Abstract: This paper reviews the research on fortification of food in the context of South Asia, with an emphasis on avenues for future research in economics and policy. We argue that while the efficacy of fortified foods in controlled settings is well established, more research is needed to evaluate the take-up and effectiveness of fortified foods distributed through standard channels. In addition, we argue that more research is needed to understand the determinants of long-term demand for fortified foods. JEL codes: I15, I18. Keywords: nutrition, micronutrient fortification, public health.
1 Introduction

Interventions combating micronutrient deficiencies have long been considered among the most cost-effective public health programs. Micronutrient deficiencies affect two billion people in the world and cause increased risk of many health conditions, including goiter, blindness, anemia, cognitive impairments, impaired work capacity and maternal mortality. Across South Asia, vitamin A, iodine and iron deficiencies are widespread and are top priorities for international development organizations such as the Micronutrient Initiative. In India, 56% of ever-married women and 70% of children under the age of five are anemic (International Institution for Population Sciences, 2007) and at least 15% are at risk of iodine deficiency (Chakravarty and Sinha, 2002). In Pakistan, 39% of pregnant women and 51% of children under the age of 5 are anemic and 7-12% of women and children manifest symptoms of vitamin A deficiency (Pakistan Institute of Development Economics, 2003). In rural Bangladesh, 68% of children under five years of age and 39% of pregnant women are anemic (Helen Keller International, 2006). Despite a relatively long history of small-scale micronutrient interventions and population-wide interventions in developed economies, there has been little progress in using these tools to combat malnutrition on a large scale in developing countries, and particularly in South Asia.

In this paper, we discuss the promise of micronutrient fortification as a means to ease the burden of malnutrition in South Asia. Fortification, defined as the addition of micronutrients to food, is to be distinguished from supplementation, most commonly implemented as the distribution of micronutrient supplements. The three most common ways to fortify food are through i) commercial fortification, which includes the addition of nutrients during the processing of food, ii) home fortification, the addition of micronutrients to food prepared at home, and iii) biofortification, which consists of breeding or genetically modifying plants to produce micronutrient-rich crops.

Fortification programs are gaining attention as an effective way of combating malnutrition in developing countries, and were ranked number 3 in the 2008 Copenhagen Consensus for being one of the most cost effective ways of addressing development challenges (Gómez-Galera et al., 2011). However, implementation of these programs still faces a number of hurdles, especially in the context of developing countries. In particular, developing countries may not have some of the prerequisites for food fortification – (i) food processing facilities (industry for food fortification is often not well established), (ii) quality control and monitoring systems, (iii) distribution infrastructure or (iv) either widespread awareness and demand for fortified foods, or regulatory support from the government (Bishai and Nalubola, 2002).

The existing nutrition literature on micronutrient fortification is extensive. Most studies find a positive impact of fortification on micronutrient deficiencies such as anemia, but less conclusive results on morbidity and cognitive development. Similarly, there is little evidence on the impact of fortification on school participation or learning (supplementation, on the other hand, has been found to increase school participation (Bobonis, Miguel, and Puri-Sharma, 2006), but there is
lack evidence on learning). Many of these studies establish causal impacts of micronutrient provision, often by using randomized-controlled-trial methodology, but one drawback is that these studies evaluate carefully implemented and highly monitored interventions. For example, in many of these studies, the intervention occurs in school with compliance ranging from 75% to 100% (Best et al., 2011). One policy-relevant knowledge gap we identify is how to design such interventions to deal with the potential issues that affect compliance such as limited awareness about the importance of micronutrients, weak incentive schemes for food providers, inadequate monitoring and the ensuing possibility of corruption and other leakages in government-run programs.

In this paper, we identify several avenues for further research, with an emphasis on economics and policy. As described in the previous paragraph, one important avenue for research is to evaluate fortification programs and policies in developing-country contexts. We also identify potential contributions relating to demand generation for fortified products, as well as the issues involved in home fortification and biofortification.

While this paper focuses on research and policy relating to fortification as a means to combat malnutrition, it is, of course, not the only means of doing so. In particular, provision of micronutrient supplements receives considerable policy attention as well. We focus on fortification precisely because supplementation has received more policy and research attention: we believe there is room in the literature for an overview piece focused on fortification. In fact, there already exist several policies and programs in South Asia that incorporate supplementation, although they have not been completely successful. Nevertheless, in section 2.4, we briefly discuss contexts in which fortification or supplementation may be more appropriate. We conclude that depending on the context and type of malnutrition, it is likely that a combination of the two approaches will be most effective in addressing malnutrition across the South Asian population.

Similarly, we focus on South Asia because of the widespread micronutrient deficiency in the region. India, Pakistan and Bangladesh together account for half the world's underweight children. Deficiencies in micronutrients such as riboflavin, folic acid, vitamin C, and calcium are common in the region, but the deficiencies creating the greatest public health burden are iron deficiency anemia, iodine deficiency disorders and vitamin A (Chakravarty and Sinha, 2002). These deficiencies have severe consequences on health, such as blindness, goiter and impaired cognitive development.

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2 Malnutrition can also be combated through dietary change, although this has received very little policy attention.  
3 For example, in India, as of 2005-06, only 23% of pregnant women had received sufficient iron and folic acid supplements during their last pregnancy and only 25% of children receive regular vitamin A supplements (International Institution for Population Sciences, 2007). In Bangladesh in 2007, only 55% of pregnant women took any iron supplements but 88% of children received vitamin A supplements (NIPORT, 2009). In Pakistan, 60% of children under age five received vitamin A supplements, but only 16% of pregnant women took sufficient iron supplements (NIPS, 2008).
In our discussion, we abstract from several important economic and policy issues relating to fortification. Importantly, we take as given the interest in pursuing policies to encourage fortification of food. We do not discuss in detail the economic rationale for pursuing these policies. This rationale could include the correction of incomplete information, poverty alleviation or paternalism. Further, we do not discuss the potential for broad mandates for fortification of certain foods or the political economy issues surrounding these mandates. While mandates are indeed an important policy tool for fortification, public acceptance of fortification as well as adequate infrastructure for fortifying and distributing fortified food are likely important prerequisites for support of these mandates.

This paper proceeds as follows. Section 2 describes what we know about fortification from the nutrition literature, including its effectiveness and the pros and cons of different strategies under certain assumptions on delivery and compliance. In Section 3 we describe the current state of micronutrient fortification policies in South Asia. Section 4 expands upon what we do not know about how to design and implement policies to use this tool to reduce malnutrition. We believe this discussion motivates numerous research questions that economists can help address, such as how to implement scalable delivery mechanisms and how to induce households or firms to adopt fortification practices. Section 5 concludes.

2 Evidence from the Nutrition Literature

In this section, we review some of the most relevant work on fortification and highlight some important findings, with an emphasis on studies conducted in developing countries. The nutrition literature draws a distinction between commercial fortification (during the processing of food, such as the iodization of salt), home fortification (in the household just before consumption), and biofortification (genetic modification of crops to be more micronutrient-rich). While most of the literature has focused on commercial fortification, the potential benefits of home and biofortification are increasingly being recognized. Thus, while we focus on commercial fortification, we briefly discuss home fortification and biofortification in the sub-sections that follow. This section concludes with a comparison of the effectiveness of fortification and supplementation.

A number of studies have established the effectiveness of fortification interventions through rigorous randomized-controlled-trials (RCTs). However, many of these studies test the effectiveness in highly controlled environments, emphasizing the need for more research in true field settings.

Surveying several studies on food fortification with iron, Alderman and Horton (2007) note that most interventions find significant reductions in the prevalence of anemia. While the literature is

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4 A more detailed discussion of these issues is provided in Musgrove (2004).
extensive and finds broadly similar results, we focus here on RCTs in South Asia.\footnote{These studies were compiled from searches through PubMed, the American Insitute of Nutrition’s online Journal of Nutrition database, and the Cochrane Database of systematic reviews. Studies were included based on the following criteria: RCTs that took place within the past decade in South Asia (although we considered work in other developing countries).} For example, in an RCT conducted in the Indian state of Karnataka, Anderson et al (2008) found that adding iron compounds to salt led to improvements in hemoglobin levels and iron status among school children. Anemia rates dropped from 16.8% to 13.2% and 7.7% after a period of 5 and 10 months, respectively. Such results seem to be robust across different types of fortification.\footnote{We discuss the potential advantages and disadvantages of home and biofortification relative to commercial fortification below.}

Varma et al (2007), in a study conducted across 30 anganwadis (daycare centers) in West Bengal, India, find that iron and hemoglobin levels increase significantly among children who ate khichdi (rice and lentils) that was mixed with an iron premix\footnote{Iron premixes often contain vitamin A or folic acid, which may improve the absorption of iron.} in the anganwadi kitchens. Anand et al (2007) conduct a study in anganwadis in Haryana, India, and also find a significant decrease in anemia when children were given candies fortified with iron and vitamin A. Akoto et al (2010) look at the effectiveness of meals fortified with multiple micronutrients including iron in schools in Himalayan villages in India. Both treatment and control groups were first dewormed at baseline. After eight months, the authors found that the prevalence of anemia as well as underweight children decreased in both groups, but more so in the treatment group.

Fortification of foods with iodine, salt in particular, has long been established as a critical long-term public health measure for improving iodine deficiency and preventing endemic goiter, although mandatory iodization does not guarantee the eradication of goiter in the short run (Jooste, Weight, & Lombard, 2000). Double fortified salt (DFS, fortified with iron and iodine) has also been found to improve both iron and iodine deficiencies (Asibey-Berko et al., 2007; Zimmermann et al., 2004), but other studies find more nuanced results.\footnote{Depending on the formula for fortifying the salt with iron, iron fortification may reduce the impact on iodine levels or change the color in some local foods in India (Anderson et al., 2008). Another study in Africa found that dual fortification increased iron status, but not hemoglobin levels (Wegmüller et al., 2006).}

In a recent review of twelve studies that test the impact of food fortification with multiple micronutrients (MMNs), Best et al (2011) concludes that MMN fortification improves micronutrient status, reduces the prevalence of anemia, reduces respiratory and diarrhea related diseases, and interacts positively with de-worming.\footnote{None of the studies reviewed in Best et al (2011) coincide with the studies we have summarized above.} At the same time, they do not find strong evidence of improvements in cognitive outcomes.\footnote{For example, a double blind, placebo RCT in the Philippines finds that a micronutrient fortified beverage improved iron and iodine status in anemic and iodine deficient children, but had no significant effects on physical or cognitive ability. However, in an RCT conducted by Whaley et. al. (2003) in Kenya, children receiving supplemental food with meat (not fortified foods) significantly outperformed all other children on the Raven’s Progressive Matrices.} The twelve studies focused on school age children and were conducted in developing countries (except for one study in Australia). Five of these studies were RCTs. Beverages were fortified in six studies, milk products were fortified in 5
two studies, biscuits fortified in two studies, and seasoning/salt was fortified in two studies. Compliance rates were reported to be between 75 and 100% in the eight studies that reported compliance.

The nutrition literature has also emphasized the cost-effectiveness of fortification, most often measured as the average cost per disability-adjusted life year (DALY) saved.\(^\text{11}\) Using data from WHO’s CHOICE (Choosing Interventions that are Cost Effective) database, Horton (2006) concludes that fortification with iron, vitamin A, and zinc averts a significant number of infant and child deaths and are highly cost-effective. Using the DALY framework to estimate cost-effectiveness, she finds a benefit-cost ratio of 70:1 for salt iodization and 6:1 for iron fortification, which rises to 36:1, if we include an estimate of cognitive benefits.\(^\text{12}\) Alderman and Horton (2007) calculate the cost per person per year of iron fortification to be in the range of \$0.10–1.00. However, Fiedler et al (2008) report enormous variation in the levels of estimated costs reported by different micronutrient interventions. The types of delivery systems used, country characteristics, year in which the study was done, program characteristics, and costing methodologies contribute to the variability in cost estimates found in the literature. It is not clear whether these cost estimates include expenses necessary to attain such high compliance rates.\(^\text{13}\)

Despite the consistency of these findings, the extent to which the results on the efficacy of nutrient fortification are generalizable to population-wide interventions and to other settings is not obvious. There are a few studies that examine population-wide interventions, such as cereal grain micronutrient fortification in the 1970s in the US (Grosse et al., 2005; Popkin, Siega-Riz, and Haines, 1996), but the counterfactual is not well-established. There is some evidence that mandatory salt iodization eradicated goiter in some countries (Switzerland, in particular), but endemic goiter has persisted in other European countries with mandatory iodization (Bürgi, Supersaxo, and Selz, 1990; Delange and Bürgi, 1989) and again it is not easy to establish causality. Further research on the true causal impacts of population-wide fortification in developed countries on micronutrient intake and health are warranted, but it would still be difficult to generalize such findings to developing country contexts. The degree of the deficiency, other health conditions such as malaria and the prevalence of worms, food consumption patterns, and nutrient inhibitors in the typical diet are some factors that can influence the efficacy of a micronutrient intervention.\(^\text{14}\) The true impact will also depend on the take-up rates when fortified foods are provided in a less controlled setting. Finally, cost effectiveness also depends on other factors such as population density, delivery systems, availability of adequate infrastructure, and transportation costs.

\(^{11}\) The DALY framework provides a way to quantify the burden of a disease, by combining measures of mortality and morbidity. See Stein et. al. (2006) for a thorough discussion of the DALY framework.

\(^{12}\) These benefit-cost ratios require several speculative assumptions about the effects of food fortification on cognitive ability and physical productivity.

\(^{13}\) We suspect these expenses, such as labor costs, are not included in the cost estimates, because the main component of fortification costs in the budgets reported is the fortificant (or micronutrient) itself, constituting as high as 80 percent of total costs.

\(^{14}\) For example, phytic acid, phenolic compounds and calcium can inhibit iron absorption (Hurrell, 2002).
2.1 Home Fortification

Some examples of home fortification are a sachet of micronutrients to be sprinkled on a meal prepared at home, or a fortified spread that can be eaten with some cereal product (Alderman and Horton, 2007). While this kind of fortification can be more costly per capita than commercial fortification (due to packaging and distribution costs), it is likely to be more effective for certain kinds of populations. The intervention can be targeted to groups that are particularly vulnerable to deficiency and less likely to obtain enough micronutrients from foods fortified for the general population, such as infants, people in isolated areas or refugees (Horton, 2006). Zlotkin et al (2001) see a reduction in the incidence of anemia among infants (6 to 18 months old) in rural Ghana when given either iron fortified sprinkles, or sprinkles fortified with both iron and zinc. The rate of recovery from malaria was higher in the treatment group that received sprinkles fortified with iron.\(^\text{15}\)

2.2 Biofortification

The technology to produce biofortified foods is still under development, but these foods have the potential to overcome some of the obstacles inherent in commercial or home fortification. Meenakshi et al. (2010) argue that biofortification has the potential to be more cost effective than supplementation and commercial fortification for governments in developing countries, especially South Asian countries. Investment in biofortification mainly involves investment in research, breeding and testing at the initial stage; these fixed costs can be spread over a large population (Alderman and Horton, 2007; Stein et al., 2006). In addition, there are fewer recurrent costs: once farmers obtain biofortified seeds, they can reproduce the seeds themselves. The fortified products can then penetrate urban areas when production surpluses, if any, are marketed (Gómez-Galera et al., 2011; Meenakshi et al., 2010). Because of the production structure, biofortification is likely to be more effective at reaching remote or rural areas, where many households rely heavily on subsistence agriculture.

The nutrition literature contains fewer studies on biofortification, but the existing studies indicate that biofortification could also be an effective way to fight malnutrition.\(^\text{16}\) For example, in a study conducted in the Philippines, Haas et al (2005) find that rice biofortified with iron increases iron content for women who had low iron content at baseline. They also observe that the subjects did not prefer regular rice to biofortified rice (or vice versa), indicating that sensory changes (such as taste or appearance of the rice), if any, were not significant.

\(^{15}\) We note that these ‘sprinkles’ could be considered a supplement, but we follow the literature in calling them home fortification. For example, Zlotkin et al (2001) compare sprinkles to a more standard supplement for infants (iron drops) and find that they are equally effective. They argue that sprinkles are easier to use and more easily accepted than iron drops, which may improve compliance.

\(^{16}\) For further discussion on biofortification, see Gillian (2012) in this volume.
2.3 Fortification vs. Supplementation

Results from the nutrition literature also provide insights into the advantages and disadvantages of fortification versus supplementation. We argue that the task for policy makers is to identify which will be more effective in the relevant context. In particular, supplementation can usually be provided in higher doses to treat more severe deficiencies, but the supply chain requirements may be more costly for widespread deficiencies or for large target populations. In addition, compliance may be higher for some fortified foods if the consumer is simply substituting products, but lower if, for example, the taste or cooking time changes appreciably. In this subsection we provide evidence from the literature on three points that speak to the context-specific advantages of each type of intervention.

First, the nutrition literature establishes that fortification and supplementation have different impacts biologically. Fortification may be less efficacious than supplementation because of technological constraints: it is not feasible to fortify food with large doses of micronutrients. In addition, the bioavailability of the compounds used in the fortification process—the fraction of the dose that is absorbed by the body—often differs from that used in supplements (Horton, 2006; Le et al., 2006). Similarly, the effectiveness of fortifying foods depends on whether enough of the food vehicle is consumed among poor populations in developing countries (Alderman and Horton, 2007; Baltussen, Knai, and Sharan, 2004). Le et al. (2006), in a study conducted in Vietnam, show that fortification is one-fifth to half as effective (at increasing iron content in the blood for moderately anemic children) as supplementation with optimal compliance, largely because of the smaller amount of iron provided in the fortified food as opposed to the supplement. At the same time, while both methods have been shown to be effective at improving health status, there is some evidence that supplementation may be associated with small additional risks.

Second, the literature suggests that the prevalence of the deficiency can affect the relative effectiveness of fortification and supplementation. In general, when the deficiency is not widespread and there is a narrowly defined target group, supplementation may be more cost-effective. For example, supplementation is considered essential for pregnant women and lactating mothers. On the other hand, supplementation may not be sustainable for large populations with widespread deficiencies. Baltussen et al. (2004) analyzes the cost effectiveness of supplementation and fortification programs under 50, 80 and 95 percent coverage. The authors conclude that iron supplementation has a larger impact on population health than fortification, but that the cost of supplementation rises sharply as coverage increases, partly because of the

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17 Part of the issue is how much of a particular food poor households can afford. However, increasing consumption may be controversial if it is at the expense of a varied diet: fortified rice, for example, could easily constitute too great a proportion of a poor household’s diet even if the absolute amount is not enough to provide a sufficient dose of nutrients.

18 Gera and Sachdev (2002) review studies on the impact of iron supplementation on the incidence of infections in children and finds that oral iron supplementation has no significant effect on incidence of infectious diseases, but does increase the risk of developing diarrhea. The authors suggest that fortification of foods may be a safer option.
difficulty of reaching remote areas. Horton (2006) also finds that supplementation costs more per DALY saved than fortification for iron, vitamin A and zinc at 80 percent coverage.

Finally, there is reason to believe that adoption and compliance rates will differ between fortification and supplementation. It may be more difficult to stimulate demand and ensure compliance for supplements, which require modification of behavior, while fortified staples may be more easily substituted for unfortified staples. Many causes of non-compliance, such as perception of side effects, delayed drug response, difficulty in keeping track of doses, and superstitions or other beliefs about the supplements, may either not arise with fortification or may be easily addressed (Galloway and McGuire, 1994). At the same time, adoption of fortified foods will depend on whether there are any appreciable differences between the non-fortified and fortified substitute (for example, in taste or cooking time). Baltussen et al. (2004) find that the effectiveness of supplementation interventions is reduced by suboptimal geographic coverage, non-compliance, and “patient” factors (patients often misunderstand instructions, have incorrect beliefs about side effects, or can become frustrated about the frequency and the number of pills).

3 Fortification Policies in South Asia

Recently, South Asian governments, along with various international organizations and donors, have stepped up efforts to address hunger and malnutrition in the region and have explored the potential of food fortification to combat these problems. Here we describe some recent initiatives to fortify food, but this should not be viewed as a comprehensive list.

3.1 India

Political support in India for micronutrient interventions and fortification, specifically, has been slow and inconsistent. Iodization of salt became mandatory in 1998 when the government banned the production and sale of non-iodized salt. These restrictions were lifted in 2000 in response to pressure from a nationalist group as part of a campaign against foreign goods (Prabhat, 2000), but were reinstated in 2005 (UNICEF, 2005). Nevertheless, in 2005-2006, 24% of households used salt with no iodine content and only 51% of households used adequately iodized salt (International Institution for Population Sciences, 2007).

Double-fortified salt (DFS) has received increasing policy attention recently. A press release from the Prime Minister’s office revealed renewed interest in the cost effectiveness of fortification to address malnutrition. The government prescribed legal standards for DFS and hinted at moving towards mandatory double fortification of salt. The government has also publicized plans for advertising DFS through a media campaign, mandating its use in government feeding programs in schools, exploring the possibility of supplying DFS to the poor through the Public Distribution System (a national food security program that distributes subsidized food and other goods to the poor across India) and establishing private-public

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19Adoption of either supplements or fortified foods will depend on how well the product is designed for the target population and the marketing strategies. We believe methods to increase compliance warrant further study.
partnerships to increase domestic production of DFS (Prime Minister’s Office, 2011). Some states, such as Tamil Nadu, have already made progress on the distribution of DFS, but these recent developments signal headway towards resolving one nation-wide obstacle in the use of fortified foods: the absence of a directive from the Central Government on the regulation of fortified foods and their use. Without such a directive, NGOs working in this area often find it difficult to motivate local governments to allocate money towards fortifying food in schools. Similarly, the food processing industry is unlikely to accept the cost increase of fortifying foods without a mandate, unless there is demand from consumers.

Some headway has also been made in the commercial fortification of wheat in India, although it has been slow and there are a number of challenges to widespread adoption. Less than 5% of the wheat processed is currently fortified with iron, despite various state government policies to promote and distribute fortified wheat flour (Dutta and Wesley, 2009). The primary challenge to this strategy is that only 20% of wheat consumed in India is processed by organized mills. The remaining 80% is processed by local mills (chakkis), which process the grain for individual households. A recent intervention aimed at getting chakkis to supplement the grain during the milling process for households demonstrated a positive impact on anemia when take-up was high, but there was no impact on anemia on average as take-up fell to 20-40% after one year (Banerjee, Duflo, and Glennerster, 2011). On the distribution side, the Government of India has taken steps to distribute this flour through the Public Distribution System (PDS), but does not currently have the necessary storage facilities and other infrastructure (Dutta and Wesley, 2009).

In addition, wheat flour is primarily consumed in North India, while rice is the main staple in the South and in the East. A large number of Indian households do not consume enough wheat to get a sufficient dose of iron from fortified flour. On the other hand, iron fortification of rice can be technically challenging, as it can change the color of the rice and make it unappetizing, although there is continued development in this area (Moretti et al., 2006). As noted above, biofortification of rice may be an effective alternative strategy (Haas et al., 2005).

Another possible food vehicle for iron fortification is ‘soyadal’, a soy-based compound that is rich in protein, and produced to look like lentils. Adding this product to regular lentils in the recommended proportions does not affect their taste or appearance appreciably. Currently, there are a few producers of soyadal in India, and while available on the market, few households purchase it regularly. It is, however, used in midday meals in primary and upper primary schools in a number of states (Naandi Foundation, 2011).

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20 The mandated use of fortified ingredients in government programs seems appropriate as a first step towards large-scale adoption of fortified foods, although a plan to distribute ready-to-eat meals through school feeding programs backfired when anganwadis (preschools) were directed to provide only cooked meals (The Telegraph, 2008). Proponents of the ready-to-eat meals cite the meals’ high nutritional content, but the proposal to replace current cooked meals with these meals generated much controversy due to reports the meals were not popular with children and mothers and of bad quality (The Times of India, 2010). Lobbyists on both sides of this debate have a vested interest in how the school meals are provided, speaking to political economy issues plaguing the implementation of large-scale programs.
3.2 Bangladesh

Salt iodization in Bangladesh has been somewhat more successful than in India. The Government mandated that all edible salt be iodized in 1989, but even in 1996, only about 20% of households were consuming adequately iodized salt. Following an increase in efforts to improve awareness of iodized salt and the implementation of a comprehensive monitoring and quality control system (UNICEF, 2011), this figure rose to 84% in 2002-2007 (World Bank Staff, 2009).

In general, there has been strong public and private sector commitment to food fortification in Bangladesh. The Bangladesh Food Fortification Alliance was formed in 2003 as part of the government’s efforts, and consists of members from the public sector, private sector, international donors and civil society. A recent study by the United States Agency for International Development documented the potential of fortifying oil and wheat flour (MOST, USAID, 2004). Fortifying soybean and palm oils with vitamin A appears to have potential: consumption of these (unfortified) oils is adequate and could supply more than 50% of the required amount of vitamin A. Technical costs are 20% cheaper than for wheat fortification and only 0.46% of the retail price of oil, but when import tariffs are included this cost rises by 50%. Between 80% and 90% of the oil imported is processed by three large producers, making commercial fortification feasible (Dary & Rassas, 2004). In 2007, a national oil fortification program was launched by the government, the Vegetable Oil Refiners Association and the Global Alliance for Improved Nutrition (GAIN), to add vitamin A to seventy percent of all cooking oil in the country (GAIN, 2007).

Oil fortification is unlikely to provide iron and other micronutrients, however. Explorations into the feasibility of wheat flour fortification suggest that the decentralization of mills may present a challenge for large-scale fortification, and given current consumption patterns, it could supply about 20% of required vitamin A, iron, folate and other micronutrients (Dary & Rassas, 2004). Along with Building Resources Across Communities (BRAC), GAIN also has a “sprinkles” project to improve the nutritional status of children aged 6-24 months. Despite these advances, the fact that rice is the main staple in Bangladesh suggests that developments in the ability to fortify rice would be more promising. Very recently, BRAC, along with the Bangladeshi government and Harvest Plus, started planning a program to fortify rice with zinc.

3.3 Other Initiatives across South Asia

In contrast to the experience of other South Asian countries, Sri Lanka has adopted a successful set of policies promoting salt iodization. According to UNICEF, 94% of households consume iodized salt (2008). Fortification of foods with other micronutrients, such as iron and zinc, has been slower. Efficacy trials using iron-fortified wheat flour did not produce promising results, perhaps due to the low consumption of wheat flour in the country. In September 2009, the government discussed the mandatory fortification of wheat flour and potential pilot studies for rice, but little progress has been made since then. Rice, rice flour, salt and sugar are currently
being considered as possible food vehicles in national food fortification programs (Hettiarachchi et al., 2004).

In Pakistan, the Universal Salt Iodization program was launched in 1994, but progress has been extremely slow. Only 17% of households consume adequately iodized salt (World Bank Staff, 2009). In 2005, Pakistan’s Ministry of Health, Pakistan Flour Mills Association, GAIN and the Micronutrient Initiative launched a program to fortify wheat flour, the country’s main staple, with iron and folic acid (GAIN, 2011). By March 2010, 125 mills were producing fortified flour and 12.7 million people had access to fortified flour. The government also took steps to provide iron-fortified flour in Islamabad, Lahore, Karachi and Peshawar at the same price as regular flour. With additional funding from GAIN, this project aims to expand fortification to 275 additional mills (GAIN, 2011).

Along with the Nepal Flour Mills Association and the Micronutrient Initiative, the Government of Nepal also launched a wheat flour fortification program in 2008. In August 2011, Nepal became the first country in South Asia to make the addition of micronutrients (iron, folic acid and vitamin A) in flour processed at roller mills mandatory. However, there is little information available on the efficacy of this program and other initiatives in Nepal.

Finally, there are multi-country initiatives as well. New public-private partnerships are being formed to explore ways of using biofortification to address malnutrition in the developing world. The HarvestPlus Challenge Programme (an iron biofortification program in India, Pakistan, Philippines, Bangladesh) is working on developing iron-rich rice and wheat varieties (Stein et al., 2006). The plan is for these seeds to reach farmers through the usual seed distribution channels without much impact on prices.

4 Avenues for Further Research

Despite the extensive nutrition literature on fortification, its ability to improve health status and its cost-effectiveness as measured in dollars per DALY saved, there is a paucity of evidence on how to effectively implement fortification policies in developing countries. In this section, we discuss the primary knowledge gaps, grouped into three topics: 1) distribution systems, including public and commercial distribution, 2) production, including how to get firms and farmers to fortify foods, and 3) demand formation and behavioral change on the consumer side. As noted in the introduction, we leave aside political economy questions related to the potential value of mandates and other regulations requiring adoption of fortified foods.

It is also worth noting that one can look to developed countries’ experiences with fortification as well as research on infrastructure, technology adoption and behavioral change to understand the challenges that developing countries face in adopting fortification. In the United States, fortification became mainstream during the twentieth century due to government legislation, the
involvement of the medical and public health community to create awareness and demand for fortified foods, and advertising campaigns of firms selling these products. Adoption of fortified foods was also facilitated by relatively high industrial concentration and by public-private partnerships between the government and the food-processing sector (Bishai and Nalubola, 2002).

4.1 Distribution systems

One important knowledge gap is how to distribute fortified products in a way that enables malnourished households to consume sufficient quantities. Many studies in the nutrition literature evaluate carefully monitored interventions where compliance rates are as high as 75-100%. In the real world, there are many factors that need to be considered in evaluating different strategies for distributing fortified foods, including who each strategy will reach, the infrastructure required, and the incentives, monitoring and enforcement needed for the food to reach its intended recipients. We discuss these in the context of three possible distribution schemes: through schools, through hospitals and through retail channels.

School-based distribution is commonly used in the existing evaluations of micronutrient fortification. One reason for this is that school-age children are important beneficiaries to target: they are undergoing substantial physical and mental development and therefore have nutritional demands beyond those of other populations. A second reason that nutrition is often provided in school is to create additional incentives for children to attend school, and thereby reduce the net costs of schooling for parents. While this might be effective when a full meal is provided, it is not obvious that fortifying an existing meal would increase the incentive, unless it is combined with programs to improve awareness of micronutrient deficiencies. Another advantage of school-based distribution is that, for some countries, the school system is the most comprehensive infrastructure available through which to reach children in remote areas. Even before there is political support for a more general mandate, governments can promote the use of fortified ingredients through schools.

The disadvantages of school-based distribution are the flip side of these benefits. There are important target groups not reached through schools. For example, there is evidence that children younger than school age are more likely to benefit from nutrition programs (Adelman, Gilligan, and Lehrer, 2008). In India, 70% of children under the age of five and 56% of ever-married women age 15-49 are anemic, making reaching these at-risk groups imperative. There is also a lack of evidence supporting the association between school-based fortification programs and cognitive development for school-age children or learning in school (Best et al., 2011), whereas there is more conclusive evidence that iron supplementation of infants and preschool children can prevent the cognitive impairment that results from iron deficiency anemia, although the long-term impacts are unknown (Horton and Ross, 2003). It is certainly possible that providing nutrition to children in school relaxes the household’s budget constraint, resulting in more nutrients for younger children and pregnant women. While there is some evidence of such
positive spillovers (Kazianga, de Walque, and Alderman, 2009), there is also evidence that parents do not substitute food away from children who receive a lunch in school (Afridi, 2010; Jacoby, 2002). In addition, reaching children currently not in school could also improve enrollment in school as the health of children out of school improves. Finally, despite the improvement in access to schools, there is substantial anecdotal evidence, particularly in South Asia, that the quality of the meals provided in school varies considerably, partly due to limited resources, inadequate infrastructure and widespread inefficiency and corruption. Currently, there is little evidence on whether and how the quality and nutritional content of these meals can be improved. Some possible strategies to improve these meals include better training for meal providers, a more direct mandate or incentives to include fortified ingredients and increased monitoring.

An ongoing study in the Indian state of Orissa compares several distribution strategies for iron-fortified soyadal (Berry, Shastry, and Tandon, 2011). Two of these strategies involve distribution through modification of the mid-day meals in primary and upper primary schools. One of these involves distribution of fortified meals through centralized kitchens, a model developed by Naandi Foundation and implemented in a number of states across India. A second strategy involves providing fortified soyadal directly to the contractors who currently provide mid-day meals for each school. These strategies will be compared both with each other and with a treatment that provides fortified soyadal to parents of schoolchildren.

Another way to provide fortification is through hospital or clinic distribution, although this might be a more natural channel for supplementation. In theory, the advantage to this strategy is that there is existing infrastructure to promote health awareness and possibly better targeting of households at-risk of micronutrient deficiencies. However, the performance of health clinics across India does not inspire confidence in either of these tasks. Health providers are absent on average 40% of the time and absence rates are higher in poor places (Chaudhury et al., 2006), where households are also more likely to be micronutrient deficient.21 Despite public health mandates to provide iron and folic acid syrup to pregnant women and vitamin A supplements to children, these treatments do not reach all of their intended beneficiaries: in India, 65% of pregnant women were given or purchased iron and folic acid syrup, but only 23% took it for more than 90 days, and only 25% of children receive regular vitamin A supplements (International Institution for Population Sciences, 2007). This is likely due in part to lack of demand for clinic services, these facilities being closed unpredictably and to the health facilities not being adequately stocked even when they are open. Research on how to improve the health

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21 A study in Udaipur, Rajasthan, demonstrated that facilities were closed 56% of regular hours, at least 40% of ‘doctors’ had no medical degree while 18% had no medical training at all, and that they provided treatment such as an injection or IV drip often without any diagnosis. Nevertheless, people claimed that the facilities improved their health, perhaps because they are better able to appreciate short-term fixes that make them feel better than preventative care and treatment with longer term benefits, such as micronutrient therapy (Banerjee, Deaton and Duflo, 2004). In addition, 20% of health-related visits were to traditional healers instead of health clinics and this was more likely among poor families in villages where the health facility was more often closed.
care sector’s performance and how to increase awareness among households on when to visit health clinics and what care to expect, are important open questions. There is little evidence on this, although one notable exception suggests that contracting to non-governmental organizations, where payment and contract renewal depend on achieving health targets, such as how many children receive vitamin A supplements, improved performance (Bhushan et al., 2007).

A third distribution option is commercial, through both private retail and public channels. While this option does not restrict the pool of recipients to children in school or households that visit health clinics regularly, it does restrict fortification to households who purchase these ingredients in the market. Because the goods provided can be more easily directed, one option would be to introduce fortified food through public or non-profit channels. For example, in India, the Targeted Public Distribution System (TPDS) sells food and other necessities to the poor at subsidized prices through “fair price” shops. However, the system is subject to substantial leakage (for instance, through the sale of goods by the shopkeepers on the black market). Khera (2011) estimates that almost 44% of foodgrains allocated for the scheme never reach the poor. The inefficiency of this system has led to calls for replacement of the scheme with food vouchers or cash transfers (see, e.g., Banerjee, 2011; Basu, 2010). Whether vouchers or cash transfers can provide better food security to the poor remains an empirical question. An on-going study is exploring the feasibility of such an intervention; a pre-pilot found that more than 95% of survey respondents expressed an interest in replacing the current system with a cash transfer program, although the minimum value of cash they required to give up the TPDS ration was higher than the value of the current subsidy (Muralidharan, Niehaus, and Sukhtankar, 2011). The State of Punjab is experimenting with the system by providing goods to some beneficiaries through a local NGO. While all beneficiaries can purchase fortified flour from the NGO, only a randomly chosen 10% receive all their goods from the NGO. An on-going study is evaluating the impact of this intervention (Nagavarapu and Sekhri, 2011).

4.2 Commercial Production of Fortified Foods

As described in Section 3, several fortified food products are already available in South Asia, and more may become available as demand develops. (We take up issues of encouraging demand below.) One way to encourage initial commercial production of fortified foods is through government procurement. Once the fixed costs of developing fortified products are sunk, commercial producers may be more likely to sell their products to the general public.

Commercial fortification is facilitated by strong infrastructure and centralization in the food processing industry, as well as quality control and monitoring systems (Bishai and Nalubola, 2002; Gómez-Galera et al., 2011). Even without such centralization, however, there are some initiatives targeted at getting small-scale producers to fortify food. For example, Micronutrient Initiative is collaborating with the World Food Programme in Rajasthan to explore a model where small-scale salt producers organize to increase their ability to iodize salt. At least 160
small producers were organized into 15 self-help groups, each with their own salt iodization plant, and more than 20,000 metric tons of iodized salt was produced within two months (Micronutrient Initiative, 2007).

4.2.1 Reaching Subsistence Consumers
One challenge to the distribution of fortified foods is reaching those who grow food for subsistence. According to the National Sample Survey Organization, 24% of rural households in India consume home-grown rice and 27% of households consume home-grown wheat (NSSO, 2007). Several options have been proposed to address this issue. First, if foods that are grown are processed in a central facility in a village, fortification could take place at that point. The study of chakkis in Rajasthan, described above, provides an example of how fortification can take place at the local level (Banerjee, Duflo and Glennerster, 2011). The intervention in Rajasthan had limited success, suggesting that more work is needed to explore whether local fortification, perhaps implemented more widely or combined with stronger information interventions or incentives, can be effective over the long term.

As described in Section 2, biofortification has been advocated as a means to reach rural populations that rely on subsistence farming or locally-sourced food. We note that biofortified crop technologies are, in large part, still at the development stage, and thus identifying the economic challenges in adoption and production is somewhat speculative. Nonetheless, we outline several potential issues below.

It is not known whether biofortified crop varieties, when developed, will be similar to currently-cropped varieties in the required inputs or yields. Prior research on the Green Revolution has shown that the need to experiment and acquire knowledge can slow adoption of new crop varieties, particularly in less educated populations (Foster and Rosenzweig, 1996). Thus, the extent to which biofortified varieties require changes in inputs can pose a challenge to adoption. Similarly, adoption can be slowed if yields are more variable or have different responses to environmental conditions compared with currently-cropped varieties. Even if the price of seeds does not change (as advocates argue), it is possible that farmers will require additional incentives to purchase these seeds, particularly since these seeds may not produce higher yields, as did the new varieties introduced during the Green Revolution.

To the extent that farmers produce food both for consumption and for sale on the market, market characteristics will also influence adoption of biofortified crops. For example, if the market for biofortified foods exhibits higher price volatility, farmers may be reluctant to adopt these crops. This may occur if the markets for these crops are thin as they develop.

To date, there has been very little research on adoption of biofortified crops. A notable exception is Gilligan (2012), in this volume. The author discusses a study on how subsistence farmers growing sweet potatoes respond to the distribution of vines bred to produce ‘orange-fleshed sweet potatoes’ that are rich in vitamin A. There was substantial take up of these vitamin A-rich
varieties in treatment areas, and the study finds evidence that social networks promoted technology diffusion. However, the study emphasizes the need to continue distributing these vines to have long-term impact.

4.3 Demand Generation

In the absence of mandates, generating demand for fortified ingredients by consumers will likely involve a combination of subsidies, information campaigns, and other promotional activities. While the potential benefits of many types of fortified foods have been quantified conditional on take-up, relatively little is known about the effectiveness of these alternative interventions in promoting adoption. Rigorous impact evaluation can assist policy makers in choosing between alternative means of promotion. Incorporating multiple interventions into a single study can allow direct comparison between alternative interventions.

Promotion of food fortification presents several specific challenges. First, research should be structured in a manner that is able to measure long-term behavioral change. Policies that are successful in promoting demand for products in the short term may have effects that erode over time. For example, the study of village-based flour fortification referenced above (Banerjee, Duflo and Glennerster, 2011) found substantial short-term impacts but modest long-term impacts. Second, not only do the longer-term effects of specific policies need to be measured, but the optimal duration of policies must be tested. This adds an additional dimension along which policies must be evaluated. In particular, researchers must identify the most cost-effective interventions and the length of time that these interventions must be in place. For example, in the short term, subsidies may be required to encourage experimentation and habit formation, but for some products, especially those that require behavioral change at home, short-term subsidies may not be enough to encourage long-term demand.22

A second challenge is measuring the effects of programs that will ultimately be implemented broadly. For example, randomized controlled trials may be unable to measure the full effects of advertising campaigns if these effects are only felt when the programs are implemented across large portions of the population.

In the case of subsidies, understanding the effects on adoption can perhaps take some initial lessons from the growing literature on pricing of health products such as mosquito nets, water disinfectant or deworming pills (see Holla and Kremer, 2009, for a review). Many of these studies find that large subsidies are needed to encourage take-up of a variety of health products. While there is some evidence that consumers with higher willingness to pay may use the products more intensively, there is no evidence that pricing encourages proper use (Ashraf, Berry & Shapiro, 2010; Cohen & Dupas, 2010). In the short term, encouraging take-up may be particularly difficult when the effects may not be immediate or felt acutely (Kremer and Miguel,

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22 Atkin (2012) in this volume, discusses how prices can generate habit formation.
2007). This may also be the case especially for fortified foods, where a single food typically provides only a fraction of the recommended allowance for a particular micronutrient.

Clearly, there are a number of differences between the health products studied in the pricing literature (e.g., water disinfectant, mosquito nets) and fortified foods, which restrict the lessons that can be learned from these studies. In particular, many fortified foods, such as double-fortified salt, require only changes in purchase behavior, but involve virtually no changes in the types of foods consumed. On the other hand, other products, such as soyadal and (perhaps) fortified rice, may require changes in cooking practices or may lead to changes in the taste of the food consumed. In this case, behavioral change is required at home, similar to many health products.

Thus far, little rigorous research has been done examining the effectiveness of information campaigns and promotional activities. As with subsidies, it is unclear whether short-term education campaigns can create persistent effects, or whether the campaigns themselves need to be persistent. In addition, because the effectiveness of information campaigns can be mediated by the type of product, context must be carefully considered in designing evaluations.

Future research should also consider the interactions between subsidies and other promotional activities in encouraging demand. It is possible that different types of take-up behavior can be encouraged by each intervention. For example, if information campaigns are not sufficient to generate initial demand alone, subsidies may be required initially to encourage short-term take-up and experimentation, and demand can be sustained through long-term information campaigns.

Ongoing work seeks to evaluate effective distribution strategies for double-fortified salt in the state of Bihar. The project aims to evaluate information campaign types and subsidy levels to encourage take-up of DFS and conduct an impact evaluation of the effectiveness of DFS availability in rural areas on health and economic outcomes (Banerjee, Barnhardt and Duflo, 2011).

5 Conclusion

This paper reviews the research on fortified food as applied to South Asia, with a particular emphasis on open questions for economics and policy. While consumption of fortified food has been established as an effective means of improving micronutrient deficiency and health, a number of important questions remain. In particular, more research is needed to establish take up and efficacy under interventions that could be adopted as widespread policy. This research should include studying the effectiveness of alternative distribution methods, such as schools, clinics, other public distribution channels, and the private sector. Within the latter two types of distribution, more research is needed to evaluate the determinants of demand for fortified

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23 Luo et. al. (2012), in this volume, report on a randomized evaluation of several health education interventions targeted at reduction of anemia. The authors find no significant impacts of the education interventions.
products, and in particular, strategies that promote long-term adoption of fortified foods. Such analysis is complicated by the potential complementarities between strategies, long-term nature of the outcomes, and diverse circumstances under which fortified food is purchased and consumed. Nonetheless, given the established effectiveness of fortified food in controlled settings, a deeper understanding of mechanisms is needed to support and inform widespread provision.

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