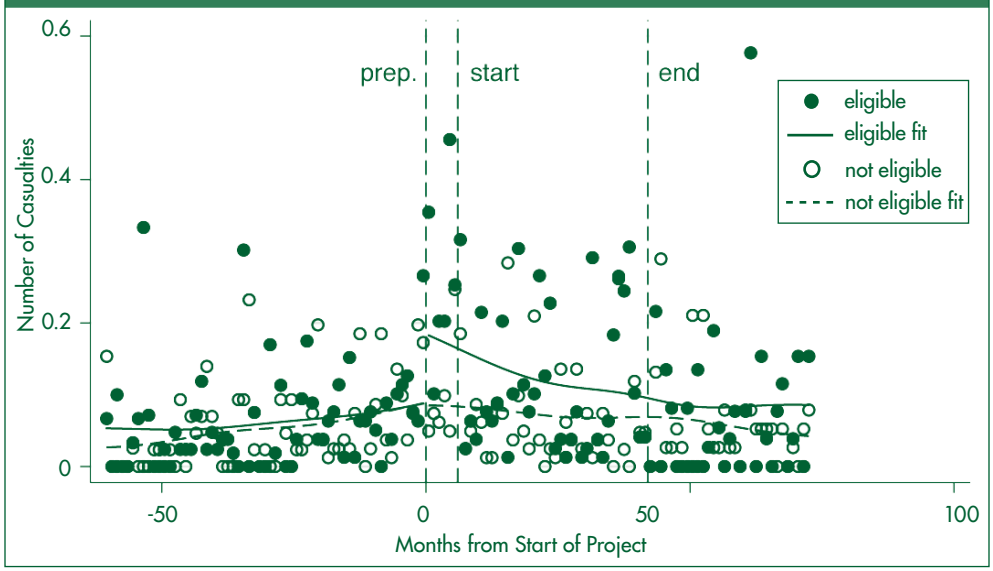
Why "Winning Hearts and Minds" Can Backfire

In a recent working paper, my co-author Patrick Johnston and I offer a simple but frequently overlooked explanation for why the strategy of winning hearts and minds often backfires: if insurgents know that successful development projects will weaken their position, they will try to derail them, which may exacerbate conflict.

To help us think more clearly about this mechanism, we developed a simple theoretical model of bargaining and conflict around development projects. The model's premise is that the government tries to implement a development project while the insurgents threaten to use force to derail it—perhaps by attacking government staff or infrastructure, or by intimidating the population into not participating in the project.

The model assumes that the government and insurgents engage in negotiations, during which the government can pay off the insurgents in return for allowing the project's peaceful implementation. However, the insurgents know that a successful project will win the hearts and minds of the population and will make it harder for insurgents to achieve their political aims in the future. Thus, if the government wants to convince the insurgents to leave the project in peace, it has to compensate them for the shift in power that a successful project will bring about.

Figure 1. Time Trend of Casualties



Previous theoretical work on the causes of conflict has shown that a large shift in power between two parties can cause bargaining to break down. Our model shows that if a project causes a shift in power that is large enough, the government may not be willing or able to compensate the insurgents and conflict will occur.

While this theoretical modeling exercise may seem somewhat abstract, it allows us to predict the conditions under which development projects are most likely to cause conflict. First, conflict is more likely if a successful project causes a large shift in the balance of power between insurgents and the government. Second, conflict is more likely if insurgents have a strong military capacity that they can use to effectively derail the project (or more precisely, if insurgent attacks cause a large decrease in the probability that the project will be successful). I will come back to these insights at the end of this article and discuss what they can tell us about the best way to implement development projects in areas affected by conflict.

Background: The KALAHI-CIDSS Program and Civil Conflict in the Philippines

To test the predictions of our theoretical model, we estimate the causal effect of a large development program—the Philippines' KALAHI-CIDSS program—on casualties in armed civil conflict.

From 2003 until 2008, KALAHI-CIDSS was the Philippines' flagship anti-poverty program with a budget of $180 million, financed through a loan from the World Bank. The program distributed grants for small infrastructure projects (e.g., roads, schools, health centers, market halls) to the poorest 25% of municipalities in the 40 poorest provinces of the Philippines. In doing so, it followed a community-driven development framework that allowed the population to propose projects and decide which projects to fund through a participatory democratic process.

We estimate the effect of this program on the ongoing conflict between the government of the Philippines and the country's two largest organizations: the communist New People's Army (NPA) and the Muslim-separatist Moro Islamic Liberation Front (for more details on the Philippine conflict, see the 2005 Philippine Human Development Report).

The New People's Army is the armed wing of the outlawed Communist Party of the Philippines, a class-based movement that seeks to replace the Philippine government with a communist system. Since taking up arms in 1969, the NPA has relied on guerilla tactics rather than conventional battlefield confrontations against government armed forces. Its current strength is estimated at 8,000 armed insurgents who operate in rural areas all over the Philippines.

The Moro Islamic Liberation Front (MILF) is a separatist movement fighting for an independent Muslim state in the *Bangsamoro* region of the southern Philippines. It was formed in 1981, when the group's founders defected from the Moro National Liberation Front, another long-standing southern Philippines insurgent movement. The MILF's core grievances stem from disputes over lands considered by the southern Muslim population to be part of their ancestral homeland. With an estimated 10,500 fighters under arms, the MILF is larger than the NPA. However, the MILF has a more narrow geographic focus and only operates in parts of the southern island of Mindanao.

Overall, conflict with these two groups has been ongoing for over four decades, caused more than 120,000 deaths, and cost the country an estimated $2–3 billion. We had access to information on all conflict incidents that involved units of the Armed Forces of the Philippines (AFP) between 2001 and 2008. These data were originally collected for the AFP's own intelligence purposes, but a declassified version has recently been made available to researchers.

Estimating the Causal Effect of Development Projects on Conflict

Estimating the causal effect of development projects is difficult under any circumstances, and particularly so in conflict-affected areas. To cleanly identify the causal effect of development aid on conflict, one would optimally like to compare two places (villages, municipalities, districts, etc.) that are exactly identical in all characteristics, except that one of them received aid while the other did not.

Since this is not possible in the real world, researchers usually use regression analysis to "control" for differences in observed variables. By controlling for a variable (e.g., population, poverty, or quality of infrastructure) in a regression, we can "hold its effect constant," which allows us to compare places that differ in the variable as if they did not.

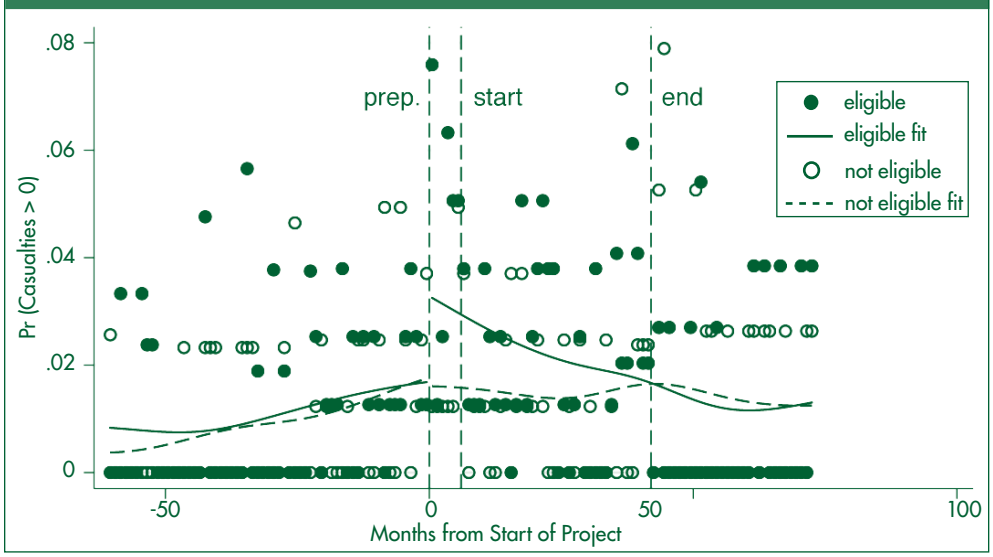
If we were able to measure all the differences between places that receive aid and places that do not, we could control for them in a regression and filter out the pure effect of development aid on conflict. Unfortunately, this is virtually impossible in the real world since many important variables are hard or impossible to measure. We may, for example, be able to measure and control for differences in demographics, poverty and access to infrastructure, but crucial variables like the strength and militancy of local insurgents and their level of support in the population are nearly impossible to measure.

If these unmeasured variables differ systematically between places that receive aid and places that do not, we run the risk of misinterpreting these differences as the causal effect of aid, which would lead us to the wrong conclusions. For example, suppose an aid agency is worried about the safety of its staff and therefore targets aid to places with little or no insurgent presence. In this case, we would most likely find that the places that receive aid from this agency experience less conflict than the places that do not receive aid. However, this does not mean that aid caused a reduction in conflict, but merely that the agency targeted aid towards places that had a low propensity for conflict to begin with. The key to estimating causal effects is therefore to ensure that one is comparing like with like—i.e., that the places one is comparing do not differ in unobserved variables.

To overcome this challenge and cleanly identify the causal effect of the KALAHI-CIDSS program on violent conflict, we employ a statistical method called Regression Discontinuity Design (RDD). This approach ensures that one is comparing like with like by exploiting arbitrary thresholds in the targeting of interventions. In our case, eligibility for the KALAHI-CIDSS program was restricted to the poorest 25% of municipalities. Thus, municipalities just below the 25th percentile of poverty were eligible and municipalities just above the 25th percentile were not.

The basic idea of the RDD approach is that—since the location of the threshold is basically arbitrary—municipalities just above and just below the threshold should not differ systematically in any unobserved variables (such as the strength of the local insurgents) that determine conflict. We can therefore estimate the program's causal effect by comparing the intensity of conflict in municipalities just below and just above the eligibility threshold.

Figure 2. Time Trend of Conflict Probability



Results

The main results of our econometric analysis are summed up in the graph in Figures 1 and 2. The graphs compare the intensity of conflict—measured respectively by the number of casualties and the probability of having at least one casualty in a given month—in municipalities that were barely eligible for the KALAHI-CIDSS program and municipalities that were barely ineligible.

Monthly averages of conflict in barely eligible and barely ineligible municipalities are denoted by solid and hollow circles, respectively. Smoothed time trends are plotted as solid lines for eligible municipalities and dashed lines for ineligible ones. The dashed vertical lines mark important dates in the project's timeline.

The first line at t = 0 marks the beginning of preparations for the project in eligible municipalities; the second line marks the start of the project's implementation six months later. The third vertical line marks the project's scheduled end after three years. The graphs show that both eligible and ineligible municipalities experienced similar levels of conflict in the period before the project.

However, at the start of the project preparations, conflict increased sharply in eligible municipalities but remained virtually unchanged in ineligible municipalities. The difference in the intensity of conflict then became smaller over time and virtually disappeared as the project ended. Overall, the graphs suggest that the KALAHI-CIDSS program caused a large increase in the intensity of conflict over the three years of its duration.

The regression results that correspond to these graphs, which are presented in detail in our paper (Crost and Johnston 2010), suggest that the KALAHI-CIDSS program caused a 70–90% increase in the number of conflict casualties in eligible municipalities. In aggregate, we estimate that the program caused approximately 500 excess casualties over the three years of its duration.

Our regression analysis also shows that eligible and ineligible municipalities did not significantly differ in pre-program or post-program levels of conflict, which supports our claim that the observed differences are really due to a causal effect of the program and not due to systematic differences in unobserved variables.

Additional results show that the majority of casualties were suffered by insurgents and government troops, while civilians appear to have suffered less. We further find that the program caused similar increases in insurgent-initiated and government-initiated violence, suggesting that the effect is not the result of a one-sided offensive by either party.

Conclusion: What Can Be Done to Avoid Conflict Around Development Projects?

Our research makes two contributions to the study of civil conflict in developing countries. First, it provides empirical evidence that development projects can cause violent conflict. This evidence is particularly strong because our method of analysis is able to overcome the central problem of causal inference: that places that do and places that do not receive aid differ systematically in important unobserved variables such as the strength of local insurgents.

By exploiting a discontinuity in the targeting of aid—the fact that only the poorest 25% of municipalities were eligible—we were able to compare municipalities that were barely eligible for aid with municipalities that were barely ineligible. Since the threshold at the 25th percentile was chosen arbitrarily, barely eligible and barely ineligible municipalities should not differ in unobserved variables, so that the difference in conflict between them reflects the causal effect of the development project.

Of course, even though our results show that development aid can cause conflict, they do not suggest that we should stop giving aid to conflict-affected areas. Many of the world's poorest and most vulnerable households live in areas affected by conflict and cutting them off from aid would be throwing out the baby with the bath water. However, we believe that our theoretical model allows us to draw some conclusions about how to implement development projects while avoiding conflict.

To draw these conclusions, we need to recall the conditions under which the model predicts conflict to occur. First, the model suggests that conflict is likely if aid causes a large shift in the balance of power between governments and insurgents. It should therefore be possible to avoid conflict by making sure that development projects do not affect this balance of power. One way of achieving this is to cooperate with both governments and insurgents in designing the project and delivering the aid.

An example of this approach is a recent cooperation of Japan's International Cooperation Agency (JICA) with the MILF in extending aid to parts of Mindanao in the southern Philippines. However, while cooperating with insurgents can be a successful strategy in some cases, there are many contexts in which it may not be feasible or ethical.

In these cases, we turn to the second condition under which our model predicts conflict: if insurgent attacks have a large negative effect on the probability that the project will be successful. This suggests that violence can be minimized by focusing aid on a small number of projects and heavily defending them. This would make it harder for insurgents to sabotage the projects (and increase their costs if they try) and thus help deter violent attacks. In addition, it may be desirable to weaken insurgents' capacity before the start of the project by military means, following a "clear, hold, build" strategy.

While more research on the precise mechanism through which development projects cause conflict is needed, our research shows that by combining careful empirical and theoretical analyses, we can identify the causal effects of development interventions and use this information to draw conclusions for development policy.

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For additional information, the author recommends:

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China's Agriculture: Achievements and Challenges

Colin A. Carter

Persistent high food prices have drawn renewed attention to the role of China in world food markets. There is concern that China will be unable to keep expanding its food supply to meet growing demand for meat, becoming more dependent on world food markets and driving prices even higher. This article reviews achievements made by China's agriculture and highlights key challenges faced by that country in agriculture.

It has been over 30 years since China abandoned its large communal farms. Each "farm" had thousands of workers, assigned to production brigades. The communes were run by inefficient and corrupt top-down management, and state monopolies procured farm production at fixed prices. The communal farming system was a complete disaster, underscored by the 1959–61 famine when an estimated 30 million Chinese residents starved to death. The communes were broken up in the late 1970s in favor of small, family-run plots with profit incentives tied to production and market-determined prices.

The economic reforms that started in China's agricultural sector in the late 1970s then spread to other parts of the economy and we all know the rest of the story. China has enjoyed very strong income growth and has emerged as a main driver of global economic growth. Deng Xiaoping moved China from a top-down planned economy to a market economy, and the results have been nothing short of phenomenal.

Achievements

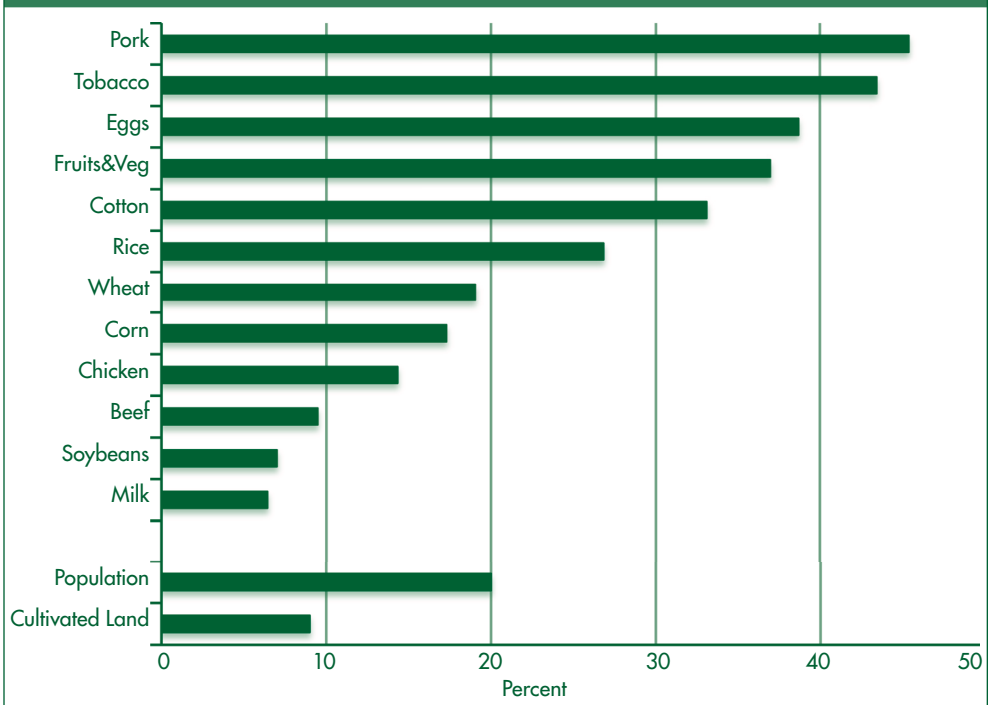
Today, China produces 18% of the world's cereal grains, 29% of the world's meat, and 50% of the world's vegetables. This success makes China the world's largest agricultural economy, and it ranks as the largest global producer of pork, wheat, rice, tea, cotton, and fish. In fact, the value of China's agricultural output is twice the U.S. total. See Figure 1 for China's share of world food production across various commodities.

With only 9% of the global sown area, today China produces about 20% of the world's food—a miraculous turnaround since the struggles faced by China's agriculture in the 1960s and 1970s under the collective farms. Despite predictions that China was going to starve the world, instead China has been able to balance its domestic grain supply and demand, with the exception of oilseeds. China's agriculture has made notable achievements in the last three decades. Will this continue?

After joining the WTO in 2001, China has played a greater role in world agricultural trade. China dramatically increased its trade dependence in agriculture, and it is currently the fifth largest exporter and fourth largest importer of agricultural products in the world. China's substantial increase in fruit and vegetable production was a major factor behind its agricultural export growth.

With imports growing faster than exports during the post-WTO accession years, China reversed its long-time status as a net agricultural exporting country to that of a net importing country since 2004. As expected, with liberalized trade and market forces at

Figure 1. China's Share of World Food Production



Source: Compiled from Food and Agriculture Organization (FAO) data.

Grain production in 2010 was 80% above the 1978 level in China, but the farms remain very small and the work remains highly labor-intensive and difficult.

work, China increased its imports of land-intensive agricultural products.

Most of the increased imports came from soybeans and cotton. Today cotton and soybeans account for 43% of China's agricultural imports, a very concentrated portfolio. China is the world's largest importer of soybeans and cotton, accounting for 60% of global soybean imports and 40% of cotton imports.

China's agriculture is supporting a population of over 1.3 billion people today, compared to about 500 million in 1950, on a relatively fixed agricultural land base and shrinking water supply. The tale of China's agricultural success in meeting this challenge is two-fold. First, China has enjoyed very strong agricultural productivity growth, measured as the difference between growth of agricultural output and the growth of all inputs aggregated. Second, China has poured on farm inputs. China's annual agricultural productivity growth rate was 2.5% from 1970–2007, even higher than Brazil's and much higher than in the United States (which is less than 1.5%). At the same time, China's farmers have intensively applied more chemicals and fertilizer to their crops to try and overcome the limitations of scarce land and water.

In the 1980s and 1990s agricultural production in China grew by 5.3% per year, much higher than in other populous countries such as India and Indonesia. Most of this growth came through yield gains rather than through increases in planted area. China boosted grain production by more than 50% during this time period. Grain production in 2010 was 80% above the 1978 level. Per capita food supply in China rose from 2,328 calories per day in 1980 to 3,029 calories in 2000, a 30% increase in just 20 years.

China's chemical fertilizer use has roughly doubled over the past two decades while pesticide use and mechanized inputs have increased even faster. China has slightly less agricultural land than the United States, but its chemical fertilizer use is now double that of the United States. China uses about one-third of the world's nitrogen fertilizer and 31% of phosphate fertilizer on its 9% share of the world's agricultural land. Unfortunately, the strong growth in chemical input use has resulted in considerable agricultural pollution.

Challenges

Let us not forget that China remains a developing country. In China 36% of the population still lives on less than $2 per day and most of these poor are in the countryside. Even though economic reform started in agriculture, non-agricultural economic growth has left the farm population to fall behind. The image we have of the new affluent Chinese consumers buying Gucci handbags in modern boutique shops does not apply to the nation's farmers. China's farms remain very small (approximately 1 acre) and the work remains highly labor-intensive and difficult.

Almost 300 million workers remain in agriculture, and most farmers remain very poor, with per capita incomes about $1,000/yr—less than one-third of the average urban income. The proportion of agriculture in China's GDP dropped from 28.1% in 1978 to 11.8% in 2010. Yet 38% of the labor force remains in agriculture (see Figure 2), a ratio that is far too high given China's level of development. As a result, labor productivity in agriculture remains low.

Raising farmers' incomes is one of the major policy challenges facing China's policy makers today. This may require relaxing a long-standing policy goal of food self-sufficiency. National food security goals require a very high grain self-sufficiency percentage, and farmers typically earn less money growing grain compared to other higher-valued crops.

Between 1981 and 2005, the percentage of people living below the poverty line dropped from 84% to 16.3%. This was part of the success story. But the challenge is that China's Gini coefficient (a measure of income inequality) grew from 29 in 1990 to 42 in 2007, reflecting a strong increase in income disparity within a relatively short period of time. Income inequality in China is now similar to that in Mexico, but the irony is that China is a communist country.

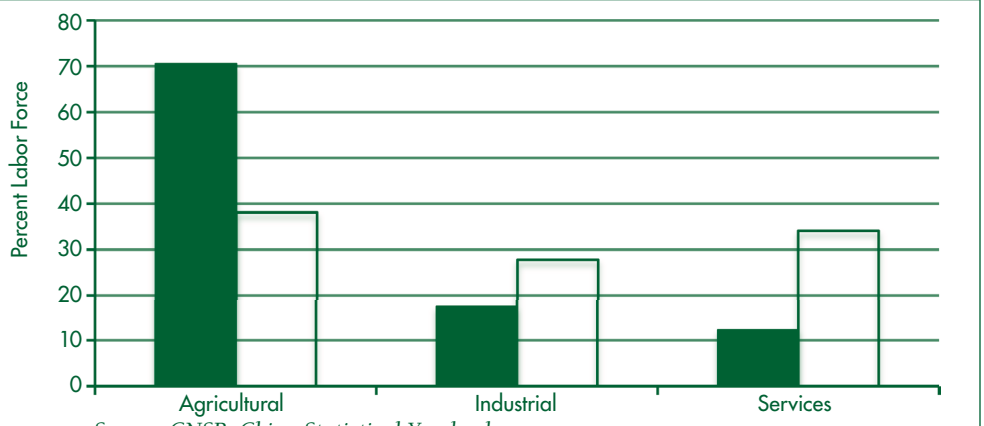
Income growth and urbanization, and the resulting changes in dietary patterns, particularly in developing countries like China, have important implications for food consumption and agricultural trade. Urbanization leads to a decrease in calorie consumption per person, but greater demand for processed food products. Low-value staples, such as cereals, account for a larger share of the food budget of the poor while high-value food items, such as dairy and meat, are a larger share of the food budget of the rich.

So rising incomes are usually associated with increased demand for meat, horticultural, and processed food products. In turn, increased demand for meat will result in increased demand for feed grains and protein meals. For instance, China's per capita incomes have more than tripled in the past 20 years and, as a result, some dramatic changes in food consumption have taken place in that country.

Per capita meat consumption has more than doubled in the last 20 years in China. Meeting increased demand for meat and other dietary changes will continue to be a challenge for China. This will require more water supplies because it takes about 2,000 liters of water to produce 1kg of wheat, compared to about 16,000 liters of water for 1kg of beef.

Today, much of China's agriculture is very irrigation-dependent. With 20% of the world's population and 7% of its fresh water, China faces important water issues. Agriculture uses 76% of the country's water, but it is facing greater competition from urban areas. In the relatively dry northern region, the water availability per person is only a quarter of that in the south. Yet the north is where almost half China's population lives, and where most of its maize, wheat, and vegetables are grown. Groundwater is intensively used in the north, but not in the south. This means that water efficiency must be improved in the north. Pricing of surface water and groundwater could play a greater role in the allocation.

Figure 2. Change in China's Employment Structure



Source: CNSB, China Statistical Yearbook

China's farmland essentially belongs to local governments, a holdover from the commune era. This means that land cannot be bought or sold by farmers, only leased. This raises a number of policy issues with respect to the transition of China's agricultural sector towards a more modern industry. Lack of land ownership discourages investment and consolidation into larger and more efficient farms. Land-use rights are now attached to village residency, discouraging permanent out-migration from agriculture and keeping farm incomes low.

Conclusion

China's agriculture has made remarkable achievements since 1980, but there remain critical issues. Grain security is still at the center of government policy and this serves to discourage the production of higher-valued horticultural crops, thus taxing farmers. Resource scarcity (especially water) and agricultural pollution are major problems that are resolvable but require immediate action. The rural-urban income gap and land tenure are also significant issues. There seems little doubt that China will become more reliant on land-intensive food imports, but at the same time it will expand exports of labor-intensive food products.

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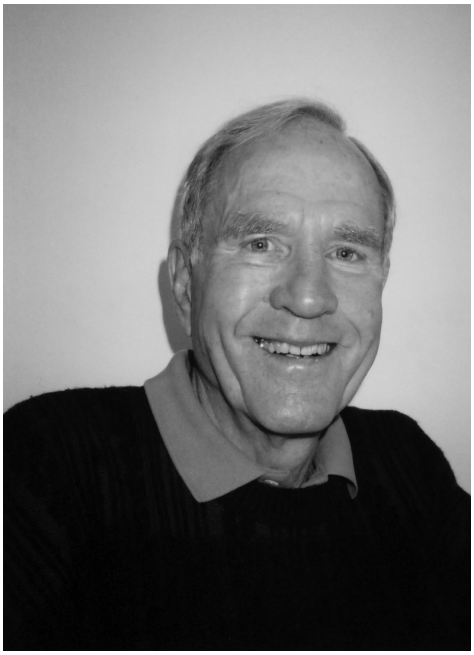
In Memoriam: Kirby S. Moulton
October 8, 1928 – May 20, 2011



Kirby S. Moulton
Cooperative Extension Economist Emeritus
University of California, Berkeley

Kirby Moulton, internationally recognized extension economist at the University of California, passed away on May 20, 2011.

Born in Berkeley, Kirby graduated from Yale University in 1950, only to return to UC Berkeley to receive his MBA in 1952. He spent the next two years serving in the United States Navy, stationed mostly in Japan. He again returned to UC Berkeley and received his Ph.D. in 1970.

Kirby spent the next ten years in various executive marketing and sales positions in the logging and timber industry along California's north coast. He eventually settled in at University of California, Berkeley as an economist in Cooperative Extension— focusing on agricultural trade, trade policy, viticulture, market liberalization in Eastern Europe, and global competition in horticultural products—until his retirement in 1996.

Kirby's work was highly influential both nationally and internationally. He worked with country representatives to create standards, forums, and policies to benefit growers globally. He traveled frequently to Washington D.C. to advise the USDA trade representative, and he was the first American to be elected President of the Commission on Economics and Legislation of the International Office of Wines and Vines (OIV). For many years, he was a delegate to the Food and Agriculture Organization's Intergovernmental Committee on Grape Products and a member of the USDA's Agricultural Technical Advisory Committee to the Secretary and U.S. Trade Representative.

Kirby's research on grape and wine markets helped guide the California wine industry into international prominence. Partnering with universities and governments, he was able to assist Eastern Bloc countries in converting agricultural industries from collective to privatized systems. His innovative work around the world led to him to becoming the first American awarded the French Merit of Agriculture.

Kirby's wide influence spread beyond his professional life. He was able to raise confidence, clarify choices, and help people realize their abilities and shape their goals, whether he was speaking with struggling farmers or his grandchildren. Kirby's favorite approach was an early evening "wine time," which gave everyone time to relax, take stock of their day, and make plans for moving forward.

Both worldly and scholarly, it is no wonder why people came to Kirby for advice on careers or life, or merely just to talk. A question he used to open the discussion at the men's book club he cofounded and remained a member for 23 years—"So...what's the book really about?"—gave insight into Kirby's vast curiosity and intellectual depth.

A lifetime resident of the East Bay, Kirby leaves his wife, Peggy, three children, Curt, Mary and Mike, six grandchildren, and many friends and colleagues who miss him greatly. At his request and in his spirit, many family and friends met recently to celebrate his life and, once again, enjoy "wine time with Kirby."

A quote by E. E. Cummings guided his relationships and embodies his life: "Be of love (a little) more careful than of everything."

Written by L. Tim Wallace, friend and colleague in the Department of Agricultural and Resource Economics at UC Berkeley. The Moulton family suggests that donations in Kirby's memory can be made to Hospice of the East Bay.

The Estimated Impact of Bee Colony Collapse Disorder on Almond Pollination Fees

Hoy Carman

Almond pollination fees have risen sharply in recent years. This article shows that the fee increase is due in roughly equal parts to the expansion of almond acreage and the occurrence of Bee Colony Collapse Disorder.

Production of many California crops is heavily dependent on pollination by honeybees provided by commercial pollination services. The most important tree crop users of pollination services include almond, apple, avocado, cherry, kiwi, pear, and prunes/plums. Other important California crops using pollination services include alfalfa seed, cucumbers, melons (cantaloupes, honeydew, watermelons), sunflowers, and vegetable seeds.

There is a well-organized market for pollination services with beekeepers from upper midwestern, northwestern and other states, as well as California, contracting with California producers to provide bees during the bloom periods for their crops. Beekeepers typically contract their colonies (hives) for more than one crop and often move their colonies from state to state to take advantage of differing bloom periods for contracted crops.

The pollination market and production of many important crops is threatened by a phenomenon, first identified in 2005 and 2006, in which worker bees leave their colonies in search of nectar and pollen and do not return. Named Colony Collapse Disorder (CCD), this phenomenon differs from other causes of bee mortality (e.g., pathogens and parasites) in that there are no dead or dying worker bees around or in the hive—the worker bees just disappear.

While researchers are still attempting to determine the causes of CCD, the economic effects are evident. Beekeepers' costs increase, as they must replace the lost bees to fulfill their pollination contracts, and the cost increase must be passed on to the producers using pollination services for the beekeepers to remain economically viable.

Almond producers, the largest user of pollination services in California and the United States have faced sharp fee increases as a result of CCD and acreage expansion. This article estimates the separate effects of CCD and almond acreage expansion on the fees that almond producers pay for pollination services.

California Almond Production

California, with 740,000 acres of bearing almond trees in 2010, produces about 80% of the world's almonds. Approximately 70% of almond production is exported, making almonds California's largest-value agricultural export.

Almonds are also California's largest user of pollination services by a considerable margin. Estimates place some 60% of all U.S. bee colonies being used for pollination in California almond orchards during the February/March bloom period. After the almond bloom, the hives move on to other crops with a typical hive being rented two to three times during the season. Almonds were responsible for 30% of all rentals and 58% of all rental income in a 2007 Northwest survey by Burgett.

Bee Colony Requirements

University of California cost and return studies to establish and produce almonds include 2.0 hives per acre for pollination in the San Joaquin Valley (North and South) and 2.5 hives per acre in the Sacramento Valley. Literature on almond pollination requirements also typically lists a requirement of 2.0 hives per acre, with five to six frames per hive.

Thus, the total number of hives required for almond pollination is a linear function of the number of bearing acres of almonds. The number of hives required for almond pollination has, thus, increased from approximately 802,000 in 1992 (401,000 acres) to 1,480,000 in 2010 (740,000 acres)—an 84.5% increase in two decades.

California County Agricultural Commissioners' data reported 1,192,687 hives used for pollination on all California crops in 1992, growing to 1,725,070 hives in 2008. Thus, with 680,000 bearing acres in 2008, almonds accounted for almost 79% of total bee colony pollination use in California.

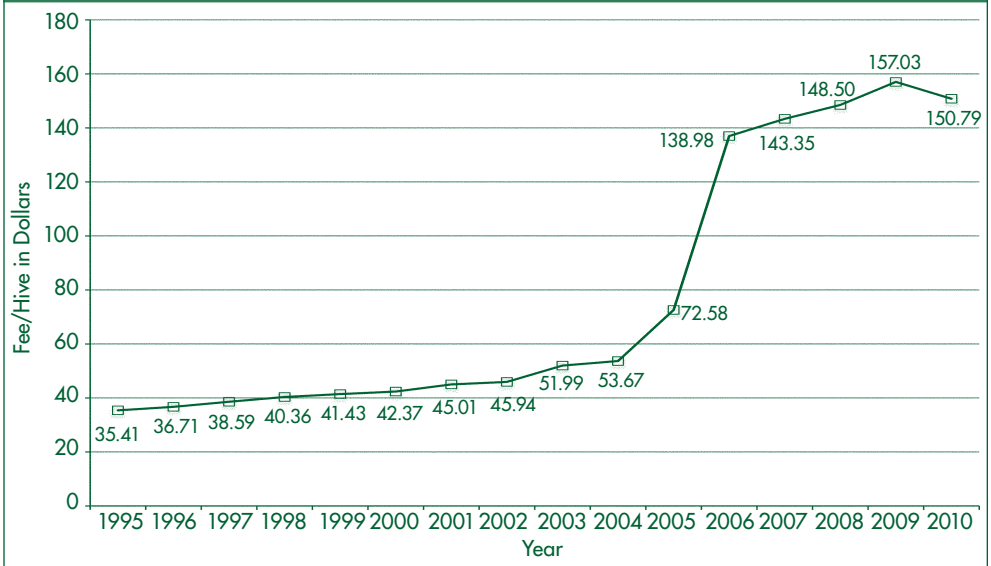
Pollination Fees

As pointed out by Sumner and Boriss, there is a well-developed and functioning market for pollination services, with fees responding to changes in the supply and demand for pollination services. Fees vary seasonally, geographically, and by crop characteristics, with valuable honey crops having fees about 50% below crops that do not provide nectar valuable for honey.

Pollination fees are highest during the almond bloom in the February/March period when hive demand is at a peak. Almonds are not a desirable source for honey production. Crops that overlap the almond bloom, including early cherries and plums, pay fees similar to almonds.

Data available from the 2010 California State Beekeeping Association Pollination Survey report an average fee per hive of $150.79 for almonds, $145.89 for early cherries, and $128.29 for plums. Average pollination fees for crops that bloom later, when supply of hives is high

Figure 1. Average Almond Pollination Fee, 1995–2010



Source: California State Beekeeping Association Annual Pollination Surveys, 1995–2010

relative to demand, are much lower than for almonds. For example, average 2010 pollination fees per hive were $25 for apples, $28.45 for melons, $29.37 for sunflowers, and $47.30 for alfalfa seed.

Average pollination fees per hive for California almonds for 1995 through 2010 are shown in Figure 1. Average fees increased from $35.41 in 1995 to $53.67 in 2004. The fees then increased to $72.58 in 2005 when CCD first became evident, and shot up $45.31 to $136.98 between 2005 and 2006.Almond pollination fees continued to increase and peaked at an average of $157.03 in 2009.

Pollination services are a growing and important cost component for almond production, recently accounting for about 20% of budgeted cultural costs per acre. We hypothesize that the two major factors associated with annual changes in almond pollination fees were (1) increased acreage of almonds, and (2) changes in overwintering bee colony losses.

Almond Bearing Acreage: California almond bearing acreage increased continually from 1995 through 2010, with the annual increase ranging from 5,000 to 40,000 acres (Figure 2). The largest increases occurred in 2007, 2008 and 2009, which was after the sharp increases in pollination fees that occurred in 2005 and 2006. Thus, while greater almond acreage increases the demand for hives, and perhaps the costs of providing them if the average distance that hives are transported increases, it does not explain the sharp increases in pollination fees in 2005 and 2006.

Overwintering Bee Losses: High winter losses of bees, regardless of the cause, impact beekeepers' costs and the supply of hives for pollination. Losses of bee colonies over the winter are expected, a loss of 15–20% to be in the usual or "normal" range. USDA reports that bee colony losses have averaged 17%–20% per year since the 1990s, attributable to a variety of factors, such as mites, diseases, and management stress.

Heavy overwintering losses were reported in 2003–2004 for many northern beekeepers. Beginning in 2005, CCD appears to be the major explanation for high winter losses. In their annual surveys, vanEngelsdorp et al reported four consecutive years of high winter losses in managed honeybee colonies in the United States. Losses totaled 32% in 2006–07, 36% in 2007–08, 29% in 2008–09 and 34% in 2009–10. The majority of beekeepers in each survey reported losses greater than what they considered acceptable. California State Beekeeping Association Annual Pollination Surveys reported winter mortality ranging from 20% to almost 30% from 2005 through 2009.

Increased loss of bees associated with CCD increases the costs of beekeeping and reduces the supply of pollination services. Beekeepers with pollination contracts must replace the lost colonies by purchasing bees to fill the empty hives. Package bees with a queen can cost over $100 per hive, depending on shipping, size of package, and type of bees. The empty beehives due to CCD are typically discovered just prior to, or as hives are being placed in almond orchards. In the scramble to secure enough hives for pollination requirements, almond producers have raised their bids for per colony pollination fees.

National surveys of overwintering bee colony losses did not occur until two years after the appearance of CCD. There are descriptions of unusually high losses in particular states or regions for years prior to 2007, but there are no national estimates of the average loss for the United States.

Estimation of an Equation for Annual Fees

While the lack of a time series for overwintering bee losses makes it difficult to determine the separate impacts of acreage increases and CCD on almond pollination fees, we can still obtain an estimate. First, we specify an equation for pollination fees as a function of bearing acreage and overwintering losses. Although we lack data on overwintering losses, we do observe that the sharp increase in pollination fees occurred when CCD was first identified as a problem.

The impact on fees of such a structural change can be estimated using a zero-one indicator variable. The equation to be estimated is:

$$\text{Fee} = f(\text{BA}, \text{D})$$

where Fee is the average annual almond pollination fee in real (2010) dollars per

hive, BA is annual California bearing acreage of almonds (1,000 acres), and D is a variable that has a value of zero for years 1995 through 2004, and a value of one from 2005 through 2010. The coefficient for D is the average annual impact of the structural change (the onset of CCD) on almond pollination fees.

Using annual data for 1995 through 2010, the estimated equation is:

$$\text{Fee} = -27.76 + 0.166\,\text{BA} + 55.97\,\text{D}$$
$$(-0.77) \qquad (2.30) \qquad (3.83)$$
$$R^2 = .90 \qquad \text{D.W.} = 1.89$$

where the values in parentheses are the t-statistics for the respective coefficients, $R^2 = .90$ and the Durban-Watson statistic is 1.89. The R^2 statistic means that the model explains about 90% of the variation in pollination fees between 1995–2010.

The estimated coefficients have the expected signs and indicate that the annual almond pollination fee increased an average of $0.166 per hive for each 1,000 acre increase in bearing acreage. After accounting for the impact of increased acreage, the fee increased an average of $55.97 per hive during the six years since CCD was first recognized.

We can do a few simple calculations to place these estimates in perspective. California's bearing acreage of almonds increased 322,000 acres over the period of the data sample—from 418,000 in 1995 to 740,000 in 2010. With an estimated real fee increase of $0.166 per hive per 1,000 acres increase, the real fee increase due to the increase in bearing acres from 1995 through 2010 is estimated to be $53.45 in 2010 dollars. In real (2010) dollars, the almond pollination fee increased from $49.84 per hive in 1995 to $150.79 in 2010, or just over $100.

Thus, it appears that increasing almond acreage and CCD each explain roughly half of the increase in almond pollination costs. Even if CCD had not occurred or if there were a complete solution to the problem of CCD, pollination fees for almonds would probably still be in the range of $100.00 per hive.

Figure 2. California Almonds: Annual Change in Bearing Acreage, 1996–2010

This does not minimize the real costs of CCD to the California almond industry. Using an average of two hives per bearing acre and an average fee increase of $55.97 per hive due to CCD, the estimated cumulative cost to the California almond industry for the six years, 2005 through 2010, is about $445 million. From 2010 forward, given current bearing acreage and recent winter bee losses, estimated costs due to CCD total almost $83 million annually.

Concluding Comments

The appearance of CCD in commercial bee colonies in the spring of 2005 focused attention on economic problems facing beekeepers and the importance of bee pollination for the production of many fruit and vegetable crops.

This paper documents another important impact of CCD, its effect on increasing costs of production for California almonds, the largest contractor for commercial pollination services. Costs of production for California almonds increased an estimated $112 per acre annually during the first six years after CCD was identified, with CCD estimated to be responsible for about half of this cost increase. Pollination fees now account for about 20% of budgeted almond cultural costs per acre. The estimated annual cost increase of $83 million for almond production due to CCD is just a portion of the economic impact of CCD in California, given that several other crops use pollination services as well.

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For additional information, the author recommends:

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