The Cost Efficiency of Home Modifications to Reduce Healthcare Costs

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Abstract

The existing quantity of housing dedicated for older adults is not sufficient to meet the needs of this growing population. And even as the Centers for Medicare and Medicaid Services reimbursement structures are shifting from traditional inpatient and outpatient settings to care in the home, it is a commonplace that most homes were not designed or built to support the needs of aging residents or the provision of healthcare. It is time for America's 100 million existing houses to be made as safe and accessible as possible for aging in place. Falls cost over $50 billion a year in medical expenses. This paper distills current knowledge regarding healthcare cost reductions from home modifications, and then calculates the cost efficiency to society and to the federal government of providing government subsidies for home modifications for older adults at the ages of 50, 65 and 75. Cost sharing among insurers, government and the beneficiary is one way to achieve the positive social returns.

*I would like to thank Louis Tenenbaum, who introduced me to this area of study and from whom I have learned many of the ideas shared here. This paper has benefited by comments from David Abraham and Louis Tenenbaum on an earlier version, but they have no responsibility for any remaining errors.

Growing older at home has long been Americans' overwhelmingly preferred housing option (AARP, 2012) (AP-NORC, 2021).[1] Appropriately, the healthcare industry is preparing for a future that includes the efficiencies of home-based care (Landers, 2016). But is the home safe? According to the US Census Bureau's 2019 American Housing Survey, of the 14(19) million households headed by someone 75+(65-74), 46%(22%) had an acknowledged accessibility problem (entering the home; getting to the bedroom, kitchen or bathroom; or using the bedroom, kitchen or bathroom). Also see Molinsky (2020).

In this paper we show how the federal government might catalyze the widespread installation of home accessibility features *and save money doing it*! As explained by Thaler and Sunstein (2008), sometimes it can be sufficient to provide a 'nudge' in the direction of desired behavior.[2]

This paper progresses through the following chain of logic to reach its conclusions. The existing housing stock, which was built for a much younger population, is simply not ready to accommodate the requirements of the evolving homeowner demographic. This outdated housing stock becomes, literally, an accident waiting to happen when it comes to its contribution to falls of older citizens. The installation of home accessibility features is uniquely foundational in its ability to limit costly falls, while also bringing many other benefits. Within a framework of the 'Economics of Prevention', a simple model is developed to derive the healthcare cost/benefit of fall-prevention from home modifications. Model simulations identify a cost-effective role for the federal government to subsidize the installation of accessibility features for adults at the ages of 50, 65 and 75 years of age. With properly designed programs the government can recover all of its subsidy, and more. The paper concludes by reviewing limitations of this work and offering next steps for policy makers.

Where we are now

In recent years people have been turning to their homes to age in place in increasing numbers. In part this is pure demographics: with steadily increasing longevity and the leading edge of the Baby Boom generation having turned 65 in 2010, the population 65 and older is expected to more than double from 35 million in 2000 to 73 million by 2030 (Howden (2011), Vespa (2018)); by 2035, a third of households are expected to be headed by someone who is aged 65+ (Joint Center, 2019b).

Economically, many Americans have no choice but to age in place because they do not have the financial resources to do anything else (Pearson, 2019). But the pandemic has also revealed previously unappreciated risks of congregate care facilities (Mathews (2020), Economist (2020), Inzitari (2020), Abrams (2021)). The Centers for Medicare and Medicaid Services (CMS) is increasingly pivoting its reimbursement policies from traditional inpatient and outpatient

[1] To limit the visual clutter, each citation in the text will provide only the first author's name even when there are multiple authors. All authors and document links are provided in the Reference list at the end.
[2] The authors define 'nudge' as 'any aspect of the (context in which people make decisions) that alters people's behavior in a predictable way without forbidding any options or significantly changing their economic incentives.'

settings towards care in the home (Pifer (2021), Holly (2020)); the healthcare industry is moving towards a 'hospital at home' model (Piatkowski (2019), Leff (2021)).

AARP has been writing about the importance of updating one's home since at least 1991 (Salmen, 1991). The National Home Modifications Action Coalition *Blueprints* report was published in 1997 (Center for Universal Design, 1997). The MetLife Mature Market Institute published its report on Aging in Place in 2010 (Tenenbaum, 2010) while the National Council on Aging and Center for Disease Control and USC Leonard Davis School of Gerontology websites all provide advice, practical information and serve as clearinghouses for information on state and local programs.[3] [4] Many existing elder care programs include home remodeling as part of their recommendations; it is one of the three pillars of the widely embraced CAPABLE program (Szanton, 2016).

The 2011 American Housing Survey included detailed questions on accessibility features and is interpreted in Bo'sher (2015) and Will (2015). Ten years ago, 33% of all housing units had the basic structural requirements of a stepless entry with a bathroom and bedroom on the main floor, but only 4% of units had those features *and* were also equipped with no steps between rooms or railings and grab bars; only 0.15% of all dwelling units were fully accessible to someone in a wheelchair. The shares were closer to 40%, 10% and 0.6%, respectively, when the sample is limited to households where someone has a disability. Ultimately, whether the accessibility feature glass is half empty or half full depends on how well the need matches reality on a house-by-house basis.

Half full? The 2011 National Health and Aging Trends Survey (NHATS) that samples specifically households headed by someone at least 65 years old found that 61% of the respondents had at least one accessibility feature to support bathing and toileting (Meucci, 2016). 20% of homeowners over age 60 say they've made improvements to age in place (AARP, 2012) and two-thirds of homeowners over age 55 say they consider themselves to be proactive in making aging-in-place renovations (Cusato, 2016).

Or half empty? Over half of home service professionals indicate that aging-in-place projects account for less than 10% of their work. Of those projects, up to a third are in reaction to medical events which means the updates often must be made at the last minute while the family is already coping with other healthcare needs (Cusato (2016), Joint Center (2019a)). Naik (2005) identifies underutilization of environmental adaptations for bathing, while Lam (2021)

[3] Many federal agencies provide programmatic and direct financial support of home remodeling for selected groups in the community, including the Department of Veteran Affairs for veterans, the Department of Agriculture for rural homeowners and the Department of Housing and Urban Development and the National Association for Area Agencies on Aging for low-income elderly. Examples of published reports are HUD (2013), Stevens (2015), Healthy Housing Solutions (2017), Convergence (2020) and Vespa (2020).

[4] Australia created its Home and Community Care (HACC) program with its Home Modification and Maintenance Services (HMMS) in 1985. See Jones (2008) and Public Health Administration (2019). The UK instituted the means-tested Disabled Facilities Grants (DFG) program under the Housing Grants, Construction and Regeneration Act 1996. Its current annual budget exceeds £500 million. A program assessment is provided in Heywood (2001).

finds that of those individuals identified as having a problem in bathing and toileting in the 2015 NHATS, four years later in the 2019 survey 42% of those needs remain 'unmet'. Admittedly it can be challenging to assess the 'true' situation out there: Ahn (2011) find self-respondents' assessment of the need for home modifications is heavily colored by their current home satisfaction.

Aging in place has been demonstrated for many to be instrumental in preserving their quality of life and supporting the social determinants of health (Carnemolla, 2018). For both family pocketbooks and the federal government, extending time spent aging in place reduces dependence on higher-cost congregate care facilities. And most easily quantified, home modifications that enable safe aging in place can reduce the frequency and severity of falls, directly saving healthcare dollars. Beyond altruism, it is in American society's financial interest to change the existing home modification delivery system.

Lessons can be learned from the market for residential solar panels, which in the last 20 years have gone from upscale oddities to commonplace commodities. Unquestionably their embrace has benefitted from technological advances and falling production costs. But generous government subsidies have been part of a positive feedback loop, promoting and in turn benefiting from higher societal demand for 'green' energy.

Fall Mitigation and Home Modifications

Falls are the leading cause of injuries and injury-related death for adults over the age of 65, in America costing over $50 billion annually along with unquantifiable life changes and disruptions (Collins, 2019). Truly a worldwide issue (WHO, 2008), there has for many years been extensive development of fall mitigation interventions generating a deep literature around program development and testing.[5]

Systematic literature reviews (SLRs) seek to identify the salient results from programs that include environmental screening for hazards, education, exercise and environmental modification. The research varies extensively in sample population age, size, pre-existing conditions, is typically combinations of interventions (multifactorial), experiences varying degrees of subject follow-through on instructions, and has performance tracking of different lengths of time and intensity.

Gillespie (2012) updates a 2009 Cochrane survey covering many kinds of fall intervention studies; its 420 pages attest to its exhaustive breadth! They limit their scope to studies utilizing

[5] The central role that housing features play in life quality and healthcare requirements is comprehensively covered in WHO (2018). In this paper we are focused on the narrower issues of accessibility and fall prevention. Specifically on these topics the WHO observes that 'the certainty of evidence that home safety modification programmes reduce the risk of injury was assessed as *moderate*, while … the certainty of the evidence that a higher number of hazards in the home is associated with an increased risk of injury was assessed as *moderate to high*' (page 62).

the statistically rigorous random controlled trial (RCT) methodology and aggregate the results of 159 separate studies covering 79,193 individuals. They find that many group-, home- or Tai Chi exercise programs can be effective, reducing falls by 30%.[6] For home safety interventions they find an average 30% reduction in falls and 20% reduction in the number of fallers; those with a higher risk of falling were found to benefit more from the intervention.[7]

As the vast majority of the time of elderly is spent 'at home,' the home is a natural place to evaluate the person-environment fit (Gitlan, 2003). Professionally published papers citing interventions identified as addressing 'home safety' or 'environment modification' can vary widely in program design. Their intensity of home assessment can range from a single visit from a government employee with a checklist moving identified hazards to multiple visits from a team of medical, physical therapy, and occupational therapy (OT) professionals followed-up with handyman services to make structural changes to the home. The timeframe for follow-up can range from 2 months to 18 months. Results for the intervention cohort may be compared with a control cohort of similar risk profile, or with the experience of the same cohort just prior to the intervention, or even with a comparable population that just hasn't yet received their requested environment modification services from the state. The number of participants in most of these studies are in the low hundreds – with one study having as low at 10 participants – limiting their ability to deliver statistically significant results beyond a few primary questions.[8]

Even as systematic literature reviews seek to make sense from the heterogeneity in test design, they can become echo chambers that amplify the findings of a handful of papers, however truly rigorous or comparable. Clemson (2008) summarizes results of 6 papers to conclude that there can be a -21% reduction in falls from 'environment interventions', with a -39% reduction for high-risk individuals (history of falling, functional decline, visual impairment). As they should, the same 6 papers show up in Gillespie (2012). Pighills (2015) reaches the same conclusions as Gillespie after reviewing 9 papers, seven of which were part of Gillespie's sample. Stark's (2017) conclusions are broadly similar as well after reviewing 36 papers, though this paper starts out by framing its question a bit differently, being to identify the 'effectiveness of home modification interventions within the scope of occupational therapy.'

The scoping review by Carnemolla and Bridge (2018) (referred to below as C&B) has a different objective and one that aligns well with the focus of this paper. It finds 77 papers from 16 countries cataloging specifically home modification impacts and they go beyond fall reduction to improved function; self-care or independence; physical health and well-being; caregiving; economic effectiveness; ageing process; and social participation. This broader view is made possible through not relying exclusively on RCT trials. The authors accept the limitations to

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[6] See Clemson (2004).

[7] Gillespie (2012) also includes results from controlled interventions of medicine management, surgery, psychological work, vision improvement and nutrition that do not concern us here.

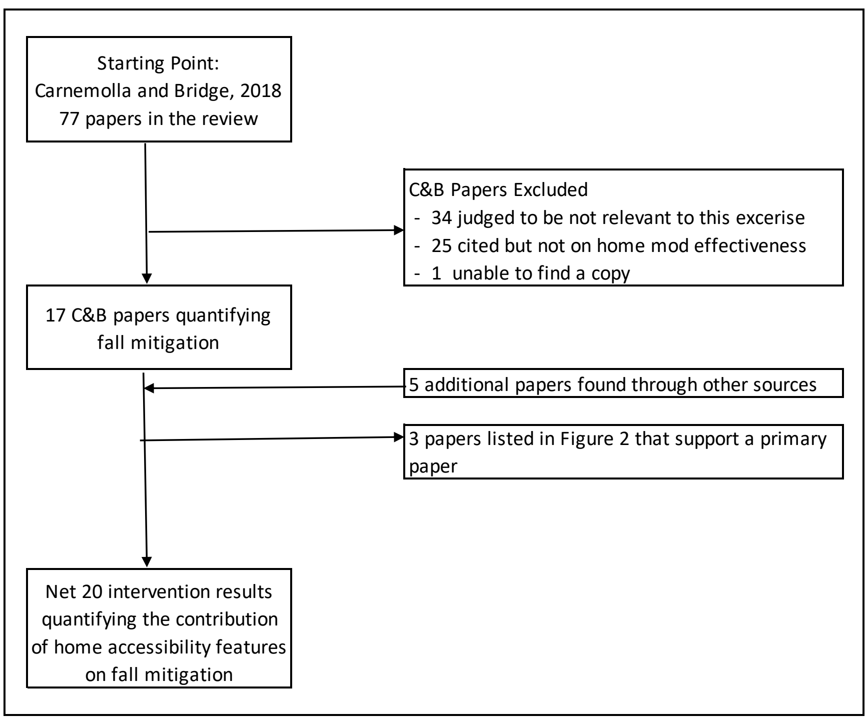
[8] There are also a growing number of programs being offered in the community that do not yet have the more rigorous statistical results of academic studies. See North Carolina Housing Finance Agency's Urgent Repair Program, Baltimore's HUBS program (IMPAQ, 2019), Detroit's MHIS (Gaydayenko, 2020) and DC's Safe at Home program (Crowell (2017), Sheffield (2013)).

tight quantification of many of these impacts, citing the absence of single-factor studies of specifically the home modifications and the imprecision across studies regarding what even constitutes a 'home modification.'

Quantification of Fall Reduction from Home Modifications

A formal systematic literature review selection process for this paper would inevitably have been largely duplicative of the surveys already cited. This paper therefore embraces the scoping review effort of C&B as its own. The paper review and selection process gone through here starts with their compendium of 77 papers, while also including readings from other SLRs cited as well as other relevant papers however sourced, as shown in Figure 1.

Figure 1
Flow Chart illustrating the Selection, Inclusion and Exclusion of Home Modification Articles listed in Figure 2



Our result is 20 papers, each of which are listed in Figure 2 along with summary information about the study population, intervention and results, and the reported quantified results of the intervention. These are all the original research papers, disintermediating literature reviews.

It is evident from the paper summaries that each one of these studies has a story of its own, with not always clear quantified results on the contributions that the installation of structural accessibility features makes to home safety. Very encouraging program results are reported in Stark (2021) which focuses on hazard removal (the only site installation is grab bars/hand rails) for a 65+ population that recently had a fall or expressed fall anxiety. Their intervention costs averaged $765.83 while generating health care savings in the 12-month assessment period that amounted to $1613.63.

Some studies reviewed but not cited here included an OT-guided 'home modification assessment' that remained vague regarding whether any structural modifications were made to the property at all. Just to give a flavor of the diversity among studies that made the grade: Keall's 'modifications' included getting smoke detectors working, correcting inadequately fenced driveways and reducing excessive hot water temperatures; Cumming's largest 'modification' was removing dangerous floor mats; many of Cumming's, Nikolaus' and Palvanen's modifications were undone by the client during the evaluation period.

The Eriksen (2015) study most closely matches our use. Their clever design looks at the fall reduction benefit from features installed in the home for the first-to-die spouse that accrue to the surviving widow(er). Their data set is 1005 homeowners that are 65 and older in the longitudinal Health and Retirement Survey who were recently widowed between 2000 and 2010. To control for the risk that the home features were installed for the survivor (which if true would invalidate a foundational premise of this exercise), in their statistical work they use the deceased spouse's functional status as measured by ADLs as an instrumental variable for the accessibility features. The safety and accessibility features are not singled out individually but statistically treated as a group using a dichotomous variable (0/1) and may include: a ramp, railings, modifications for a wheelchair, grab bars or shower seat, call system and 'other features.' For those receiving the intervention, the study finds a -21.8% reduction in serious falls for the whole population and a -38.6% reduction for individuals aged 75 and older. They observe from their data that the 'safety and accessibility features do not reduce overall fall activity, but instead attenuate the severity of falls,' that is they find a reduction in 'serious' falls that incur expenses.

For our Baseline model simulation below we adopt the results of Eriksen: the installation of accessibility features brings a 20% reduction in serious falls for individuals 65 and over and a 40% reduction for individuals 75 and over with chronic conditions. These numbers are consistent with a scan of the final column of Figure 2. In fact, the consistency of the 20%/40% results in that Figure is striking, even while each study may have a small sample size, quirks in adoption rate, definition of 'home mod' and effort at behavior modification.

Figure 2

Fall Reductions from Home Modifications

#	Reference*	Description	Finding
1	Eriksen (2015)	Population: #1005; 65+ mean age 75; in US Intervention: track widower fall rates controlling for dead spouse's safety features Results: no reduction in falls but significant reduction in serious falls	-21.8% in serious falls -38.6% serious falls 75+
2	Tinetti (1994)	Population: #301; age 70+ with risk factors; in US Intervention: Medication review, behavior and exercise instruction, If nec grab bars, handrails, and raised toilet seat; 4.5mths of engagement Results: fall reduction; cost of $12,392/fall requiring medical attention	-24% fall reduction -31% falls per person-week
3	Hornbrook (1994)	Population: 3182; age 65+ mean age 73; in US Intervention: removal of fall hazards, teaching, fitness classes, help installing bars Results: reduction in falling, reduction in fallers, but not serious falls; tracking through 24m	-15% fall reduction 0% effect on injury falls 0% effect on multiple falls
4	Plautz (1996)	Population: #144; 60+ mean age 75; in US Intervention: VISTA worker with checklist; Avg $92.80 hardcosts and $50-100 labor Results: Track 6mth prior and post intervention	-59% in total falls
5	Close (1999)	Population: #397; aged 65+ mean age 78; selected post fall treatment in hospital; in Australia Intervention: Medical treatment, OT visit with checklist, move rugs; refer to govt for equipment Results: 4,8,12m follow up; observe some falls b/c ice on pavement or external hazards	-61% in total falls -67% in recurrent falls 0% diff in serious injuries
6	Cummings (1999)	Population: #530; 65+ with mean age 77; in Australia Intervention: most common is to remove floor mats; 50% compliance at 12 months Results: only helped those with prior falls (-36%); conclude need OT to change behavior	-19% in total falls
7	Peel (2000)	Population: #252; aged 51+ mean age 69; in Australia Intervention: OT with checklist; renovations negotiated with govt services 59% have atleast one mod to environment v 32% in control group Result: reduced concern about falling; fall differences btwn groups all statistically insig after 12m, -5% fall and -30% injurious fall; after 24m, +8% fall and +9% injurious fall	0% change in falls
8	Salkeld (2000)	Population: #530; aged 65+ mean age 76; in Australia Intervention: OT with checklist; renovations installed with govt services Mods: rug removal, nonslip bath mats, install handrails, pathway repairs, lighting Result: oddly find higher total medical costs for intervention Group	-36% decline in falls for those with fall in previous year
9	Stevens (2001)	Population: #1737; aged 70+, RCT; in Australia Intervention: home hazard assessment; free installation and education Results: 12m report window; no difference inside v out, around hazards or in total falls	0% change in falls
10	Day (2002)	Population: #1090; aged 70+; in good health; in Australia Intervention: city staff labor use checklist and up to $54 to fix hand rails, floor coverings, etc Results: no fall reduction even though home hazards decreased from 10.2 to 7.4	0% change in falls
11	Nikolaus (2003)	Population: #360; mean age 82 with multiple chronic conditions; in Germany Intervention: home mods, OT, PT, social worker Results: within 12 months many changes reversed; conclude need to change behavior	-31% in total falls -37% for frequent fallers -15% injuries
12	Liu (2009)	Population: #9447; aged 70+; comparison of 2 waves of LSOA survey; in US Intervention: track functional abilities of residents with varying mod install levels Result: 2yr report window; modestly greater functional decline without mods	-3.1% decline in physical function
13	Stark (2009)	Population: #67; aged 60+ with mean age 82; in US Intervention: pre/post compare with OT guided AT, safety mods and structural changes Results: 3m and 24m follow-ups; avg mod cost of $635	'improved' performance of daily activities; 'reduced' environmental press
14	Pighills (2011)	Population: #238; age 70+ with fall history; RCT; in United Kingdom Intervention: OT v Home Health worker guided enviro assessment and hazard removal 'where possible hazards were removed or repaired during 1-2 hr visit;' Results: no reduction in fear of falling; -46% in falls in OT group; -22% insig fall drop in HH group	unclear resuts
15	Mitoku (2014)	Population: #547; age 65+ mean age 81; in Japan Intervention: install handrails, eliminate floor heights, change lavatory basin Results: fragility and mortality tracked at years 2, 3, 4.7	-48% mortality after 2 yrs -35% mortality after 4.7 yrs
16	Palvanen (2014)	Population: #1269; age 70+ at high risk; RCT trial at Fall clinic; in Finland Intervention: many services; 1 hr home visit with checklist, with home hazards 'reduced' Results: 12 month tracking period; home mod adherence was at 14% at 12 months	-28% in total falls -22% in fallers -26% in fall-induced injuries
17	Szanton (2014) &(2019) Ruiz (2016)	Population: #263; lower income; 65+ mean age 76; difficulty with 1 ADL or 2 IADLs; in US Intervention: CAPABLE which is OT, PT and $1222/client in home mod fixes Results: 20 week tracking period; $22k/2yr savings to Medicare Ruiz estimates a $22,000 net Medicare savings over two years	-30% in ADL disability score Improved Quality of Life scores
18	Kamei (2015)	Population: #110, aged 65+ mean age 76; RCT; in Japan Intervention: home hazard self modification after education session; grab bars only structure change Results: 12w and 52w check-in; insig results for <75 year olds intervention group had 16-30% of identified hazards removed at 12w/52w check-ins	-14% falls of 75+ after 52w -11% indoor falls of 75+ after 12 w
19	Keall (2015)	Population: #842 mean age 43; people on govt subsidies; in New Zealand Intervention: Mean $450US spent fixing hazards and safety issues assessed by builders Results: 3 year observation Efficacy challenged in Robinovitch (2015)	per person per year: -26% in injuries caused by falls -39% in home mod related falls
20	Stark (2021)	Population: #310; aged 65+ mean age 75; RCT with AAA clients in US Intervention: OT-guided home hazard removal: grab bar installation, adaptive equip, task mod Results: After 12 months; achieve 90+% compliance; find avg $765.83 cost with $1613.63 savings	No reduction in # of fallers -38% in total falls No change in other 2nd outcomes

* Only first author. All interventions identified in Carnemolla and Bridge (2018) and in many other SLRs, with the exception of Eriksen (2015), Stark (2021) and Hornbrook (1994)

This is not to discount the legitimate concerns of Keall (2015) and Cummings (1999) that it may be more the person than the environment that needs the modification: the introduction to the home of accessibility improvements without *some* behavior modification would clearly achieve nothing.[9] Rather we'd suggest that the consistency across study results points to there being a likely wide variety of methods for achieving behavior modification that are not limited to training from occupational therapists. The consistency in finding a larger effect for interventions for people with prior falls – perhaps they are more receptive to the message – may be a reminder that for change to be sustained it needs to be embraced by the client and not imposed from the outside. In the Eriksen study, the old-dogs may have learned their new tricks by watching their (now deceased) spouse utilize the home accessibility features.

A Framework for Evaluating Home Modifications

A central thesis of this paper is that expenditures to update homes with accessibility features should be recognized as cost effective healthcare *prevention*. But proving that is a tough mountain to climb because true prevention means incurring costs for many who may ultimately never benefit from the intervention. (And while not a problem with the intervention proposed in this paper, many medical interventions can be accompanied by negative side-effects.) Congressional Budget Office (2020) states that 80% of prevention spending improves healthcare but on net, increases costs.[10] That only 20% of prevention spending is deemed cost effective in part reflects CBO's specific methodology which uses a 10-year window for discounting expenditures and savings, incorporates only *federal government* expenditures and savings, and seeks to incorporate all secondary impacts on federal spending -- noting in particular any cost shifting *towards* the federal government such as incremental healthcare spending that results from delayed mortality.

The CBO acknowledges that even if only 20% are cost effective according to their criteria, a higher 60% of prevention spending produces clinical benefits that the research community considers reasonable. Typically, research conclusions are reached through derivation of an incremental cost effectiveness ratio (ICER) of dollars per quality adjusted life year (QALY) or disability adjusted life year (DALY). That approach to evaluating home modifications is discussed in a later section; the modeling focus in this paper embraces the CBO approach.

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[9] As noted in Lord (2006), there is a complex interaction between capability and environment, with the existence of hazards not equating to realized falls. For example, more active individuals may take greater risks and hence experience greater falls than frail individuals. Lord concludes the greatest home modification benefit comes to those with a history of falls and mobility limitations.
[10] See (Carroll, 2018).

Figure 3
The Three Stages of Prevention

	Primary	Secondary	Tertiary
Prevention Conceptual Structure*	Measures intended to prevent the onset of a condition	Measures intended to detect disease in clinically asymptomatic people at an early stage when it is most treatable.	Measures to slow the progression of a disease after it is clinically obvious and a diagnosis established.
As applied to modifying a home with accessibility features	This is the broad population with undiagnosed needs but, if they live long enough, will eventually 'age-in' to needing accessibility features to keep safe.	Individuals of advanced age are at risk of needing accessibility features.	Established fall-risk individuals. Likely of advantaged age, may have fallen previously, may have multiple chronic conditions.
Conceptually in the Model	Households headed by someone age 50+ who is planning to renovate their home and might consider including accessibility features in their scope.	Households headed by someone age 65+ who is covered by federal health insurance (Medicaid or Medicare).	Households headed by someone 75+ who is already 'disabled'. Conceptually this is comparable to the CAPABLE study population.
In the Model Simulation	P1. The 1.36 million households headed by someone who turns 50 in 2020 that do not already have accessibility features installed in their home.	P2. The 1.50 million households headed by someone who turns 65 in 2020 that do not already have accessibility features installed in their home.	P3. The 200,000 households headed by someone who turns 75 in 2020 who is identified as 'disabled' in the American Housing Survey.

* Academy Health (2013)

Expenditures to prevent or reduce healthcare spending can be usefully characterized as falling into one of the three stages shown in Figure 3 labeled primary, secondary and tertiary (Academy Health, 2013). Cost versus benefit calculations will be unique to each of the three-stages as conditions vary with how tightly each population is identified, treatment side effects, false positive results and the duration of effectiveness:

- Tertiary prevention treatment (P3) applies to those individuals who are of particularly advanced years (here taken to be 75 years old), have a history of falls, may have multiple chronic conditions, and may be limited in their ADLs or IADLs. We think of this group as being conceptually comparable to the CAPABLE study population.
- The secondary prevention population (P2) is considered to be all 65+ year olds who have now aged into being 'at risk' for needing accessibility improvements and who are all covered by federally-sponsored Medicaid or Medicare healthcare insurance.
- Finally, we consider the primary prevention population (P1) to be those individuals who could choose to install accessibility features in their home even while being years away from actually 'needing' them themselves. Over half of home remodeling expenditures are made by households headed by someone aged 50+ (Joint Center, 2021), so this is a population ripe to be incentivized to add accessibility features.

The populations we've described that fit into these groups are Americans at the ages of 50+, 65+ and 75+, respectively. For simplicity in the simulation work below we focus on the age cohort that in the year 2020 turned 50, 65 or 75.

A Model of Cost Savings

A straightforward Excel model of the cost effectiveness of home modifications has been developed for this paper.[11] Model inputs for the P1, P2 and P3 prevention Baseline scenarios are shown in Figure 4. This aging model starts with a given population of owner-occupied households (2020's 50 year-olds, 65 year-olds or 75 year-olds with a disability in lines 1-3), modifies all of their homes spending line 14, and plays-out the effects on falls (lines 7-10) being reduced (or not) in every subsequent year of their lives while they remain in the same property. The population at the start of each subsequent year is the prior year figure less move-outs and deaths (lines 4-5). We run each simulation until the (initially) 50-, 65- or 75-year old reaches the arbitrary age of 90. At that point an individual in each cohort has a 20-25% probability of remaining alive and in their original residence; for federal government cost-effectiveness calculations the meaningful time period is just the first 10 years. To make our calculations we need data on the healthcare system cost of serious falls (line 11) and fatal falls (line 12) and the percent reduction in falls from the home improvement intervention (line 16).

Figure 4
Baseline Model Inputs for all scenarios*

		P1	P2	P3
Population				
Population	1	1,491,868	1,759,036	1,250,747
Population share eligible	2	100%	100%	28%
Share needing home mod	3	91%	85%	57%
Moves and Deaths				
Annual Move-out rate (Avg)	4	0.82%	1.48%	1.73%
Annual Mortality rate (Avg)	5	1.35%	5.33%	7.46%
Life expectancy (years @ start)	6	31.45	19.17	12.03
Fall Rates				
Annual fall rate (Avg)	7	11.42%	30.20%	32.80%
Serious falls share of annual falls (Avg)	8	15.37%	36.80%	37.20%
Serious fall rate creating costs (Row7*Row8)	9	1.75%	11.11%	12.20%
Fatal fall rate of population (Avg)	10	0.013%	0.070%	0.105%
Fall Costs				
2020 cost of serious falls ($000)	11	11.499	11.499	11.499
2020 cost of fatal falls ($000)	12	30.972	30.972	30.972
2020 per capita healthcare spending ($000)	13	22.765	22.765	22.765
Home Improvement				
Cost of home improvement ($000)	14	4.400	4.400	4.400
Baseline annual rate of home mods	15	2.5%	2.9%	4.3%
Fall reduction from intervention after age 65	16	-20%	-20%	-40%
Fall reduction effectiveness in year 5	17	100%	100%	100%
Financial				
Government share of Home Mod cost	18	100%	100%	100%
Government share of medical costs	19	75%	75%	75%
Medical cost inflation rate	20	3.0%	3.0%	3.0%
Discount rate	21	3.0%	3.0%	3.0%

* (Avg) indicates simulations use values that vary across time; the value reported here is the simple average through age 90

The baseline simulations assume the government absorbs all of the accessibility modification costs (100% in line 18). That proves to be too large a share to be cost effective – even with a

[11] A conceptually similar approach is undertaken in Smith (1998) for a population close to our P3. They construct a decision tree model, populate transition rates sourced from an OT consultant and published sources, and adopt a home mod fall reduction of -25% based on Tinetti (1994). With inputs of $172 in home modification costs and $17,208 fall injury costs, they find a net savings of $92 per person (all in 1996AUS$) in their ten-year simulation.

75% government share of fall costs (line 19). As shown in the numerical results below and discussed at greater length in the conclusion, smaller government home mod payment shares do prove to be cost effective, leading to the positive result in this paper.

In the simulation federal government costs are assumed to *increase* when falls are reduced from two avenues: fewer deaths mean that some people live longer, so we need to know per capita federal healthcare spending (line 13) and life expectancy (line 6); modifications that occur in the first year of the simulation at the government's expense are substitutes for self-financed modifications that would have occurred in subsequent years, so we need to know the existing rate of home mods (line 15).

Documentation for the sources and thinking behind each of the model inputs is provided in Appendix A. A printout of the model for the Baseline P3 simulation, along with text describing out the simulation works, is provided in Appendix B.

Figure 5 reports the Baseline results along with selected sensitivity exercises to some of the key assumptions. The columns report key simulation summary statistics separately for society (the Direct Financial Savings Results) and for the federal government (Government Savings Results). For each of these accounting views the columns include: the year that cumulative savings finally exceed costs (if it occurs), the cumulative net savings at year 10, and cumulative savings in the final year of the simulation (year 16 for P3).

The full Baseline simulation is displayed in Figure A2; key summary statistics are bolded in the top line of Table 5. We see it takes 11 years for society to recover the $878M of intervention costs. The federal government accounting, which recognizes only 75% of the healthcare savings and includes other modest incremental costs from the intervention, never breaks even. In year 10, the end of CBO's time frame, the government is carrying an intervention deficit of $420M; at the end of the simulation in year 16, the government's discounted deficit has fallen to $235M.

There is no need to perform sensitivities to the total population figure (lines 1-3 in Figure 4) since the effect of that number is simply to scale the entire cost effectiveness calculation. If move-out or death rates are higher than baseline (line 2 in Figure 5), savings are reduced. If the cost of the home modification is only $2000 instead of the baseline $4400 (line 3) *with no change in fall reduction effectiveness*, savings increase and move the society cross-over point ahead to year 5; the government reaches break even in year 9. If the home modification is only half as effective in reducing falls than the baseline's -40% assumption, costs exceed benefits, with an only slightly smaller effect if the modification's fall reduction effectiveness degrades over 5 years to being only half as effective (for P3 to -20% starting in year 6). If fall costs are $30,000 rather than the baseline's $11,500 (line 7), savings are greater. Small changes to the inflation rate or discount rate (lines 8 and 9) yield modest changes to the savings numbers.

Figure 5
P3 Results Sensitivity to Alternative Input Variable Assumptions

Sensitivity	Specific Change		Direct Financial Savings Results: Year Discounted Savings > Costs	Direct Financial Savings Results: Cum Net Savings @ Year 10 ($Mil)	Direct Financial Savings Results: Cum Net Savings @ Cohort aged 90 ($Mil)	Government Savings Results: Year Discounted Savings > Costs	Government Savings Results: Cum Net Savings @ Year 10 ($Mil)	Government Savings Results: Cum Net Savings @ Cohort aged 90 ($Mil)
Baseline		1	**11**	**-56**	**+242**	**never**	**-420**	**-235**
House Tenure	Increase the mortality/move-out rate by 5 percentage points	2	never	-208	-56	never	-506	-412
Home mod expense	Decrease to $2000	3	5	+423	+721	9	+59	+244
	Increase to $10,000	4	never	-1174	-876	never	-1537	-1353
Fall Reduction	Decrease fall reduction from -40% to -20%	5	never	-467	-318	never	-649	-556
	Decrease fall reduction effectiveness to 50% in year 5	6	never	-366	-218	never	-594	-502
	Increase nonfatal fall cost from $11,499 to $30,000	7	4	+1234	+2001	6	+492	+1008
Inflation/Discounting	Inflation=3%/Discount rate=6%	8	14	-142	+68	never	-481	-358
	Inflation=6%/Discount rate=3%	9	10	+73	+507	never	-347	-77
Fed Cost Sharing	Reduce Fed HM cost share from 100% to 50%	10				10	+19	+203
	Reduce Fed HM cost share from 100% to 20%	11				4	+283	+467
	Increase Fed cost share from 75% to 100%	12				never	-255	-5
	Reduce Fed Medical cost share from 75% to 58%	13				never	-532	-392
Fed Cost Increments	Zero out Fed increments (R,S)	14				never	-262	-38

The federal government remains in the red for the Baseline and most of these sensitivity exercises. However, reducing the government's payments for the modification to 50% (line 10) it breaks even in year 10; reducing its cost share to 20% (line 11), it breaks even in year 4. Line 14 teaches us that the incremental fed cost increments amount to $160M over the ten-year period (158=420-262). These various sensitivities show that more accelerated net benefits and a positive federal result are possible for reasonable alternative input values, particularly with cost sharing, but there is also a good chance the real world economics can be worse than in the baseline.[12]

Figure 6 provides a table for P2 simulation results and sensitivities. Key changes from the P3 simulation are the fall reduction effect of -20% in P2 versus -40% in P3, and the additional ten-year length of the simulation that gives the opportunity for greater societal savings to cumulate. Compared to P3, here the baseline Direct Savings no longer show the home modifications costs are more than balanced by the healthcare savings from fall reduction (alone). In general, the pattern of results across the sensitivity exercises is similar to P3, but with a much more delayed cross-over point. If the costs are shared 50/50, the government

[12] It's useful to see how the widely embraced CAPABLE program would present in this framework. Szanton (2019) only reports program performance metrics around reduced ADL and IADL difficulties, improved walking, self-care and less depression. But Ruiz (2017) quantifies the healthcare savings as being $2765 per quarter per person for 2 years. With the program spread out over 2012-2016 (so assume 2014 dollars) we can translate that into $13,184 annual savings in 2020 dollars. The program spending per client was $2825 for all services, including up to $1300 in home modification expenses (one third less than our line 3 figure of $2000). Updated to 2020 that's $3368. That's a hugely worthwhile investment: to pay $3368 and receive at least two years of $13,184 savings.

savings turn positive now after 23 years rather than the 10 years shown in Figure 5. When the federal government shares in only 20% of the costs, the government gets its investment back in 8 years, within CBO's 10-year time horizon.

Figure 6
P2 Results Sensitivity to Alternative Input Variable Assumptions

			Direct Financial Savings Results			Government Savings Results		
Sensitivity	Specific Change		Year Discounted Savings > Costs	Cum Net Savings @ Year 10 ($Mil)	Cum Net Savings @ Cohort aged 90 ($Mil)	Year Discounted Savings > Costs	Cum Net Savings @ Year 10 ($Mil)	Cum Net Savings @ Cohort aged 90 ($Mil)
Baseline		1	**never**	**-3441**	**-329**	**never**	**-4912**	**-3043**
House Tenure	Increase the mortality/move-out rate by 5 percentage points	2	never	-4045	-2695	never	-5236	-4434
Home mod expense	Decrease to $2000	3	10	+148	+3259	20	-1323	+545
	Increase to $10,000	4	never	-11814	-8702	never	-13285	-11416
Fall Reduction	Decrease fall reduction from -40% to -20%	5	never	-5010	-3454	never	-5745	-4811
	Decrease fall reduction effectiveness to 50% in year 5	6	never	-4667	-3112	never	-5567	-4632
	Increase nonfatal fall cost from $11,499 to $30,000	7	8	+1512	+9549	13	-1341	+4079
Inflation/Discounting	Inflation=3%/Discount rate=6%	8	never	-3794	-1819	never	-5167	-4117
	Inflation=6%/Discount rate=3%	9	18	-2915	+2210	never	-4630	-1534
Fed Cost Sharing	Reduce Fed HM cost share from 100% to 50%	10				23	-1623	+246
	Reduce Fed HM cost share from 100% to 20%	11				8	+351	+2220
	Increase Fed cost share from 75% to 100%	12				never	-4326	-1804
	Reduce Fed Medical cost share from 75% to 58%	13				never	-5311	-3885
Fed Cost Increments	Zero out Fed increments (R,S)	14				never	-4225	-1891

Results for the P1 simulation are not reported. Using the model as described earlier, there is no fall reduction savings for the first 15 years until the homeowner turns 65. That eliminates the prospect for finding any savings to the federal government within the first 10 years.

It's not only about fall reduction

In the discussion so far the dollar savings from home modifications have come exclusively from reducing falls that precipitate high healthcare expenses. But C&B identify disciplined studies that document other less tightly quantified benefits that include improvements in physical and mental well-being, self-care and independence, and caregiving. A literature survey from the UK concludes, 'there are already findings that the provision of housing adaptations and equipment for disabled people produce savings to health and social care budgets' (Heywood, 2007, page 9).

Changes to the built environment provide many other advantages to residents that go beyond fall mitigation and can be measured, but just not so easily in dollars and cents. Findings in the literature include improving independence and slowing the rate of functional decline generally (Mann, 1999) and for dementia patients (Gitlan, 2001) and for those with developmental disabilities (Hammel, 2002) and for those with early-onset disability (Wilson, 2009). Petersson

(2008) finds no improvement in independence but observes reduced difficulties and greater safety when performing ADLs. Gitlin (1999) finds greater safety from the installation of bathroom equipment.

Home modifications can bring reduced dependence on caregivers along with greater safety (Carnemolla, 2011). A (self-reported) survey of 157 recipients of (Australian) government-subsidized home modifications with a mean age of 72 years found meaningful reductions in formal (-16%) and informal (-42%) caregiver hours, (Carnemolla, 2019). The results of Anderson (2013) are broadly consistent, finding assistive technology, which in that paper includes bath and toilet rails, to be complements to formal caregiving and substitutes for informal caregiving.

Modest home remodeling expenditures – that may include property maintenance as well as accessibility improvements - can be valuable for keeping low-income elderly safe and living in their community rather than forcing them into congregate care facilities and increasing costs to Medicaid. Relying on a resident's resourcefulness and existing network of home services for even a handful of months that delays a move to congregate care can make renovations cost-effective. Eriksen (2015) finds that accessibility features lower move-out rates leading to a 10% reduction in nursing home stays during their 2-year observation window. Tinetti (1997) draws a direct link from serious falls to increased likelihood of moving to a skilled nursing facility. Hwang (2011) finds that modifications extend the time people age in place in their home, while Newman (1990) finds the opposite, that they do not reduce the likelihood of institutionalization.[13] The City of Chicago's HomeMod Program has reduced the cost of personal care services and emergency transportation for its participants by roughly $7000, however its service population is low-income individuals with disabilities *under* age 60 (Cowan, 2020). A study for the state of Minnesota providing a cost comparison of home-based living versus facility-based living identifies a monthly cost difference of $1000 (assisted living) to $4000 (skilled nursing); their estimate of the average renovation expenses needed for their population was $15,749 (Warren, 2016). Genworth reports annually on the 'Cost of Care' across service providers. Their numbers for 2020 range from homemaker services for someone remaining in their home (44 hours weekly) at a monthly cost of $4500 to a private room at a nursing facility at a cost of $8800.

There may also be a benefit from anticipating a potential future need that is not strictly prevention. Homes that are made accessible to those with disabilities can make it possible for individuals who require rehabilitative services to return to their home after a hospital stay rather than be forced to relocate to an institutional setting to remain safe. To our knowledge, no studies have examined that potential benefit, which is only recently becoming a true option as home-services and insurance reimbursement allows. Importantly, prepared homes also support the visitability of family or social acquaintances who require these accommodations.

[13] Safran-Norton (2010) identifies a more complex scenario, with couple household transitions unaffected by home modifications, while single household transitions are reduced by exterior improvements while an increase is correlated with interior improvements.

These comments should not be construed to suggest home modifications are an alternative to the services of occupational therapists. One would hope that any healthcare situation with an identified need for OT services is already receiving them. Rather as laid out in Figure 3, here the emphasis is on prevention *before* there is an identified need. Should a need then occur, the presence of already installed accessibility features or government subsidies that facilitate their timely installation become a tool for successful OT results.

All of these study results and community programs represent an acknowledgement that value accrues to residents and communities from upgrading their housing stock with accessibility features. Therefore, the federal government needn't be the only source of funding, and perhaps even shouldn't be.

The Model not Taken

An alternative to the simple modeling approach taken here would be to use a 'markov macro-simulation model'. There, as is done here, a starting population transitions through a sequence of various events leading to differing outcomes and costs until death or a terminal point. Knowledge of state transition heterogeneity across sub-populations can generate much more nuanced results than reached here.

Pega (2016) uses this technique to address a very similar question to ours: 'to determine the health gain, cost-utility and health equity impacts from home safety assessment and modification (HSAM) for reducing injurious falls in older people.' They analyze the cost-effectiveness of a HSAM program in place for 65+ year-olds in New Zealand that pairs an OT assessment with home modifications, including total intervention costs in 2011 of only US$169(!). The model input assumption of the fall reduction magnitude from the intervention is -19%, drawn from Gillespie (2012).

Pega's broad conclusions are strikingly similar to ours here: lifetime dollars saved do not cumulate to exceed upfront costs; concentrating efforts on higher risk populations (either those older or those with a history of falls – roughly our P3 versus P2) reduces the cost-effectiveness gap but doesn't flip the results to net savings. In addition to dollars they measure savings in terms of 'quality adjusted life years' (QALY), a metric that has been in use since the 1960s and embraced by the WHO and in many countries.[14] They find significant gains in QALYs and a very favorable incremental cost effectiveness ratio (ICER) of $6000(US) per QALY, far below the standard threshold of $50,000 per QALY. They point out that concentrating efforts on higher risk populations does create better ICERs and could well be the prudent starting point for policy

[14] The British National Health Service uses QALY metrics to resolve competing demands for treatment within its limited financial resources. QALY offers a systematic process for combining morbidity (quality of life) and mortality (length of life) into a single index that can be used to evaluate the relative benefits of qualitatively different treatments. Despite its perhaps dubious theoretical underpinnings, it has been embraced through its introduction of rigor and sheer convenience MacKillop (2018). However, the commonly cited threshold of $50,000/QALY warrants review (Marseille (2014), Neumann (2014)).

initiatives, but that total QALYs saved by society will be lower than with a broad-based (i.e. P2 type) approach.[15]

Limitations

A consistent theme from the many SLRs that consolidate results from the wide range of fall mitigation programs is concern over their small samples and hence limited 'power' (the ability to reject a false hypothesis). That naturally leads to efforts like Gillespie (2012) to commingle data across even heterogeneous studies.

We acknowledge that challenge, which is one of the reasons we have emphasized the careful study by Eriksen (2015). A presumption that the placement of accessibility features in the home, even without the guidance of an occupational therapist, will bring a meaningful reduction in falls is central to achieving the cost-effectiveness of government support. While the breadth of multifactorial study results are consistent with the 20%/40% reductions used here, only the Eriksen study supports the results for a modification-only intervention. And of course, the Ericksen paper itself identifies its own potential limitations.[16]

There are abundant reasons one could question the strength of our result and hence the implications of this study: it is possible that those individuals at greater risk (e.g. already fell) might be more proactive at mitigating their own risks, limiting the nascent fall savings from the remainder incented to build in accessibility features (sensitivity #5); we assume no depreciation in the effectiveness of the intervention through the home tenure, which may be too aggressive as studies frequently report people reverting to former behaviors (sensitivity #6). Our analysis assumes there is no correlation between individual fall frequency and remediation costs, even though in the real world the distribution of population falls is skewed towards multiple falls of a more intensely at-risk population, making it likely that these multiple-fallers will endure quicker mortality or institutionalization and thus may not generate savings for as many years as assumed in the model (sensitivity #2). To simplify the simulations we have assumed all of the modification benefits occur immediately, when in practice it could take many months to complete all modifications, changing costs little but shaving the fall-reduction benefits. Each of

[15] Olij (2018) is an SLR that reviews the effectiveness of a cross section of 31 fall mitigation programs (exercise, home assessment, medication adjustment, multifactorial, other) through the lens of their reported ICERs, finding 'investing in fall prevention programs for adults aged 60 and older is cost-effective, particularly home assessment for community-dwelling older adults… programs were found to be more cost-effective as the age of participants increases.' Frick (2010) finds home modification programs that include OT and PT services to be the 'best value' across alternative hip-fracture reduction programs, costing $14,794/QALY. Jutkowitz (2012) calculates ICER relative to a straightforward measure of 'life years saved' (LYS) by tracking mortality 2 years after the ABLE (the pre-CAPABLE) program intervention in 2003. They find a $13-15,000 cost per LYS. A back-of-the-envelope calculation at the end of Keall (2015) finds a favorable ICER relative to a measure of 'disability adjusted life-years' (DALYs) from their HSAM program.

[16] Turner (2011) reads many of the same papers discussed here and comes to the, to us inexplicable, conclusion that 'there is very little high-grade evidence that interventions to modify the home physical environment affect the likelihood of sustaining an injury in the home.'

these cautions warrants a close look, even as we believe the core message here is sound and should not be subject to death-by-a-thousand-cuts.

Conclusion and Policy Implications

This paper has not produced a new result that overturns the tepid 'C' rating by the US Preventive Services Task Force on the preventative benefits of home modifications.[17] But Stevens (2005) gets right to the point that 'falls and fall-related injuries represent an enormous burden to individuals, society, and to our health care system. Because the U.S. population is aging, this problem will increase unless we take preventive action. We need to refine, promote, and implement effective interventions.' Kochera (2002) goes further to observe that 'approaching programs from a cost perspective focuses on what can be easily measured or estimated and does not include other hard to quantify, but arguably more important, factors such as improved quality of life and peace of mind for older persons and their families. In addition, this type of approach does not factor in the non-health care costs that older persons and their families save (such as lost time from work) as a result of fewer falls.' More than 15 years later, this paper provides a path to moving more aggressively from research to modifying behaviors and practice, as noted in Noonan (2011).

The surest way to provide homeowners with a nudge to stimulate them to modify their home to anticipate future needs and prevent falls is to give them a financial incentive. The model simulation here demonstrates that the federal government can do that and get a positive return when it shares the up-front expense. For the P3 population, even paying up to 50% of the home modification costs would allow the government to recoup all of its upfront investment within CBO's 10-year methodology window. For the P2 population, the federal government reaches a cross-over point in year 8 with a 20% cost sharing. That could be accomplished by allowing qualified home modification expenditures to be deductible against income taxes.

The model simulation for the P1 population in this paper might appear to be guaranteed to fail CBO's effectiveness criteria since we seek to change homeowner behavior when they are in their 50s while the benefits don't start accruing until after the homeowner is 65 years old and

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[17] The US Preventive Services Task Force (USPSTF) performs the important role of constantly sifting through medical research to provide an official government imprimatur on when the research is convincing enough to demonstrate efficacy of proposed cures or preventive interventions. Their highest level of endorsement is an 'A' rating that there is a high certainty of benefit. Medical insurance offerings are required to cover expenses related to 'A' interventions as well as those with a 'B' rating of moderate to substantial benefit. USPSTF (2018), consistent with its earlier 2012 study, found that 'multifactorial interventions' which might include home modifications as a component of a suite of activities warrant a 'C' rating, using language stating "The USPSTF recommends selectively offering or providing this service to individual patients based on professional judgment and patient preferences. There is at least moderate certainty that the net benefit is small."

covered by Medicare/Medicaid. But allowing an exemption from the current 10% penalty for early withdrawal of funds in an IRA/401k investment pool would not cost the federal government revenue while achieving the important goal of providing a financial 'nudge' at exactly the time the homeowner is going through a home renovation.[18] As stated in Powell (2017), 'there is good evidence that people can be put off installing adaptation until they reach a point of crisis, in part because they do not wish to change or 'medicalise' their home.' A nudge at the moment when remodeling work is already being performed could start to change that mindset.

When it comes to program design, requiring the insurance and client beneficiaries to have some skin in the game of home renovations is likely a good idea to limit waste and fraud. The precise details of how to craft a tax credit/exemption/deduction that achieves the desired purposes are not the focus here and can be left to others.[19] Experience of one retailer suggests that a 20% discount can be sufficient to pivot consumer behavior (Lieber, 2020)

The societal need for safely aging in place is already upon us, with education and training promoted by the Administration for Community Living and other organizations. It is our hope that the introduction of government subsidies for home accessibility improvements, prompted by the disciplined support given here, can similarly catalyze demand and supply in the home remodeling industry to address this current need.

[18] There are understandable policy concerns regarding the wisdom of allowing early withdrawals from retirement savings (Bernstein, 2021). We would point out that home improvements are a way to transform personal financial capital into physical capital (their home) that has the potential to create a tremendous return during retirement. Of course, as with any investment, there is no certainty regarding the magnitude of that return.

[19] The legislative objectives here fit well within the mainstream of bipartisan proposals currently circulating on Capitol Hill, such as the Choose Home Care Act of 2021 S.2562 and the Americans Giving Care to Elders (AGE) Act S.234/HR.3689.

Appendix A – Model Inputs

Population

The P3 population is the number of owner-occupied households where at least one individual turns 75 years old in 2020 and where this individual has multiple chronic conditions with limitations of at least one ADL and one IADL. This is derived from Joint Center household estimates (Spader, 2019). Their base estimate of households headed by a 70-74 year old in 2018 is 6.878 million. Assuming an even distribution by age and shaving that figure by two years of mortality (3%/year) and move-outs (1.7%/year) yields 1,250,747 million households. Using the same methodology for P2, 65 year-old households (with 1.3% mortality and 0.8% move-outs) yields 1,759,036. Using the same methodology for P1, 50 year-old households (with 0.4% mortality and 0.8% move-outs) yields 1,491,868.

Reality check: These figures are reasonably close to the 2019 AHS report of owner-occupied households if we take one-tenth of the 10-year spans of 65-74 year households (14,696,000), 55-64 year households (18,602,000) and 45-54 year households (15,135,000).

Data from the 2014 University of Michigan Health and Retirement Study finds that 28% of 65-79 headed households have a mobility disability, and if self-care disabilities are included the total may be higher (Joint Center, 2016). Reality check: the 2019 AHS reports a variety of disability categories; assuming the 'not reported' numbers distribute proportionately, 34% of 65-74 householder residences are 'with a disabled person.'

Some of the properties occupied by these households will already be equipped with accessibility features, so are not in need of further improvements. This will reduce the 'eligible population' of individuals or structures for P3. The 2019 AHS finds that of the 75+ households identified as 'disabled', that 43% (=(806+2320)/7246) rated their home as meeting their accessibility needs with a 4 or 5 out of a 5 point scale. That suggests that the total number of properties that are prospects for home modifications may be only 57% of the population with a disability. Among all households 65 to 74 the percentage with a 4 or 5 is 15%, and for households 55 to 64 the percentage is 9%.

Reality Check: Liu (2009) find that 38% of households with 70+ year olds had some accessibility features in 1995.

Moves and Deaths

Each year some of the community-living adults in owner-occupied housing will move out of their homes for a variety of reasons that can include lifestyle, moving to be close to kids, to move in with kids, or to a congregate care facility. Any of these moves eliminates the fall-reduction savings of installed accessibility features. Munnell (2020) uses the University of

Michigan's Health and Retirement Survey (HRS) to segment the population into cohorts they call: never movers, stable movers (move once around retirement), frequent movers (lifestyle) and late movers (likely healthcare motivated) whose shares differ between their 50-54 age cohort, their 70-74 age cohort and their synthetic cohort. In Figure A1 just below we translate their cohort shares into annual move-out rates for our age 50, 65 and 75 cohorts for three different age ranges.

Reality check: Safran-Norton (2010) finds much higher transitions in the 1998 and 2000 waves of the HRS for the 65+ cohort: over that two year period 7.4%(8.7%) of couples(singles) moved primary residence, while 1%(4%) moved into nursing homes and 6.7%(9.5%) died.

Figure A1
Derivation of Annual Move-out Rates for Simulation

	Original Paper's Cohorts			Translation to Our Cohorts		
	Age 50-54	Age 70-74	Synthetic	Age 50	Age 65	Age 75
Never Movers	63%	75%	53%			
Stable Movers	19%	7%	17%	17%/40yrs	7%/25yrs	7%/15yrs
Frequent Movers	18%	11%	14%	14%/40yrs	14%/25yrs	11%/15yrs
Late Movers		8%	16%	16%/15yrs	16%/15yrs	8%/15yrs
Derived Annual Move out rates used in this paper						
Ages 50-64				0.0078		
Ages 65-74				0.0078	0.0084	
Ages 75+				0.0184	0.0191	0.0173

Source: Munnell (2020)
We assume mortality at age 90; age 65 cohort is blend of age 70-74 and synthetic cohort values

In addition to move-outs, we need to know the mortality rate and expected longevity for individuals at each age of life. This information is provided by the Census Bureau for 2017 (Medina, 2020). Our values are a simple average of the male and female rates; no adjustment was made for the underlying data being three years prior to 2020.

Fall Rates

According to a CDC phone survey in 2014, (Bergen, 2016) 28.7% of community-dwelling adults 65 years or older reported falling, of which 37.5% needed medical treatment or restricted their activity for a day or longer. The survey results are broken out by age ranges of 65-74, 75-84 and 85+, yielding 26.7%, 29.8% and 36.5% for individual fall rates, and of those falls, 36.3%, 36.6% and 37.9% for serious falls, respectively. Taken together the average figures yield a roughly

11% (=0.287*0.375) 'serious' fall rate; in the model we use the age-specific rates. In absolute numbers, for 65+ year olds, the CDC reports 29 million falls, 7.0 million fall injuries, 2.8 million emergency room visits, 800,000 hospital stays and 27,000 deaths. The CDC reports a 10.5 bps annual mortality rate from falls over 2008-2014 for ages 75+, 1.4 bps for ages 65-74 and 0.5 bps for 50-59.

Reality Check: Kochera (2002) finds a 5% serious fall rate that requires emergency room services. Todd (2020) finds a 2.1% rate for Philadelphians 65+ year olds being admitted to hospitalization from falls in 2018; 75+ year olds had a higher 4.5% fall-driven admit rate. Todd also finds 3% mortality from serious falls, yielding a 6 bps rate of death for 65+ Philadelphians.

Fall Costs

The source of fall costs is Burns (2016) which bases non-fatal costs on 1998-99 data updated with a healthcare inflator. Their 2012 cost estimate for fatal falls is $25,487 and for non-fatal falls is $9463. The cumulative PCE healthcare deflator (what they use and is consistent with the US BEA's recommendation) increase from 2012 to 2020 is 21.52% yielding 2020 costs of $30,972 and $11,499, respectively.

Reality Check: The Senate Committee on Aging (Collins, 2019) reports a $30,000 cost per fall-generated hospital stay, citing Burn's $30,550 figure for 2012 hospital costs. Data for Philadelphia from Todd (2020) reports a higher $65,000 average cost for a median four-day hospital stay.

Bottomline Reality Check. The Senate report estimates the annual cost of falls for 65+ year-olds is $50 billion, taken from Florence's (2016) number for 2015. Increasing that figure by the 17.9% increase in the PCE and 16.8% population increase from 2015 to 2020 gives $69 billion, close to what we get from a 55.7 million 65+ population in 2020, times 11% fall rate times a $11,499 cost per fall yielding $71 billion.

Home Improvement

Each household starts with a different physical layout while each resident will have their own unique needs, making it evident than no single dollar figure can capture what will be needed to make any specific home 'accessible.' And what is needed for any individual will evolve over time. Home modification expenditure budgets vary considerably across the papers cited with published results: Jutkowitz (2012) gives the average modification spending in the ABLE program to be $439 in $2010. Szanton (2019) gives the average modification spending in the CAPABLE program of $1222; Plautz (1996) cites an average hard cost of $92.80 and $50-100 for labor; Keall (2015) cites a $450 (US) figure; Eriksen (2015) cites a $1700 figure (in $2000) spent over a two-year period on home modifications from their longitudinal data source. Heywood (2007) cites an average cost of a disabled facilities grant as being £6000 that typically includes a stairlift and a level access shower.

Community programs that provide home modifications to low-income residents have a much higher dollar threshold than these academic studies: the DC Safe at Home program has a cap of $6000 and spent an average of $3700 per client on home modifications in early 2020 (private correspondence); the Federal Home Loan Bank (FHLB) of Indianapolis' Accessibility Modification Program offers grants up to $12,000 (and can include regular home repairs); the Carol M. Peterson Housing Fund at the FHLB of Cincinnati offers grants up to $7500. The City of Chicago's HomeMod Program spends between $12,200 and $15,150 per participant, though they are serving those with a disability under age 60 and often install vertical power lifts (Cowan, 2020). In its study for the State of Minnesota, Wilder Research estimated the average cost of safety home improvement needs of low-income older adult homeowners at $6989 per household (Warren, 2016, p54).

The JCHS (2021) reports the average expenditure on 'discretionary' home remodeling was $13,302. The HomeAdvisor website says that the average grant for an accessibility remodel will be $4350 in 2021.

We adopt HomeAdvisor's $4400 figure, perhaps erring on the high side. Some of the programs written about benefit from below-market labor costs (Plautz uses VISTA workers; CAPABLE uses Americorps). While the hard costs for a few grab bars and a raised toilet seat can run only a few hundred dollars, too small a dollar amount for a federal tax deduction program can make it too unattractive and hence unused.

Federal government healthcare costs

Kochera (2002) estimates that 75% of the $9359 total direct cost of falls leading to an emergency room visit for 65+ year olds in 2000 is covered by the federal government. An alternative estimate can come from CMS which reports annually on national health expenditures. Their most recent breakdown by recipient age is for 2014, and shows that in total, Medicare covered 52% of spending for 65+ year olds and Medicaid another 10%. Figures from Kochera (2002) show the federal share of Medicaid spending to be 56%, suggesting a perhaps total 58% for the federal share of healthcare spending for 65+ year olds (0.576=0.52+0.56*0.10). Given the striking consistency of the $9359 and Burns (2016) $9463 figures, we will use the 75% federal government share in our baseline and run a sensitivity with the 58% figure.

Additional Costs From Reduced Falls

The CBO methodology seeks to derive net government savings compared to current policies. We include two calculations that reduce the net government savings versus direct savings: an estimate of how much reduced falls leading to mortality can increase government medical insurance costs, and we haircut the government savings from subsidized modifications that simply replace future self-initiated home modifications.

It is too complicated to consider whether there are *higher* medical costs for people who now don't fall but who previously fell and survived. But we can estimate how much healthcare those now non-dead people might consume *on average* over the rest of their lives. CMS puts the per-person healthcare spending in 2014 for individuals 65+ at $19,098. The healthcare PCE indicates cumulative inflation was 19.2% to 2020, bringing that to $22,765 in 2020. Assuming 75% of that is federal expense yields an average annual M/M cost of $17,074. For each person who doesn't die, we multiply that annual cost by the remaining years of life expectancy. (We use the inflated nominal dollar figure from the year life is saved for all of the subsequent years.)

Reality check. CMS reports the Medicaid spending per enrollee in 2018 for individuals 65+ of $18,272 for low level data useability (close to the $18,583 average of the medians for high, moderate and low data useability). Medicare spending per enrollee in 2019 was $10,536. The healthcare PCE shows a 5.1% increase from 2018 and 2.6% from 2019 to bring both Medicaid ($19,204) and Medicare ($10,811) numbers to 2020 and a 43/57 split (to match 2019 expenditures) yields an estimate of $14,420, which is 84% of the number above. Close enough.

There is another source of increased costs to the government from their providing widespread home modifications. Many individuals every year make their own home improvements without the benefit of government subsidies, with the resulting healthcare savings already built into existing fall and cost statistics. For these people, a government intervention is effectively paying for the modifications (and getting the medical savings) 'earlier' in time. The healthcare savings the federal government is currently receiving 'free' but would now start paying for is an incremental cost from the federal government's perspective. To calculate this cost to the government we turn to the 2019 AHS, which asked: how many owner-occupants planned to make accessibility improvements over the next two years? And we accept the answer at face value. For 75+ year olds with disabilities that figure is 8.6% yielding an annual rate of 4.3%. For all 65+ year olds the annual figure is 2.9%. Therefore either 4.3% or 2.9% of the nonfatal falls 'savings' are not net-new savings but would have already happened in the baseline each year, so these need to be removed from the estimate of annual government savings.

Appendix B – Baseline P3 Model Simulation

How the model plays out in each year for the Baseline P3 simulation is shown in Figure A2. The starting population is 199,619 (line C) households that reflect the product of the numbers in lines 1-3 (of Figure 4). For simplicity, all of these households are assumed to instantaneously receive a home modification on the first day of the calendar year they turn 75, which is also the first day of the simulation. Falls occur at rates in lines 9 and 10, which using costs in lines 11 and 12 create total costs in lines E and F; The Line 16 percent of falls don't occur creating savings in line G, which are cumulated in line H. Households are decremented annually by move-outs and deaths (lines K and L).

The intervention hard-cost is line M. Savings (line G) are increased by inflation (line 20) and decreased by the discount rate (line 21) to create discounted savings in lines N and O. Line P is line O plus line M.

The federal government's costs include its share of the modification costs (line Q), the increased Medicaid/Medicare cost of fewer deaths in lines I and J yields line R and an estimate of the savings individuals would have gained from future self-modifications that have been pre-empted by the government's action at age 75 (line S). That yields the annual and cumulative increase in nominal federal costs (lines T and U) and discounted costs (lines V and W). Netting costs versus savings (lines X and Y) yields net federal costs (line Z).

In the baseline scenario where cost inflation exactly matches the discount rate, it takes 11 years for society to recover the $878M of intervention costs. The cells that show this result are highlighted in orange. In year 10, the end of CBO's time frame, the government is carrying an intervention deficit of $420M; at the end of the simulation in year 16 the government's discounted deficit falls to $235M. The cells that show this result are highlighted in green.

Figure A2
Baseline Model Simulation of P3 Cohort

Model																	
Year	A	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Age	B	Age 75	Age 76	Age 77	Age 78	Age 79	Age 80	Age 81	Age 82	Age 83	Age 84	Age 85	Age 86	Age 87	Age 88	Age 89	Age 90
Population																	
At risk	C	199,619	190,118	180,448	170,622	160,662	150,584	140,376	130,046	119,647	109,245	98,903	88,681	78,642	68,866	59,446	50,494
Percent remaining	D		95%	90%	85%	80%	75%	70%	65%	60%	55%	50%	44%	39%	34%	30%	25%
Risk events																	
Cost of serious falls (net of HM)	E	$ (154,721)	$ (151,777)	$ (148,379)	$ (144,508)	$ (140,155)	$ (135,304)	$ (129,916)	$ (123,966)	$ (117,475)	$ (110,479)	$ (130,666)	$ (120,676)	$ (110,226)	$ (99,418)	$ (88,394)	$ (77,336)
Cost of fatal falls (net of HM)	F	$ (4,012)	$ (3,936)	$ (3,847)	$ (3,747)	$ (3,634)	$ (3,508)	$ (3,369)	$ (3,214)	$ (3,046)	$ (2,865)	$ (2,671)	$ (2,467)	$ (2,253)	$ (2,032)	$ (1,807)	$ (1,581)
Net Costs saved because of home mod	G	$ 105,822	$ 103,808	$ 101,484	$ 98,837	$ 95,859	$ 92,541	$ 88,856	$ 84,787	$ 80,347	$ 75,563	$ 88,892	$ 82,095	$ 74,986	$ 67,634	$ 60,134	$ 52,611
Cumulative Nominal savings	H	$ 105,822	$ 209,630	$ 311,114	$ 409,951	$ 505,810	$ 598,351	$ 687,208	$ 771,995	$ 852,342	$ 927,905	$ 1,016,796	$ 1,098,892	$ 1,173,878	$ 1,241,512	$ 1,301,646	$ 1,354,257
Fewer deaths b/c of fall reduction	I	84	80	76	72	67	63	59	55	50	46	42	37	33	29	25	21
Incr. cost from longer lives	J	$ (23,650)	$ (21,946)	$ (20,276)	$ (18,627)	$ (17,016)	$ (15,438)	$ (13,907)	$ (12,428)	$ (11,023)	$ (9,672)	$ (8,404)	$ (7,223)	$ (6,123)	$ (5,119)	$ (4,219)	$ (3,420)
Move outs	K	3,453	3,289	3,122	2,952	2,779	2,605	2,429	2,250	2,070	1,890	1,711	1,534	1,361	1,191	1,028	874
Deaths	L	6,048	6,381	6,704	7,008	7,299	7,603	7,901	8,150	8,332	8,451	8,511	8,505	8,416	8,228	7,923	7,494
Financial Results																	
intervention cost	M	$ (878,325)															
Discounted Home Mod Savings	N	$ 105,822	$ 100,785	$ 95,659	$ 90,450	$ 85,170	$ 79,827	$ 74,416	$ 68,940	$ 63,427	$ 57,913	$ 66,144	$ 59,308	$ 52,594	$ 46,055	$ 39,756	$ 33,769
Cumulative Discted Savings	O	$ 105,822	$ 206,606	$ 302,265	$ 392,715	$ 477,884	$ 557,711	$ 632,127	$ 701,067	$ 764,493	$ 822,406	$ 888,550	$ 947,857	$ 1,000,451	$ 1,046,507	$ 1,086,262	$ 1,120,031
Cumulative Net Fin Savings	P	$ (772,503)	$ (671,718)	$ (576,060)	$ (485,610)	$ (400,440)	$ (320,613)	$ (246,198)	$ (177,258)	$ (113,831)	$ (55,919)	$ 10,225	$ 69,533	$ 122,127	$ 168,182	$ 207,938	$ 241,707
Federal Government																	
Govt Modification Costs	Q	$ (878,325)															
Fed Incr. cost from longer lives	R	$ (17,737)	$ (16,460)	$ (15,207)	$ (13,971)	$ (12,762)	$ (11,579)	$ (10,430)	$ (9,321)	$ (8,267)	$ (7,254)	$ (6,303)	$ (5,417)	$ (4,592)	$ (3,839)	$ (3,165)	$ (2,565)
Fed Incr. Baseline savings from self mod	S	$ (4,550)	$ (4,334)	$ (4,113)	$ (3,889)	$ (3,662)	$ (3,433)	$ (3,200)	$ (2,964)	$ (2,727)	$ (2,490)	$ (2,844)	$ (2,550)	$ (2,262)	$ (1,980)	$ (1,709)	$ (1,452)
Annual Incr. Nominal Fed Costs	T	$ (900,612)	$ (20,793)	$ (19,321)	$ (17,860)	$ (16,424)	$ (15,011)	$ (13,630)	$ (12,285)	$ (10,995)	$ (9,744)	$ (9,147)	$ (7,968)	$ (6,854)	$ (5,820)	$ (4,874)	$ (4,017)
Cumulative Nominal Fed Costs	U	$ (900,612)	$ (921,405)	$ (940,726)	$ (958,586)	$ (975,010)	$ (990,021)	$ (1,003,651)	$ (1,015,936)	$ (1,026,931)	$ (1,036,675)	$ (1,045,822)	$ (1,053,790)	$ (1,060,643)	$ (1,066,463)	$ (1,071,337)	$ (1,075,355)
Annual Discted Fed Costs	V	$ (900,612)	$ (20,188)	$ (18,212)	$ (16,344)	$ (14,592)	$ (12,949)	$ (11,415)	$ (9,989)	$ (8,679)	$ (7,468)	$ (6,806)	$ (5,756)	$ (4,807)	$ (3,963)	$ (3,222)	$ (2,579)
Cumulative Discted Fed Costs	W	$ (900,612)	$ (920,800)	$ (939,011)	$ (955,356)	$ (969,948)	$ (982,897)	$ (994,312)	$ (1,004,301)	$ (1,012,980)	$ (1,020,448)	$ (1,027,254)	$ (1,033,010)	$ (1,037,817)	$ (1,041,780)	$ (1,045,003)	$ (1,047,581)
Nominal Govt savings	X	$ 79,366	$ 77,856	$ 76,113	$ 74,128	$ 71,894	$ 69,406	$ 66,642	$ 63,590	$ 60,260	$ 56,672	$ 66,669	$ 61,572	$ 56,240	$ 50,725	$ 45,101	$ 39,458
Cumulative Govt Nominal Savings	Y	$ 79,366	$ 154,955	$ 226,699	$ 294,536	$ 358,413	$ 418,283	$ 474,095	$ 525,800	$ 573,370	$ 616,804	$ 666,412	$ 710,893	$ 750,338	$ 784,880	$ 814,697	$ 840,024
Cumulative Net Fed Savings	Z	$ (821,246)	$ (766,451)	$ (714,027)	$ (664,050)	$ (616,597)	$ (571,737)	$ (529,556)	$ (490,136)	$ (453,561)	$ (419,871)	$ (379,410)	$ (342,897)	$ (310,305)	$ (281,583)	$ (256,641)	$ (235,331)

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