

Zombie Credit and (Dis-)Inflation: Evidence from Europe*

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Abstract

We show that “zombie credit”—subsidized credit to non-viable firms—has a disinflationary effect. By keeping these firms afloat, zombie credit creates excess aggregate supply, thereby putting downward pressure on prices. Granular European data on inflation, firms, and banks confirm this mechanism. Markets affected by a rise in zombie credit experience lower firm entry and exit, capacity utilization, markups, and inflation, as well as a misallocation of capital and labor, which results in lower productivity, investment, and value added. If weakly-capitalized banks were recapitalized in 2009, inflation in Europe would have been up to 0.21pp higher post-2012.

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1 Introduction

In response to the global financial crisis and the European sovereign debt crisis, the European Central Bank (ECB) and other European central banks provided substantial monetary stimulus, including longer-term refinancing operations, negative deposit rates, and large-scale asset purchase programs. However, even post-stimulus, Europe’s economic growth and inflation have remained depressed and consistently undershot projections (see [Figure 1](#)). In the words of former ECB President Mario Draghi, “...the ECB’s monetary policy has been expansionary, but it has not been enough to bring inflation back to target. In fact, inflation has been consistently below target since 2015. This is a puzzle because the ECB has been doing everything it can to bring inflation back to target. The only explanation is that the economy is stuck in a deflationary trap.”

Europe’s “missing inflation puzzle” in the years between its sovereign debt crisis and the Covid-19 pandemic bears a striking resemblance to Japan’s “lost decade.” Besides a deflationary pressure, both economies have been characterized by highly accommodative and lenient central bank policies and “zombie lending” by weakly-capitalized banks.¹ In this paper, we propose and test a theory that can explain the concurrence of the rise of zombie firms and the disinflationary pressure shown in [Figure 1](#). While the share of zombie firms in Europe increased from 4.5% to 6.7% between 2012 and 2016, inflation dropped from roughly 3% to zero. During the same time, inflation forecasts started to significantly overshoot the actual inflation rate.

Political constraints led to a hesitant introduction of recapitalization measures in Europe in the aftermath of the 2008 global financial crisis (see [Acharya et al., 2018b](#)), leaving

¹See Mario Draghi’s speech “Twenty Years of the ECB’s monetary policy” at the ECB Forum on Central Banking in Sintra on June 18, 2019. The speech is available at [https://www.ecb.europa.eu/press/pr/speeches/2019/speech190618_en.html](#).

²See, e.g., [Caballero et al. \(2008\)](#), [Giannetti and Simonov \(2013\)](#), [Acharya et al. \(2019\)](#), [Bonfim et al. \(2022\)](#), [Schivardi et al. \(2022\)](#), and [Blattner et al. \(2023\)](#).

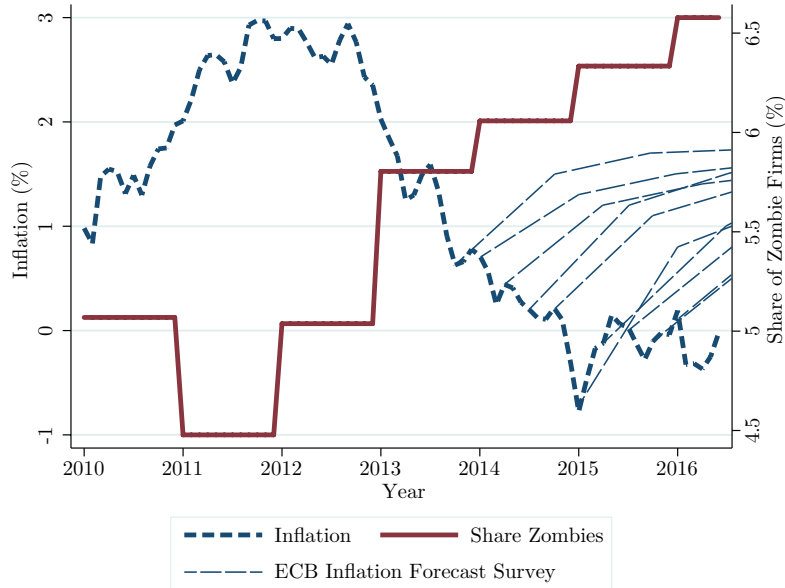


Figure 1: Zombie Credit and Inflation. This figure shows the year-over-year (yoy) growth of the CPI on the left axis and the asset-weighted share of zombie firms on the right axis in our sample. A firm is classified as zombie if it is low-quality (i.e., above median leverage and below median interest coverage ratio) and receives subsidized credit (interest expenses/debt lower than that of AAA-rated industry peers in a given year). See Section 3.2 for a detailed explanation of how we identify zombie firms in the data. The inflation forecasts are from the ECB Survey of Professional Forecasters (one, two, and five year ahead). Sources: Eurostat, ECB, and Amadeus.

many banks weakly-capitalized and, in turn, creating zombie lending incentives. By extending subsidized loans to non-viable borrowers, weakly-capitalized banks can avoid regulatory repercussions and “gamble for resurrection.”

Building on Caballero et al. (2008), we illustrate in a simple model that by keeping non-viable firms artificially alive, zombie credit creates excess supply, which puts downward pressure on prices. In equilibrium, zombie credit causes a decrease in firm entry and exit rates, markups, capacity utilization, and CPI growth, as well as a misallocation of capital and labor, which results in lower productivity, investment, and value added.[‡]

[‡]The Italian concrete and cement industry offers a textbook example of this mechanism at work. Following the 2008 crisis, many firms in this sector relied on their banks to remain alive. The CEO of Cementir,

Our empirical results support the zombie credit channel. In our analysis, we combine product-country level Consumer Price Index (CPI) data with industry-country-level information from Eurostat and detailed firm-level information from Bureau van Dijk’s Amadeus for 1.1 million firms from 12 European countries across 65 industries. Using linking tables, we calculate changes in consumer prices at the industry-country level from the CPI data. Using Amadeus data, we identify zombies as firms that meet two criteria: (i) they are of low-quality, that is, their interest coverage (IC) ratio is below the median and their leverage ratio is above the median, and (ii) their borrowing costs are lower than the costs paid by their most creditworthy industry peers. Post-zombification, the (low) profitability of the firms classified as zombies does not improve, their leverage increases, and they are more likely to default in the long-term—suggesting that their access to cheap credit is not due to a positive outlook and/or relationship lending.

In the cross-section of countries and industries, we find that industry-country pairs (henceforth called “markets”) that experience a 2.2 percentage point (pp) increase in the share of zombies (i.e., the observed zombie share increase from 2012 to 2016) subsequently have a 5.3 basis point (bp) lower CPI growth. In our most stringent specification, we include industry-country, country-year, and industry-year fixed effects, which absorb time-invariant industry-country characteristics as well as industry- and country-specific shocks (most importantly demand shocks). Moreover, we control for the share of low-quality firms to capture industry-country-year specific demand factors that affect firm quality. We also show that our main results are robust to employing an array of alternative zombie classifications and to measuring price changes with the producer price index (PPI) instead of the CPI.

one of the industry leaders in Italy, stated in 2017 that “*in Italy, in the cement industry, we have zombies kept alive by banks. [...] Banks do everything they can to keep these zombies alive to avoid realizing losses on their balance sheets.*” In a 2017 Senate hearing, industry representatives stated that “*the excessive production capacity caused an unprecedented price competition that, in turn, caused firms to realize large losses*” (audizione di AITEC, 2017). In 2015, the price of cement in Italy was 22% below the EU average.

To mitigate concerns that the negative correlation between the zombie share and CPI growth could be driven by demand shocks, we conduct a robustness check where we consider three additional criteria to identify zombies that are unrelated to demand effects. For the first more stringent zombie share measure, we exclude firms that already enjoyed low interest rates and then turned into a zombie because their quality deteriorated. In addition, we then further restrict the zombie share measure to instances where firms are connected to (i) weak banks and (ii) to a single weak bank, respectively. The estimated effects of zombie credit on CPI growth are larger for these more stringent zombie measures than in our baseline OLS specification, suggesting that our estimates are not materially driven by demand-side effects.

To further address potential omitted variable biases, we instrument a market’s zombie share exploiting that weaker banks have stronger zombie lending incentives. In particular, we employ a Bartik-style shift-share instrument (see [Bartik, 1991](#)) based on the ex-ante capitalization of the banks connected to the firms in the respective market and aggregate loan growth, where loan growth is a proxy for time-varying country-level bank shocks (we also use non-performing loan growth as a robustness test).

The idea is that the average bank health differs across markets at the beginning of the sample period and markets linked to ex-ante weaker banks are more likely to see an increase in zombie lending when the banking system experiences a negative shock.^J Our instrument thus gets all of the cross-sectional variation in exposure to weak banks from $eq_{i,t}^{CSZL}$ lending shares, and all of its time-series variation from country-level loan growth. Our instrumental variable (IV) regression estimates confirm the negative effect of zombie credit on CPI growth. Our calculations suggest that in the hypothetical case where weakly-capitalized banks were recapitalized in 2009 to a 9% Tier-1 capital ratio, the annual CPI growth in Europe would

⁴Our plausibility checks confirm that the relation between a market’s exposure to weak banks and its zombie prevalence is stronger in markets that should conceptually be more prone to zombie lending (i.e., markets that are depressed, uncertain, or characterized by lenient bank supervision).

have been on average 0.21pp higher between 2012 and 2016.

Consistent with the insights of our theoretical framework about the inner workings of the zombie credit mechanism, we also find that, in the cross-section of countries and industries, markets that experience a stronger increase in the share of zombie firms subsequently have: (i) more active firms and aggregate sales growth, (ii) lower firm default and entry rates, (iii) higher average idle capacity, (iv) lower average markups, and (v) higher average material and labor costs. The positive correlation between zombie credit and sales growth provides further evidence that the negative correlation between zombie credit and CPI growth is not demand driven (as lower demand would $\Downarrow \mathcal{Q}$ sales). The positive correlation between zombie credit and firm input costs is consistent with relatively more firms demanding the same inputs sustaining their prices. In line with this finding, we confirm, using PPI data and input-output tables from the World Input-Output database, that the zombie credit mechanism also affects prices along the supply chain.

At the firm-level, we show that the market-level outcomes are at least partly caused by negative spillover effects to non-zombie firms. In particular, healthy firms that face competition from a growing number of zombie firms have lower markups, profitability, and sales growth, as well as higher input costs.

We present a set of tests that provide further evidence for the zombie credit channel. Specifically, we show that the effect of an increase in the zombie prevalence on CPI growth is driven by (i) high fixed cost industries and (ii) national markets for nontradable goods and supranational markets for tradable goods. We also show that the zombie credit mechanism appears to be a short- to medium-term phenomenon.

Finally, our results show that the zombie credit channel affects investment and employment. Markets with a stronger increase in the zombie share subsequently experience a higher misallocation of capital and labor—measured as the dispersion of the marginal revenue product of capital and labor, respectively. The lower allocative efficiency in these markets results in lower average net investment, productivity, and value added.

Our findings show that a central bank that implements policy measures that contribute to a persistent zombification of the economy with the objective of restoring inflation and growth might end up working against its own objectives. Conversely, accommodative monetary policy might be more effective in times of a weakening financial sector, if accompanied by a targeted bank recapitalization program.

Literature Review. We contribute to three strands of literature. First, we contribute to the literature on zombie credit, starting with the evidence from Japan in the 90s (see [Peek and Rosengren, 2005](#), [Caballero et al., 2008](#), and [Giannetti and Simonov, 2013](#)).^I More recent evidence suggests that zombie credit has increased globally ([Banerjee and Hofmann, 2018](#); [McGowan et al., 2018](#)) and, in particular, in Europe. In the European context, [Blattner et al. \(2023\)](#) shows that zombie lending in Portugal increased input misallocation across firms reducing firm productivity; [Schivardi et al. \(2022\)](#) shows that non-viable Italian firms obtained favorable bank credit; and [Acharya et al. \(2019\)](#) links zombie lending to the ECB’s OMT program.^V We build on this literature and show that, by allowing non-viable firms to stay afloat, zombie lending elevates aggregate production, affecting product prices.

Second, we contribute to the literature on the effects of financial frictions on inflation. [Chevalier and Scharfstein \(1996\)](#) suggests that liquidity-constrained firms might raise prices to increase cash flows—the “liquidity squeeze channel.” [Gilchrist et al. \(2017\)](#) and [de Almeida \(2015\)](#) show that this mechanism helps to explain the pricing behavior of U.S. and European firms following the financial crisis. [Barth III and Ramey \(2001\)](#) proposes the “cost channel,” arguing that firms’ marginal costs depend on their funding costs, which implies an increase

⁵[Peek and Rosengren \(2005\)](#) documents that weakly-capitalized banks extended credit to their weak borrowers to avoid realizing losses on outstanding loans; [Caballero et al. \(2008\)](#) shows that this zombie lending behavior affected healthy firms, reducing their investment and employment; and [Giannetti and Simonov \(2013\)](#) shows that large capital injections can prevent zombie lending.

⁶[Angelini et al. \(2021\)](#), [Kulkarni et al. \(2021\)](#), and [Bonfim et al. \(2022\)](#) find that banks became less likely to engage in zombie lending after regulatory bank inspections and in presence of stricter supervision.

(decrease) in inflation after a monetary tightening (loosening). [Christiano et al. \(2015\)](#) shows that the cost channel helps to explain the modest disinflation in the U.S. during the Great Recession. Our results draw further attention to the impact of supply-side financial frictions on inflation, showing that the zombie credit channel, by hampering supply adjustments, contributed to the disinflationary trend in Europe after its sovereign debt crisis.

Third, we contribute to the literature on resource misallocation.^u Most related to our work, [Bertrand et al. \(2007\)](#) analyzes a French banking deregulation in the 80s, which curbed subsidized lending that created implicit entry and exit barriers. They find that, once banks cut back on “(cheap) credit to poorly performing firms” entry and exit rates rose, improving the allocative efficiency across firms and raising employment. [Peters \(2020\)](#) shows that when entry and exit is hampered, incumbents have time to gain market power, which increases markups and misallocation, reducing productivity. Relatedly, [Liu et al. \(2022\)](#) shows that low interest rates can trigger a relatively stronger investment response by market leaders, which can create entry barriers and lower productivity growth. [Gopinath et al. \(2017\)](#) shows that an interest rate reduction led to capital misallocation in Southern Europe in the 90s.

2 Mechanism of the Zombie Credit Channel

In this section, we define the zombie credit concept and lay out the intuition of the zombie credit mechanism and its testable predictions. In [Appendix A](#), we present two formal models. First, an extensive margin model in which firms’ production scales are exogenously set, and where we focus on the impact of zombie credit on prices through its effect on the number of active firms, and, in turn, aggregate supply. Second, an intensive margin extension where,

^u[Hsieh and Klenow \(2009\)](#) shows that resource misallocation reduces productivity. Extending this work, [Whited and Zhao \(2021\)](#) analyzes the misallocation of debt and equity in the U.S. and China. [Midrigan and Xu \(2014\)](#) shows that financial frictions distort entry and technology adoption, causing productivity losses.

in addition, we consider the effect on firms' individual production scale choices.

Zombie Definition and Zombie Credit. We consider a firm to be a zombie if (i) the net present value (NPV) of its operating profits is negative and (ii) it is kept alive by a bank with zombie lending incentives. While providing more debt to a zombie firm has a negative NPV on a standalone basis (i.e., just considering the debt interest and debt principal payments) and from a welfare perspective, such incentives might make it privately optimal for weakly-capitalized banks to extend zombie credit. The theoretical zombie lending literature (see, e.g., [Bruche and Llobet, 2014](#), [Homar and van Wijnbergen, 2017](#), [Begenau et al., 2021](#), and [Acharya et al., 2022](#)) has highlighted two different zombie lending incentives: avoidance of regulatory costs and risk-shifting or gambling-for-resurrection.

According to the first mechanism, zombie lending lowers a weak bank's likelihood of having to recognize losses on its non-viable borrowers' loans in the near term. These losses would lower the bank's capital, which can result in regulatory costs. Zombie lending allows the bank to "buy time" hoping that it eventually recovers. According to the second mechanism, a weak bank with material exposure to zombie firms (or, more generally, to the market where these firms operate) has an incentive to further raise this exposure if its debt is not fairly priced (e.g., due to bailout guarantees). Zombie lending allows the bank to "shift" additional returns in solvency states and potential losses in insolvency states.

Both zombie lending incentives induce weak banks to extend subsidized zombie credit to non-viable firms, turning the NPV of continuing the business for zombie firms positive. We provide a thorough discussion of both zombie lending incentives in [Appendix A.1](#). [Acharya et al. \(2019\)](#), [Bonfim et al. \(2022\)](#), [Schivardi et al. \(2022\)](#), and [Blattner et al. \(2023\)](#) provide evidence for zombie lending behavior in Europe in the aftermath of the sovereign debt crisis.

Extensive Margin Model. Since our focus is the analysis of the effect of zombie credit on CPI growth, we include zombie credit in our model as an exogenous force that prevents some (zombie) firms from defaulting, and compare changes in product prices in an economy with zombie credit versus an economy without zombie credit.

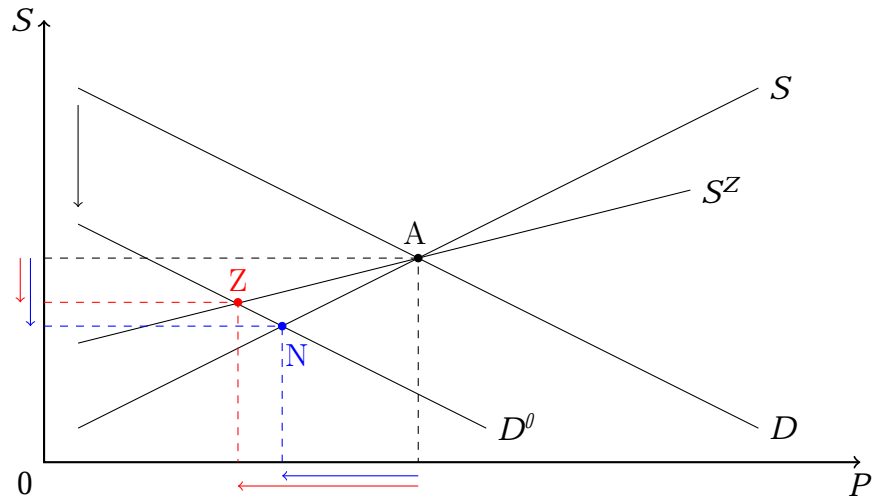


Figure 2: Intuition. This figure shows how zombie credit affects the equilibrium quantity and price.

We consider an environment with imperfect competition among firms that produce a single good, with fixed and marginal costs. The firms' production scales are drawn from a random distribution, and firms simultaneously set prices. Incumbent firms that draw a low production scale might be forced to exit and entrant firms that draw a high scale might enter the market. The demand for the good is exogenous and its aggregate supply is the sum of the production by incumbent and entrant firms.

Suppose the economy is in a steady state, namely the number of firms that default each period is exactly offset by the number of entrants. The equilibrium is illustrated by point A in Figure 2, where the exogenous demand is equal to the production by the constant number of incumbent firms. To illustrate the effect of zombie credit, we analyze how the economy transitions to a new equilibrium following a demand shock that reduces the demand to D^0 .

In the case without zombie credit, the demand shock causes the price and quantity to decrease along the supply curve S to the new equilibrium N . The shock causes a drop in price, making the economy less attractive for both entrant and incumbent firms. More incumbent firms default and fewer potential entrant firms enter. The lower number of active firms has a positive effect on price, but not enough to offset its initial decline.

In the case with zombie credit, the adjustment in aggregate supply through firm exits is

hampered as zombie credit keeps some incumbent firms afloat that would otherwise default, which results in a higher number of active firms (each with an exogenously set production scale) and, in turn, a higher aggregate supply. The result is a flatter supply curve S^Z : aggregate supply is elevated compared with the case without zombie credit, leading to a relatively lower equilibrium price level (Z).

Intensive Margin Model. In our intensive margin model, we extend our extensive margin framework by allowing firms to choose their individual production scales.

Now, firms face a negative production shock with some probability. When this shock occurs, the NPV of continuing the production turns negative. The likelihood of this shock increases with the chosen production scale. Distressed firms (i.e., firms with a high operating and/or financial leverage), however, have a positive likelihood of being “bailed out” by their lenders when they experience the negative shock. When being bailed out, these (zombie) firms receive subsidized zombie credit that makes continuing the production economically viable, allowing them to avoid defaulting, which would involve bankruptcy costs. By lowering the expected costs associated with choosing a higher output quantity, zombie credit incentivizes these firms to “overproduce”—lifting aggregate supply also through the intensive margin, in addition to the extensive margin effect (i.e., by keeping zombies afloat).

The elevated aggregate supply, in turn, reduces the equilibrium price, inducing both, zombie and non-zombie firms, to produce less. Overall, zombie credit thus increases aggregate supply, but with asymmetric effects on the individual production scale of zombie and non-zombie firms. It has a strictly negative effect on the production scale of non-zombie firms due to the lower equilibrium price, and two opposing effects on the production scale of zombies: positive due to the incentive to overproduce and negative due to the lower equilibrium price.

Insights from the Model. Our empirical analysis is in the spirit of [Figure 2](#) and compares equilibrium product prices in markets that—because of the heterogeneity in the prevalence of zombie firms—have a different supply curve. We present this analysis in [Section 4](#).

The inner workings of the zombie credit mechanism generate insights beyond the effect on

product prices, which provide the basis for our empirical analysis in [Section 5](#) and [Section 6](#). First, zombie credit reduces firm default rates, thereby increasing the number of active firms. The resulting elevated aggregate production reduces product prices, making the market less attractive to potential entrant firms. Moreover, while the elevated number of active firms reduces sales for individual non-zombie firms, the depressed output prices slightly increase aggregate demand, which leads to relatively higher aggregate sales. As a result, markets with a higher zombie prevalence experience a relatively lower drop in sales growth in response to a negative demand shock. We test these predictions in [Section 5.1](#).

Second, our numerical exercises in [Appendix A.2](#) suggests that, for markets with a high zombie prevalence, the elevated number of active firms and the resulting lower equilibrium price can lead to a higher average idle capacity for individual firms, outweighing the incentive of zombies to overproduce in anticipation of potentially being supported with zombie credit. We test the effect of zombie credit on idle capacity in [Section 5.2](#).

Third, the mirror image in our model of product prices and zombie credit is the congestion of input markets due to zombie credit. By sustaining the number of active firms and their production, zombie credit increases the aggregate demand for labor and intermediate inputs, thereby raising input costs. We test these predictions in [Section 5.3](#).^D

Fourth, zombie credit creates negative spillover effects for non-zombie firms; these firms experience lower markups, sales, and profitability as they are forced to share the market demand with zombie firms. We test these spillover effects in [Section 5.4](#).

Finally, the effect of zombie credit on prices should be more pronounced (i) when the zombie share measure comprises the precise scope of the respective market (i.e., national for

⁸In our theoretical framework, we develop predictions on how zombie credit affects product prices normalized by costs. Our baseline model assumes a form of rigidity on the cost side but can be adapted to a setting where firms set prices for their inputs (i.e., labor and materials). Our framework implies a positive effect of zombie credit on input prices as “too many” firms demand the same input factors.

nontradable goods and supranational for tradable goods) and (ii) in industries characterized by high fixed costs. The intuition for the latter effect is that zombie credit lowers firms' expected bankruptcy costs associated with sustaining a high fixed costs base and the resulting high optimal production scale. We test these predictions in [Section 6](#).

3 Data and Empirical Work

In this section, we describe our data and our strategy to identify zombies. We test the zombie credit mechanism in the context of the European economy during the 2009-2016 period, which is well-suited to analyze the effect of zombie credit and the associated supply adjustment frictions following a negative demand shock. First, Europe was hit by the global financial crisis and the subsequent sovereign debt crisis. Second, while the U.S. banking system was recapitalized decisively in the aftermath of the 2007-08 financial crisis, the European banking system remained weakly-capitalized after its crises, which led to zombie lending behavior (see, e.g., [Acharya et al., 2019](#)).

3.1 Data

Our core data set combines detailed firm-level and industry-country-level data, as well as product-level inflation data from 2009 to 2016. The firm-level data are financial information, firm characteristics, firm default information, and information about firms' bank relationships from Bureau van Dijk's (BvD) Amadeus database.⁹ BvD obtains the data, which is initially collected by local chambers of commerce, through roughly 40 information providers

⁹The coverage of the Amadeus 2017 version is incomplete before 2009. Amadeus provides the names of the most important relationship banks. We obtain the time-series of the "banker" variable through historic vintages. For some tests, we also include lending relationship information from Refinitiv's DealScan database.

including business registers. [Kalemli-Ozcan et al. \(2019\)](#) shows for selected European countries that Amadeus covers roughly 75-80% of the economic activity reported in Eurostat. Moreover, we obtain industry-country level data on the number of active firms, firm entry and exit rates, labor costs, labor productivity, as well as value added from Eurostat.

The inflation data are also from Eurostat, which provides information for various consumer price indices for all European countries. This data set is very granular as we observe consumer prices at the five-digit COICOP (product category) level. Since the firm data are at the industry (NACE) level, we use COICOP-NACE linking tables to merge these two data sets. More precisely, we use the linking tables to obtain inflation at the industry-country level, by calculating a weighted CPI growth average of all COICOP categories that are related to a NACE (two digits) industry. Consider, for example, the textiles industry (NACE 13). This industry's CPI is a weighted average of the following COICOP categories: (i) clothing, (ii) furniture and furnishings, carpets and other floor coverings, (iii) household textiles, (iv) goods and services for routine household maintenance, and (v) other major durables for recreation and culture. Following the literature, we exclude utilities and financial and insurance industries from the sample.

Our final sample consists of 1,167,460 firms for 12 European countries and 65 industries. The 12 European countries are Austria, Belgium, Denmark, Finland, France, Germany, Italy, Poland, Portugal, Slovakia, Spain, and Sweden.^c[CE](#)

3.2 Identifying Zombie Firms

Since our objective is to analyze the effect of zombie credit on prices, we need to identify (i) whether a firm is distressed and (ii) whether it receives subsidized debt financing. Hence,

¹⁰For the other European countries either the inflation data is not reported at a sufficiently granular level or is reported incompletely, and/or key financial firm data are missing.

in the spirit of Caballero et al. (2008) and Acharya et al. (2019), we classify a firm as zombie if it meets the following two criteria that capture these two elements of zombie credit.^{cc} First, the firm is of low-quality, which we define as having an IC ratio below the median and a leverage ratio above the median, where the medians are calculated at the industry-country-year level.^{cl} Note that we use a two-year average for the IC ratio criterion to avoid misclassification. Low-quality firms are thus impaired in the sense that they have both operational problems (captured via the IC ratio criterion) as well as a high debt level (captured via the leverage criterion). Second, the firm obtains credit at very low interest rates, i.e., the ratio of its interest expenses relative to the sum of its outstanding loans, credit, and bonds in a given year is below the interest rate paid by its most creditworthy industry peers, namely AAA-rated firms in the same industry and year in our sample.^{cf} In Section 4, we conduct several robustness checks with regard to the zombie firm definition.

Zombie Share. Figure 1 shows that the share of zombie firms in our sample increased from roughly 4.5% to 6.7% between 2012 and 2016 (with a large cross-sectional variation across countries and industries).^{cj} In Figure 3, we document that this rise of zombie firms is mainly driven by more low-quality firms obtaining credit at very low interest rates and not by firms that already enjoy access to cheap credit deteriorating in quality. Panel A shows that, while the share of low-quality firms remains at roughly 27% during our sample period, the share of zombie firms relative to low-quality firms increased from 17.5% to 22% between

¹¹Also note that, as argued by Caballero et al. (2008), defining zombies solely based on their operating characteristics would hard-wire a negative correlation between the zombie prevalence in a particular market and the market’s average profitability and growth. Adding the borrowing cost criterion allows us to test for the relationship between the zombie prevalence and market-level outcomes.

¹²The firms’ IC ratio is defined as EBIT/interest expense and the firms’ leverage ratio is defined as (loans + short-term credit + long-term debt)/total assets.

¹³We infer ratings of firms from their IC ratio as in Acharya et al. (2019).

¹⁴The standard deviation in the annual growth rate of the zombie share is 7.5%. In Figure D.1 and Figure D.2, we show that alternative zombie definitions yield a similar time-series pattern. Table C.12 presents summary statistics of the zombie share and the average CPI growth by industry and country.

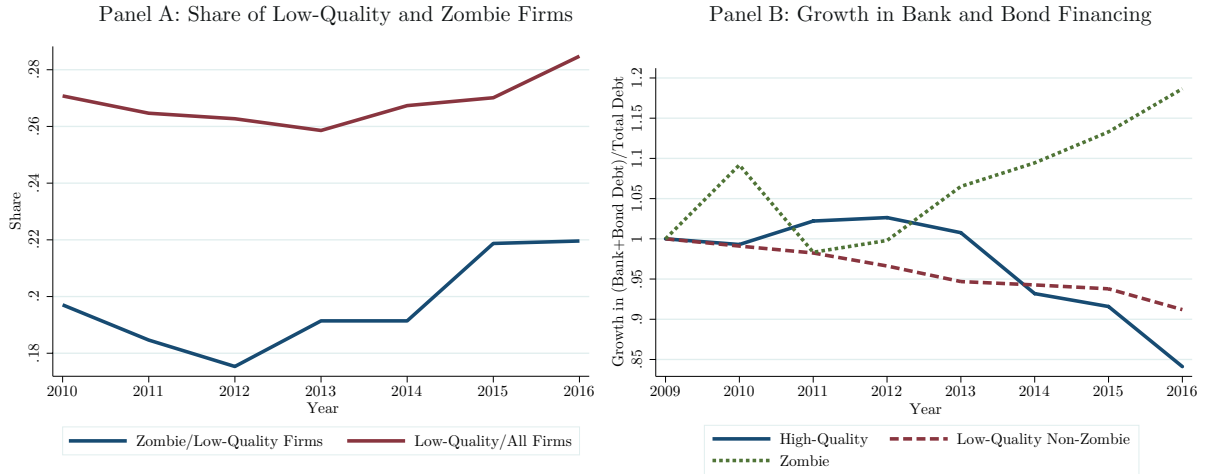


Figure 3: Firm Shares and Firm Financing. Panel A shows the share of zombie firms relative to all low-quality firms (blue line) and the share of low-quality firms relative to all firms (red line). Panel B shows the growth rate in bank and bond financing as a fraction of total debt relative to the beginning of our sample period for zombie firms (green dotted line), low-quality non-zombie firms (red dashed line), and high-quality firms (blue solid line).

2012 and 2016. Panel B shows that bank loans and bonds play an increasingly important role in the debt funding mix of zombie firms.

Zombie Firm Characteristics. Table 1 presents descriptive statistics for our sample firms separately for high-quality firms, low-quality non-zombie firms, and zombie firms. Zombie firms are weaker than low-quality non-zombie firms along several observable dimensions. Zombies have on average a lower market-to-book ratio, lower (even negative) IC ratio, lower EBITDA/assets ratio, lower net worth, and higher leverage. The market-to-book ratio of zombie firms is close to one, suggesting that these firms have limited growth prospects. Nevertheless, zombie firms pay extremely low interest rates, even compared with high-quality firms. Given their high leverage and low profitability, zombie firms would have likely had a higher default rate if they had not received subsidized debt.

Importantly, zombie firms are not younger nor more reliant on short-term credit compared with low-quality non-zombie firms, suggesting that our zombie definition does not simply capture early stage companies or companies reliant on short-term debt. The lower debt costs of zombie firms also does not seem to be due to differences in collateral availability

	High-Quality	Low-Quality		(2)-(3)
		Non-Zombie	Zombie	
	(1)	(2)	(3)	
Markup	1.13	1.05	1.01	0.040***
EBITDA/Assets	0.090	0.046	0.014	0.032***
Material Cost	0.424	0.476	0.552	0.076***
Total Assets (th EUR)	1,617	1,726	1,607	119.0***
Tangibility	0.327	0.312	0.190	0.122***
IC Ratio	4.90	1.01	0.53	1.540***
Net Worth	0.224	0.107	0.069	0.038***
Leverage	0.161	0.351	0.437	0.086***
ST Debt/Total Debt	0.337	0.510	0.525	0.015
Firm Age (years)	17.5	17.3	17.8	0.500*
Interest Rate	0.028	0.039	0.009	0.030***
Market-to-Book	2.07	1.88	1.03	0.85*

Table 1: Summary Statistics. This table shows descriptive statistics for our sample firms. We split firms into high-quality, low-quality non-zombie, and zombie firms. A firm is classified as low-quality if it has below-median IC ratio and above-median leverage, where medians are calculated at the industry-country-year level. A low-quality firm is classified as zombie if its interest rate paid on its debt financing is lower than the rate paid by AAA-rated industry peers in the same year. The estimation of firm markups is discussed in [Appendix B](#). Material cost is material input cost/turnover. Total assets is measured in thousand euro. Tangibility is fixed assets/total assets. IC Ratio is EBIT/interest expense. Net worth is total shareholders funds and liabilities - current and non current liabilities - cash, divided by assets. Leverage is debt/total assets. Market-to-book is the ratio of a firm’s market capitalization to its book value. The last column is a test for the difference between Column (2) and Column (3).

as zombies have less tangible assets. Finally, based on syndicated loan data, [Acharya et al. \(2019\)](#) show that there are also no significant differences between zombie and low-quality non-zombie firms in other loan characteristics like loan size, maturity, or loan type.

Zombie Firm Performance. Finally, we track the performance of the firms we classify as zombies over time to confirm that these firms are not only temporarily weak, that is, firms that “look weak” based on observable characteristics but that might actually have a promising outlook that allows them to obtain cheap debt financing. In [Figure 4](#), we plot the time-series evolution of leverage and incurred interest rate, where year zero corresponds to the first sample year where the respective firm is classified as zombie.

Panel A of [Figure 4](#) shows that the average interest rate on outstanding debt paid by zombie firms decreased substantially in the year in which these firms became a zombie, while

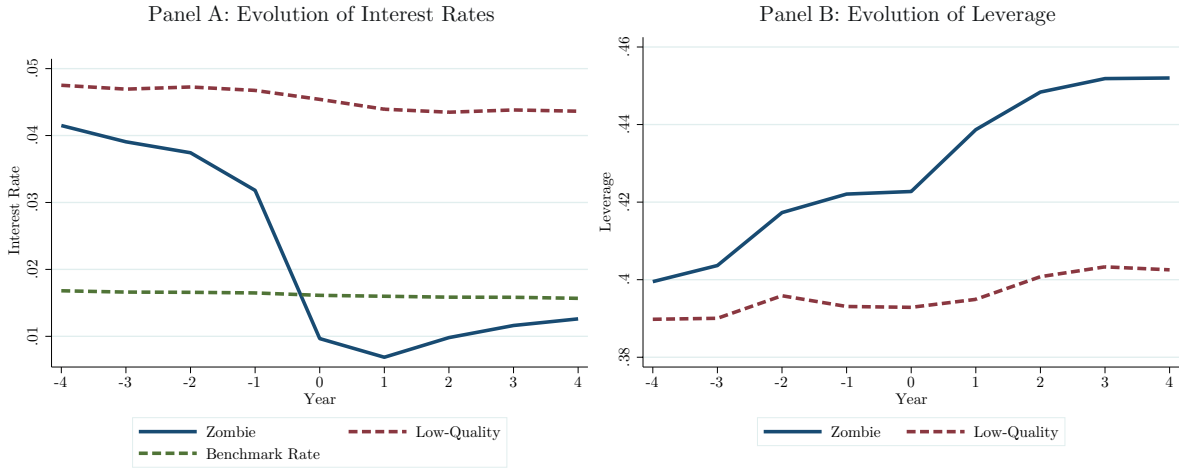


Figure 4: Evolution of Leverage and Interest Rates. This figure shows the evolution of interest rates and leverage for zombie firms. Year 0 corresponds to the first sample year when a firm is classified as zombie. The zombie status can change after year 0, i.e., the zombie condition is not imposed for years 1 to 4. The performance of zombies is compared to a matched sample of low-quality firms. Panel A shows the evolution of asset-weighted interest rates, while Panel B shows the evolution of asset-weighted leverage. The green dashed line in Panel A represents the benchmark interest rate below which debt is classified as subsidized.

before their “zombification” these firms had to pay interest rates comparable to the rates incurred by low-quality non-zombie firms. Using syndicated loan data, Acharya et al. (2019) shows that this rate reduction for zombie firms is driven by both, very advantageous interest rates on newly raised debt and renegotiations of the interest rates on pre-existing loans, which then turn the respective low-quality firms into zombies.

Panel B of Figure 4 shows that, after becoming zombies, these firms experience a leverage increase. Since zombies have on average a negative IC ratio (even though they benefit from subsidized debt), they are unable to meet their current interest payments from their earnings. To avoid default, these firms thus have to raise additional debt (which thanks to zombie credit is cheap) to obtain the liquidity necessary to meet payments on other outstanding loans.

Figure D.3 shows that zombie firms experience a sharp drop in their sales growth and profitability in the run-up to becoming a zombie firm. While these firms’ sales growth temporarily increases after turning into a zombie, their (very low) profitability does not materially improve. The fact that the interest rate paid by zombie firms is not generally

6B;m`2 8t@SQbi 6B`K .27 mHB_Mi2HX b?Qrb i?2 +mKmH iBp2 2t@TQbi /27 mHi
}`Kb U}`Kb i? i ? p2 #22M xQK#B2b +QMiBMmQmbHv bBM+2 i H2 bi kyRkV M
UHQR@[m HBiv MQM@xQK#B2 }`Kb i? i r2`2 M2p2` +H bbB}2/ b xQK#B2bVX S
aT2+B}+ RBX M U

HQR2`- #mi /`QTb 2t +iHv ii?2 iBK2 r?2M i?2B` T`Q}i #BHBiv /2i2`
i? ii?2b2 }`Kb BM/22/ #2M2}i 7`QK bm#bB/Bx2/ BMi2`2bi` i2bX

AMB;m`-2r2 M Hvx2 2t@TQbi /27 mHib- MQM@T `K2i`B+ HHv B
+ HHv BM S8SM2HX b?Qrb i? ii?2 /27 mHi` i2 Q7 xQK#B2 }`Kb BM+
2M/ Q7 i?2 b KTH2 T2`BQ/- bm;;2biBM;i? i U i H2 bi bQK2V xQK#B
pQB//27 mHi /2bTBi2 i?2B` +?2 T /2#i }M M+BM;X q2 i2bi i?Bb /2
BM i?2 bm#b KTH2 Q7 HQR@[m HBiv }`Kb- i?2 7QHHQRBM; bT2+B}+

Default $i_{hjt} = + I_t \text{ Zombie}_{hjt} + X_{ihjt} + h_{jt} + i_{hjt}; \quad URV$

r?2i2Bb }`Ki-?2 +QmjM?2vBM/mbit`i?2M2i_t`XBb v2 `Hv BM/B+ iQ`p `B
2[m HiQ=R BM0 Qi?2`rBb2_hjt M2 BM/mbi`v@+QmMi`v@v2 `}t2/2z2+i
X_{ihjt} BM+Hm/2b i?2 mMQM#B`2B i2H2 b r2HH b Qi?2` }`K +? ` +i2`B

R8 Q` i?Bb M HvbBb- r2 2KTHQv i?2 H2; H bi imb p? Bv# B2 k7y QNK K /2mb Ub22

RN

6B;m`2 @M~ iBQM .vM KB+b LQM@S ` K2i`hB+BpBm2Mib2Qrb BM~ iBQM Uv2 ` v2 `*SA ;`Qri?V iKQMi?Hv 7`2[m2M+v 7Q`K `F2ib i? i2tT2`B2M+2/ M #Qp2 #2HQR K2/B M UGQR wQK#B2V BM+`2 b2 BM i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B

+Q2{+B2THQii2/ BM S ME;h" iQ7M}`Kb i? i xQK#B2 }`Kb /27 mHi KQ i? M MQM@xQK#B2 }`Kb iQr `/b i?2 2M/ Q7 Qm` b KTH2 T2`BQ/X

h?2b2 };m`2b bm;;2bi i? i xQK#B2 }`Kb- 2p2M rBi? i?2B` bm#bB/ mM/2`T2`7Q`K2/ Qi?2` }`Kb- BM+Hm/BM; HQR@[m HBiv MQM@xQK p HB/ i2b Qm` xQK#B2 K2 bm`2- bm;;2biBM;i? i Qm` K2 bm`2 /Q2b r2 F }`Kb i? i `2 +im HHv TQbBiBp2 LSo T`QD2+ib 7Q` i?2 H2M/2 Qmi i? i+?2 T +`2/Bi Bb T`QpB/2/ /m2 iQ `2H iBQMb?BT H2M/BM;

9 wQK#B2 6B`Kb M/ *SA :`Qri?

AM i?Bb b2+iBQM- r2 T`QpB/2 2pB/2M+2 +QMbBbi2MirBi? M2; iBp }`Kb QM BM~ iBQM BQ-A10 X R2 b2Mib PGa 2biBK i2b /Q+mK2MiBM; `C +Q``2H iBQM #2ir22M i?2 T`2b2M+2 Q7 xQK#B2 B`KN2MQ16/A;+iQri?

M Ao 2biBK iBQM iQ 7m`i?2` //`2bb TQi2MiB H 2M/Q;2M2Biv +QM q2 bi `i #v T`QpB/BM; MQM@T ` K2i`B+ 2pB/2M+2 QM i?2 +Q``2 ir22M i?2 xQK#B2 b? `2 M/ *SA ;`Qri?- Qm` K6BMmp`2 BQ#H2?Q7 BM

v2 `@Qp2`@v2 `*SA ;`Qri? 7Q` K `F2ib rBi? ?B;? U #Qp2 K2/B M
;`Qri? Q7 xQK#B2 }`KbX *QMbBbi2Mi rBi? i?2 `Bb2 Q7 xQK#B2b b
#2;BMMBM; BM KB/@kyRk- K `F2ib rBi? ?B;?2` BM+`2 b2 BM i?
bi`QM;2` /2+HBM2 BM *SA ;`Qri?X

9XR PGa 1biBK iBQM

q2 i2bi i?2 2z2+i Q7 xQK#B2 +`2/Bi QM *SA ;`Qri? #v 2biBK iBM; i?

$$Y_{hjt} = \text{Share Zombies}_{hjt} \cdot 1 + \text{ht} + \text{jt} + \text{jh} + \text{hjt}; \quad \text{UkV}$$

r?2`2 i?2 mMBi Q7 Q#b2`ph iBQM nbbi`M/mvXYjt Bb i?2 MMm H *SA
;`Qri? ` i2X Pm` F2v 2tTH M iQ`v p `B #H2 Bb i?2 H ;;2/ U bb2i@
}`Kb BM T `iB+mH Shark Zombies,ijt 1X AM i?2 KQbi +QMb2`p iBp2 bT2-
r2 +QMi`QH 7Q` BM/mbi`v@+QmMi`v- +QmMi`v@v2 `- M/ BM/mbi`
Pm` }t2/ 2z2+ib HHQr mb iQ BbQH i2 i?2 2z2+i Q7 xQK#B2 +`2/Bi
Bmi2`2bi- ?QH/BM; +QMbi Mi i?2 iBK2@p `vBM; /2K M/ i i?2 BM/m
+QmMi`v@v2 ` }t2/ 2z2+ib #bQ`# HH b?Q+Fb i i?2 M iBQM H H2p
+QmMi`v@H2p2H /2K M/ b?Q+Fb- +? M;2b BM i t` i2b M/ M iBQM
v2 ` }t2/ 2z2+ib #bQ`# HH b?Q+Fb i i?2 BM/mbi`v H2p2H U2X;X- B
AM/mbi`v@+QmMi`v }t2/ 2z2+ib +QMi`QH 7Q` iBK2@BMp `B Mi BM
h?2 2biBK iBQM `2bmHib BM2SQM2)HK iQ 7i K `F2ib i? i 2tT2`B2M
BM+`2 b2 BM i?2 b? `2 Q7 xQK#B2 }`Kb bm#b2[m2MiHv ? p2 HQR2

R^aMB;m`2-.K29b?Qr i? i Qm` ;;`2; i2 *SA ;`Qri? K2 bm`2- + H+mH i2/ 7`QK C
K `F2i@H2p2H *SA / i - +HQb2Hv i` +Fb i?2 Q{+B H *SA ;`Qri? 7Q` Qm` b KT
#2+QK2b 2p2M bK HH2` r?2M r2 2t+Hm/2 62ti`2K2 K `F2ib-ô i? i Bb- K `F2ib i?
MMm H *SA ;`Qri? Q7 KQ`2 i? M 8yW U}p2 K `F2ibVX HH`2;`2bbBQM`2bmHi
BM+Hm/2 Q` 2t+Hm/2 i?2b2 }p2 Kh`F22bXX b?QrM BM

S M2H , qBi?Qmi Zm HBiv	*SA	*SA	*SA	*SA	
a? `2 wQK#B2b	yXykR	yXyR3	yXyk8	yXykJ	UyXyyV
P#b2`p iBQMb	j-33y	j-33y	j-33y	j-33y	
_@b[m `2/	yX9Ne	yXdjk	yX8ke	yXde9	
S M2H ", " b2HBM2	*SA	*SA	*SA	*SA	
a? `2 wQK#B2b	yXyk8	yXykR	yXyk3	yXyk9	UyXyyNV
a? `2 GQR@Zm HBiv	yXyy8	yXyy9	yXyy9	yXyyk	UyXyyjV
P#b2`p iBQMb	j-33y	j-33y	j-33y	j-33y	
_@b[m `2/	yX9Ne	yXdjj	yX8ke	yXde9	
S M2H *, SH +2#Q	*SA	*SA	*SA	*SA	
a? `2 GQR@Zm HBiv	yXyyR	yXyyy	yXyyy	yXyyk	UyXyy9V
P#b2`p iBQMb	j-33y	j-33y	j-33y	j-33y	
_@b[m `2/	yX9N8	yXdjR	yX8k9	yXdej	
*QmMi`v@AM/mbi`v 61	X	X	X	X	
u2 `61	X				
AM/mbi`v@u2 `61		X		X	
*QmMi`v@u2 `61			X	X	

h #H2,kS`2p H2M+2 Q7 wQK#B2 6B`Kb M/h`SA:G H2X`2b2Mib 2biBK iBQM`2br
aT2+B)+ iBQMhUX h?2 /2T2M/2Mi p`B #H2 Bb i?2 MMm H *SA;`QriQ`i2 UBM
tXa? `2 wQK#B2 6B`Kb M/h`SA:G H2X`2b2Mib 2biBK iBQM`2br
} `Kb BM T`iB+mH t K1`F2ibT2+iBp2HvX } `K Bb +H bbB}2/ b xQK#B2 B7 Bi
T B/ /p Mi ;2Qmb BMi2`2i+iBQ7Q7KQ`2 /2i BHbVX ai M/` /2`Q`b `2 +Hmb
BM/mbi`v@+QmMi`v H2p2H M/`2TQ`i2KBM`4y`2WBi`2`K2Bx T

+Q2{+B2Mi Bb bi #H2 b r2 // /Bz2`2Mi H v2`b Q7 }t2/ 2z2+ibX "
*QHmKM U9V- kXkTT2?wQK#B2 6B`Kb M/h`SA:G H2X`2b2Mib 2biBK iBQM`2br
kyRe b?Q6B;Bm2Bb bbQ+B i2/ rBi? 8XR#T HQR2` *SA ;`Qri?X
TQi2MiB H +QM+2`M Bbi? ii?2 M2; iBp2 +Q``2H iBQM #2ir22M
+QmH/ #2 /`Bp2M #v M2; iBp2 /2K M/ b?Q+Fb- r?B+? KB;?i bBKmH
M/ BM+`2 b2 i?2 MmK#2` Q7 HQR@[m HBiv } `Kb U M/- BM im`M- xC
+QM+2`M rBi? irQ b2ib Q7 i2bibX 6B`bi- r2 //BiBQM HHv +QMi`Q
BM 2 +? K `F2iX a2+QM/- r2 +QMbi`m+i KQ`2 bi`BM;2Mi xQK#B2 b`

//BiBQM H +`Bi2`B iQ B/2MiB7v xQK#B2 }`Kb i? i `2 mM`2H i2/ i
 aT2+B}+ HHv- 7Q` Qm` }`bi i2bi- r2 // +QMi`QH 7Q` i?2 b? `2
 T `iB+mH `K `F2i iQ aV2+B}+ iBQM U

$$Y_{hjt} = \beta_1 \text{Share Zombies}_{hjt} + \beta_2 a_{jt} + \beta_3 GQR_{hjt} + \beta_4 H Biv_{hjt} + \beta_5 U_{hjt}$$

r?2`2_{hjt} Bb ; BM i?2 MMm H *SA ;`Qri? ` i2X h?Bb //BiBQM H +QM
 +QmMi`v@v2 `bT2+B}+ 7 +iQ`b i? i z2+i p2` ;2 }`K [m #HB2vX h?2
 kb?Qri? i i?2 +Q2 {a?B 2MGQ7@ Zrb BNB bB;MB}+ Mi M/i? i //BM;i?B
 ? b HKQbi MQ 2z2+i QM i a2 +Q 2(Q K # B 2 Q 7

b 7m`i?2` `Q#mbiMh #H 22b K2B M THQv M Hi2`M iBp2 HQR@[m
 K2 bm`2 i? i BM+Hm/2b QMHv }`Kb i? i `2 Q7 HQR@[m H B Zm #H B i SIAW,`Qri?-
 LWX q?BH2 i?2`2 Bb TQbBiBp2a?Q`2 GH i B Zm #H B i SIAW,`Qri?-
 BM+Hm/BM;i?Bb Hi2`M iBp2 K2 bm`2 /Q2b MQi K i2`B HHv z2+i
 i?2 2+QM QKB+ K aMB 2mw Q K # B 2 b

6BM HHv- BM S M 22H 2 Q Q M/m+i TH +2#Q i2b a?M/2bwm Q K #B i 2bi 2
 BM aT2+B}+ v i BQM U2 GQR@ X m i B i Q 2{+B2Mi`2K BMb BMbB;MB}+
 6Q` Qm` b2+QM/ i2bi- r2 2KTHQv i?`22 KQ`2 bi`BM;2Mi xQK#B.
 BM+Hm/2 //BiBQM H +`Bi2`B # b2/ QM i?2 xQK#B2 H2M/BM; K2+
 7`QK r2 FHv@+ TBi HBx2/# MFb iQ MQM@pB #H2 #Q``Qr2`bV i? i
 bB/2 7 +iQh #H 2 A M Q HmKM URV r2 QMHv +QM bB/2` +? M;2b iQ i?2
 Q++m``2//m 2 B Q B M i?2 /p Mi ;2Qmb B Mi2`2bi` i2b +`Bi2`B QMX aT
 +H bbB7v }`Kb b xQK#B2b i? i }`bi`2+2Bp2//2#i i HQR B Mi2`2bi`
 i? M xQK#B2 H2M/BM;V- M/i?2M im`M2/ B Mi Q xQK#B2 #2+ mb2

AM *QHmKMb Ukv M/ UjV- r2 7m`i?2` `2bi`B+i i?2 xQK#B2 b? `2
 BMbi M+2b r?2`2 }`Kb `2 +QMM2+i2/ iQ r2 F # MFb- i? i Bb- # MF

	*SA	*SA	*SA
a? `2 wQK#B2b UA_V	yXyjR		
	UyXyR9V		
a? `2 wQK#B2b UA_Yq2 F " MFbV	yXyeR		
	UyXykdV		
a? `2 wQK#B2b UA_Yq2 F aBM;H2 " MFbV	yXy3j		
	UyXyj9V		
P#b2`p iBQMb	j-33y	k-y3y	k-y3y
_@b[m `2/	yXde8	yX3yd	yX3y8
*QmMi`v@AM/mbi`v 61	X	X	X
AM/mbi`v@u2 `61	X	X	X
*QmMi`v@u2 `61	X	X	X

h #H2,j*SA :`Qri? ai`BM;2Mi wQK#B2 a? `2 h2Bbm`#H2 T`2b2Mib 2biBK iBQM`
7`QK aT2+B}jVXBQ12U2T2M/2Mi p`B #H2 Bb i?2 MMm H *SA t`QriQ X i2 UBM~
}`K Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B2+VbCMQ2Qmb BM
KQ`2 /2i BfbVxwQK#B2K2LbAm`2b i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM`
it 1 r?2`2 r2 QMHv +QMbB/2` xQK#B2 bi imb +? M;2b i? i Q++m`2/ /m2 iQ b
BMi2`2bi` i2b +`Bi2`BQMX AM *QHmKMb UkV M/ UjV- r2 //BiBQM HHv`2[mB`2
}`Köb # MFb? p2 QM p2` ;2 hB2`@R + TBi H` iBQ #2HQR NW Uq2 F " MFbVX A
`2[mB`2 7Q` i?2 xQK#B2 +H bbB}+ iBQM i? i i?2 }`K Bb QMHv +QMM2+i2/ iQ bE
7Q` i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ ` /2`Q`b `2 +Hmbi2
M/ `2TQ`i2/ BM T `2Mk?y2y2R-X yXyTB < yXR X

hB2`@R` iBQ #2HQIANW*BM mkyM NjV- r2 //BiBQM HHv`2[mB`2 i?
+QMM2+i2/ iQ QM2 # MFX wQK#B2 H2M/BM; BM+2MiBp2b b?QmH/
`2bT2+iBp2 # MF /Q2b MQi M22/ iQ rQ` `v i? i i?2 xQK#B2 HQ M Bb
h?2 K ;MBim/2b 7Q` i?2b2 KQ`2 bi`BM;2Mihx QK#B2Hb?;22 K?2 M m`2
Qm` # b2HBM2h`2bixH6Q BM`2 xQK#B2 b? `2 K2 bm`2 BM *QHmKM
RXdTT BM+`2 b2 7`QK kyRk iQ kyRe- BKTHvBM; 8Xj#T HQR2`
K2 bm`2 BM *QHmKM UkV H2 /b iQ RXk8TT xQK#B2 b? `2 BM+`2
+Q` `2bTQM/b iQ /`QT BM *SA ;`Qri? Q7 dXe#TX 6Q` i?2 KQbi bi`B
BM *QHmKM UjV- r2 Q#b2`p2 RXR8TT BM+`2 b2 7`QK kyRk iQ kyR

Rq2 b2ii?2 hB2`@R + TBi H` iBQ i?`2b?QH/ iQ NW bBM+2i?2 1m`QT2 M " MFb
#v kyRkX J2 bm`BM; + TBi HBx iBQM BM kyyN`mH2b Qmii? i# MFb `2 r2 FHv
/2K M/ b?Q+Fb /m`BM; Qm` b KTH2 T2`BQ/X Pp2` HH- kRW Q7 Qm` b KTH2 # MF

*SA ;`Qr^{R3}?X

h?2b2`2bmHib T`QpB/2 7m`i?2` 2pB/2M+2 BM bmTTQ`i Q7 i?2 xQ
i? i Qm` 2biBK i2b `2 MQi K i2`B HHv #B b2/ #v /2K M/@bB/2 2z
i? i BM+Hm/BM; KQ`2 bi`BM;2Mi +`Bi2`B # b2/ QM i?2 xQK#B2 +`
K ;MBim/2 Q7 i?2 PGa 2biBK i2 ?BMib iQr `/b `2/m+iBQM BM i?
r2 KBb+H bbB7v ói`m2ô MQM@xQK#B2 }`Kb b xQK#B2b `2H iBp2
h?2b2 KBb+H bbB}+ iBQMb + M H2 / iQ M mM/2`2biBK iBQM Q7 i
*SA ;`Qri? BM Qm` # b2HBM2 bT2+B}+ iBQM bBM+2 i?2v BM~ i2 i?
i?2 KBb+H bbB}2/ }`Kb /Q MQi +QMi`B#mi2 iQ i?2 /QrMr `/ T`2bbm
2pB/2M+2 i?mb bm;;2bib i? i Qm` # b2HBM2 PGa 2biBK i2 +QMbi
2z2+i Q7 xQK#B2 +`2/Bi QM *SA ;`Qri?X

b 7m`i?2` TH +2#Q +?2+F ~~BM H2j 2 QMT2HQQ b~~ T2+B}+ iBQMb BI
r2 QMHv +QMbB/2` }`Kb i? i `2 +QMM2+i2/ iQ # MFb rBi? M p2` ;2
H2 bi NW M/ }`Kb i? i `2 QMHv +QMM2+i2/ iQ KmHiBTH2 # MFb i?
+ TBi H` iBQ #Qp2 NW- `2bT2+iBp2HvX q2 biBHH }M/ r2 F 2z2+
bT2+B}+ iBQM U@yXyRR V- #mi i?2 2z2+i /Bb TT2 `b 7Q` i?2 H ii2

6BM HHv- r2 +QM/m+i b2p2` H`Q#mbiM2bb +?2+FbX 6B`bi- r2 b
iQ mbBM; Hi2`M iBp2 xQK#B2 ~~h #H b VXY+AMBQMiBubn2~~ - r2 UBV +
K2/B M p Hm2b 7Q` H2p2` ;2 M/ A* ` iBQ i i?2 BM/mbi`v@v2 ` H2
+QmMi`v@v2 ` H2p2H- UBBV +QMbB/2` bQH2Hv i?2 A* ` iBQ +`Bi2
BMbi2 / Q7 #Qi? +`Bi2`B - M/ UBBBV + H+mH i2 i?2 A* ` iBQ mb
BMbi2 / Q7 1"AhfBMi2`2bi 2tT2Mb2bX JQ`2Qp2`- iQ KBiB; i2 +QM-
+ iBQM Bb BM~m2M+2/ #v BM~ iBQM@BM/m+2/ /Bz2`2M+2b BM HQ

^{R3}h?2b2 K ;MBim/2b `2 +QMbBbi2Mi rBi? i?2 7 +i i? i i?2 K DQ`Biv Q7 xQK#B
rBi? hB2`@R` iBQ #2Hqr NW U8eWV- QMHv`2TQ`i QM2 # MFBM;`2H iBQMb
i?`Qm;? brBi+? BM i?2 BMi2`2bi` i2 +`Bi2`BQM UdyWVX h?2b2 b? `2b `2 2p2

M Hi2`M iP2 xQK#B2 /2}MBiBQM i? i BM+Hm/2b /2#i +Qbi /D
#2ir22M i?2 BM~ iBQM Q7 i?2 `2bT2+iBp2 }`Köb ?QR^{R2} +QmMi`v M
a2+QM/- Qm` `2bmHib `2 `Q#mbiiQ 2KTHQvBM; Hi2`M HiBp2 xQK
*XYX aT2+B}+ HHv- r2 UBV mb2 r2B;?iBM; #v im`MQp2` BMbi2 / C
+ H+mH iBQM M/ UBBV ++QmMi 7Q` i?2 TQi2MiB H MQM@HBM2
b2iiBM; i?2 paHm2 QK#B2` Q B7 Bi Bb #2HQR 8W Q` kW- `2bT2+iB
h?B`/- Qm` `2bmHib /Q MQi K i2`B HHv +? M;2 B7 r2 /`QT QM2 +C
UBB;m`2V.X6Qm`i?- r2 b?Qri? ii?2 xQK#B2 +`2/Bi K2+? MBbK + M
r2 K2 bm`2 T`B+2 +? M;2b rBi? i?2 SSA BMBi2XQR7mKM RS/X UB7i?
r2 }M/ i? ii?2 2z2+i Q7 ?B;?2` xQK#B2 b? `2 QM *SA ;`Qri? Bb /`E
bBM;H2 Hi2`M/2`V9?B+? Bb +QMbBbi2Mi rBi? i?2 xQK#B2 +`2/Bi K
TT2M/Btr2 b?Qri? i Qm` `2bmHib `2 MQi 2tTH BM2/ #v Hi2`M iP2

9Xk Ao 1biBK iBQM

hQ //`2bb TQi2MiB H QKBii2/ p `B #H2 #B b2b M/- BM T `iB+mH
i?2 M2; iP2 +Q` `2H iBQM #2ir22M i?2 T`2b2M+2 Q7 xQK#B2 }`K
#v /2K M/ 2z2+ib- r2 `mM M Ao `2;`2bbBQMX hQ i?Bb 2M/- r2 7Q+
BM+2MiBp2b Q7 r2 FHv@+ TBi HBx2/ # MFb b T`2/B+iQ` 7Q` i?2
"v 2ti2M/BM; bm#bB/Bx2/ HQ Mb iQ MQM@pB #H2 #Q` `Qr2`b- r2 F
`2;mH iQ`v `2T2`+mbbBQMb M/ ; K#H2 7Qm+2 BmM/2 GKBQ#2 iUb22-
>QK ` M/ p M qBDMy#2d22MM m 2kyHx M/+? `v 2i-kyKX
a2+iBQM29KHXBm b Qm` " `iBF@bivH2 b?B7ii@ Q MT92B2MM ibm K2 Mi

^{RN}?2 +Qbi Q7 T`QpB/BM; +`2/Bi Bb TQbBiBp2Hv HBMF2/iQ BM~ iBQMX >2M+2
HQ M` i2b KB;?i7QHHQR- r?B+? + M K2+? MB+ HHv BM+`2 b2 i?2 xQK#B2 b? `2
?B;?2` HBF2HB?QQ/ Q7 T vBM; BMi2`2bi` i2b #2HQR i?2 #2M+?K `F` i2`2H i

2biBK iBQMà 2b iBQimX2k2Mib p HB/Biv M//B2;MQQimT2k2MiX
+QmMi2`7 +im H 2t2`+Bb2 iQ bb2bb i?2 2+QMqKB+ K ;MBim/2 Q

9XkXR a2imT

q2 mb2 " `iBF@bivH2 b?B7i@b? `2 BMbi`m`K2MiMPr?B`#H2 TT`
BMbi`mK2Mi K `F2iöb xQK#B2 b? `2 rBi? i?2 T`Q/m+i #2ir22M i?
` iBQ BM kyyN Q7 # MFb +QMM2+i2/iQi?2 }`Kb BMi?Bb K `F2iUr2B
} `K `2H iBQMb?BTbV M/ +QmMi`v@H2p2H HQ M ;`Qri? UQ#i BM2/
6Q`K HHv- Qm` " `iBF BMbi`mK2Mi Bb,

$$B_{hjt} = \frac{X}{b} [m_{bhj}; 2009 \quad hB2` @ R` iBQQ M :` Q]r; i? \quad U9V$$

r?2`r_{bhj;2009} /2MQi2b i?2 MmK#2` Q7 # MF `2H iBQMj b0B TM r07i}vKb B
BM +QmMii`Q #BMFM kyyN /BpB/2/ #v i?2 iQi H MmK#2` Q7 # MF `2H
Q7 K `Hj2X hB2` @R` B B @ M B hB2` @R ` iBQ BM kyyN-ct r BBH22GQ M :
;;`2; i2 HQ M ;`QriöBM @ mMF i`v Q7 BM+iQBTKQ` iBQM

h?2 HQ;B+ #2?BM/ Qm` b?B7i@b? `2 BMbi`mK2Mi Bbi? ii?2 p2`
iQ } `Kb BM i?2 `2bT2+iBp2 K `F2ib /Bz2`b +`Qbb K `F2ib ii?2 #2;B
M/ K `F2ib HBMF2/ iQ r2 FHv@+ TBi HBx2/ # MFb `2 KQ`2 HBF2H
H2M/BM; r?2M i?2 K +`Q2+QMqKB+ +QM/BiBQM b /2+HBM2X

Pm` BMbi`mK2Mi ;2ib HH Q7 i?2 +`Qbb@b2+iBQM H p `B iBQM
7`QK T`2 @2tBbiBM; H2M/BM; b? `2b- M/ HH Q7 Bib iBK2@b2`B2b
?2 Hi? b?Q+FbX h?2 BMbi`mK2Mi i?mb #`BM;b //BiBQM H BM7Q`K
BM/mbi`v@+QmMi`v- BM/mbi`v@v2 ` - M/ +QmMi`v@v2 ` }t2/ 2z2+

ky +? `v 2iUHyXNb?Qrb i? i # MFbö hB2`@R + TBi H ` iBQ Bb ;QQ/ T`2/B+iQ`

+`Qbb K `F2ib M/ Qp2` iBK2X Hi?Qm;? i?2 r2B;?ib +QmH/ `2~2
+`Qbb BM/mbi`v@+QmMi`v T B`b- i?Bb ?2i2`Q;2M2Biv /Q2b MQi
i`QHH2/ 7Q` #v i?2 BM/mbi`v@+QmMi`v }t2/ 2z2+ibX

F2v B/2MiB}+ iBQM bbmK TiBQM Bb i? i i?2 p `B iBQM BM BMB
iQ p `B iBQM BM i?2 T`2p H2M+2 Q7 xQK#B2 }`KbX q2 #2HB2p2 i
2KT B`B+ H +QMi2ti 7Q` i?`22 `2 bQM bX 6B`bi- i?2 b? `2 Q7 xQK#B
7Q` KQbi 1m`QT2 M +Qm Mi: B2 bMU2i2k1F2X;K K 2` b b Q-My2iR MX
" M2`D22 M/ >-Q y Kk MMW xQK#B2 }`Kb r2`2 i?mb MQi K DQ` 7 +iQ`
1m`QT2 M 2+QM QKv 2tT2`B2M+2/ bB;MB}+ Mi BM+`2 b2 BM xQK
6B;m`VXR a2+QM/- i?2 p `B iBQM BM 2[mBiv + T Bi HBx iBQM +`Q
r b H`;2Hv /`Bp2M #v i?2B` 2tTQbm`2 iQ i?2 IXaX ?QmbBM; K `F2
BM+m``2/- 7Q` 2t KTH2- QM KQ`i; ;2@# +F2/ b2+m`BiB2b M/ /m2
>2M+2- # MFbö + T Bi HBx iBQM BM kyyN r b K BMHv /2i2`KBM2/
+Q`TQ` i2 H2M/BM;X h?Bb Q#b2`p iBQM Bb HbQ `2~2+i2/ BM i?
HQ M H2p2Hb Q7 1m`QT2 M # Mrf b B M F-2jy kX U b 2 B`-#2X2 b-X Qrb
i? i i?2`2 Bb MQ bB;MB}+ Mi`2H iBQM b?BT #2ir22M # MF +QKTQb
+`Qbb /Bz2`2Mi K `F2ibV M/ K `F2i +? ` +i2`BbiB+bX

q2 mb2 i?2 +QmMi`v@H2p2H HQ M ;`Qri? b T`Qtv 7Q` iBK2@p `
b2+iQ` ?2 Hi? bBM+2 i?2`2 Bb KTH2 2pB/2M+2 i? i /`QT BM HQ M
bi`2bb2/ # MFBM; b2+iQ` U7Q` i?2 1m" Q T Q M B Q y R i 2 H i m 2 x B X;X-
2i H X y R 3+? `v` 2i-kH R 3.2 J `+Q y R N M /H i i M 2` 2k y k j X 7 Q` i?2 IXaX
b22- 2Xp Xb-? BM M/ a+R y R y Q 2 B M i 2 k y R R M ? Q / Q` Q r @ k y B X?

9XkXk 1biBK iBQM _2bmHib

h #H2T92b2Mib i?2 `2bmHib 7Q` i?2 Ao bT2+B}+ iBQM X AM Qm`
/2i2`KBM2 # MF@}`K `2H iBQM b?BTb mbBM; #Qi? K /2mb M/ .2
`Q#mbiM2bb +?2+F- r2`2/Q Qm` M HvbBb mbBM; # MF@}`K `2H iB

S M2H , a2+QM/ ai ;2 *SA	*SA	*SA	
Share Zombies	yXRkk UyXy8RV	yXRy8 UyXy93V	yXRjy UyXy8jV
P#b2`p iBQMb	k-y3y	R-3jN	k-y3y
S M2H ", 6B`bi ai ;a? `2 wQK#B2b a? `2 wQK#B2b a? `2 wQK#B2b			
hB2`@R kQ QNM :`Qri? RyXy8	UkXjdV	RjX38 UjXkRV	NXNd UkXjdV
6@h2bi	jyX3	jdX9	jyXd
P#b2`p iBQMb	k-y3y	R-3jN	k-y3y
_@b[m`2/	yXe3d	yXeNR	yXe3d
a KTH2	K /2mb	K /2mb	K /2mb
	Y .2 Ha+ M	PMHv	Y .2 Ha+ M Ai Hv
*QmMi`v@AM/mbi`v 61X		X	X
AM/mbi`v@u2 `61	X	X	X
*QmMi`v@u2 `61	X	X	X

h #H2,9AMbi`mK2Mi H o `B #H2 1b?Bk iB#QHX`2b2Mib i?2 2biBK iBQM `2bmHib
bT2+B}+ iBQMX h?2 }`bi bi ;2 `2bmHib `2 b?QrM BM S M2H " M/ i?2 b2+QM/
/2T2M/2Mi p `B #H2 BM i?2 b2+QM/ bi ;2 Bb i?2 MMmaH`SAQK#B2bmi2UBM~ i
i?2 bb2i@r2B;?i2/ b? `2 Q7xQK#B2 @RkkyN`2bi?2 hB2`@R` iBQ Q7 i?2 # MF
iQ i?2 }`Kb BM i?2 T `iB+mH `k?F2iwUQK#B2BM; Bib hB2;?@R kQ QNM :`Q7iQK 1[X
+QmMi`v@H2p2H Q7 i?2 # MFöb +QmMi`v Q7 BM+Q`TQ` iBQMX " MF`2H iBQMb
.2 Ha+ M BM *QHmKM URV- bQH2Hv K /2mb BM *QHmKM UjV- b r2HH b K /2m
BM *QHmKM UjVX ai M/ ` /2`Q`b `2 +Hmbi2`2/ i i?2 BM/mbi`v@+QmMi`v H2p2
KyXyR-<yXy8<yKRX

U*QHmKM kV M/ UBBV 7`QK .2 Ha+ M 7Q` Ai Hv U K /2mb /Q2b MQ
7Q` Ai HvV M/ 7`QK K /2mb 7Q` Qi?2^{kR}+QmMi`B2b U*QHmKM jVX
h?2 }`bi bi ;2- b?QrM BM S M2H "- 2tTH BMb i?2 b? 1`BQ 7 xQK#B
T `iB+mH `k?F2iwUQK#B2BM; Bib hB2;?@R kQ QNM :`Q7iQK 1[X
UV- r?2`2 i?2 HQ M ;`Qri? Bb k2b m`2QMiqQHBM; 7Q` bi`BM;2Mi
2z2+ibX h?2 BMbi`mK2Mi Hr vb ? b M2; iBShareZombiesM B?+ Mi 2z2

^{kR}:Bp2Mi? i K /2mb /Q2b MQi`2TQ`ii?2 }`Kbö K BM # MFb 7Q` HH +QmMi`B2
r?2M 7Q+mbBM; QM K /2mb / i QMHvX q?2M2p2` p BH #H2- r2 + M m;K2Mi }`
HQ M / i 7`QK .2 Ha+ MX aiBHH- BM bQK2 BM/mbi`v@+QmMi`v T B`b bvM/B+ i
Qm` Qp2` HH b KTH2 bBx2 Bb HQR2` 7Q` Qm` Ao 2biBK iBQMX

6@bi iBbiB+ ` M;2b #2ir22M jyXd M/ jdX9- r?BH2 i?2 T@p Hm2 Bb
i?2 bi`2M;i? Q7 i?2 BMbi`mK2MiX

AM i?2 b2+QM/@bi ;2 2biBK iBQM- b?QrM BM`S MQK#B2B `2TH
i?2 T`2/Share/Zombies7`QK i?2 }`bi bi ;2X h?2 Ao 2biBK i2/ +Q2{+B2M
M2; iBp2 2z2+i Q7 M BM+`2 b2 BM i?2 T`2p H2M+2 Q7 xQK#B2 }`
+QM+2`Mb i? i Qm` 2z2+i KB;?i #2 /`Bp2M #v Mh Q#KBi#2/2p `B #H
b?Qr i? i Qm` `2bmHib `2 `Q#mbi iQ mbBM; i?2 +QmMi`v@H2p2H ;
ULSGbV b T`Qtv 7Q` +QmMi`v@H2p2H b?Q+Fb iQ i?2 ?2 Hi? Q7 i
;;`2; i2 HQ M^{k-k} Qri?X

*QKT `BM; i?2 K ;MBim/2b +`Qbb Qm` PGa M/ Ao 2biBK iBQMb
2{+B2Mib # b2/ QM i?2 KQ`2 bi`BM;2Mi xQK#B2 +H bbB}+ iBQMb `
2biBK i2b- i?2v `2 biBHH bK HH2` i? M Qm` Ao 2biBK i2bX h?2 `2
i?2 PGa M/ Ao 2biBK i2b `2 HBF2Hv /m2 iQ /2pB iBQM #2ir22M i
U h1V 7`QK Qm` PGa 2biBK iBQM M/ i?2 HQ+ H p2` ;2i`2 iK2Mi 2
2biBK iBQMX aT2+B}+ HHv- Qm`2+B;MMBMB;Bj2bi2i0bi2Qm` Ao`2b
`2 /`Bp2M #v bm#b2i Q7 # MFb- i? i Bb- r2 FHv@+ TBi HBx2/ H
i?2b2 # MFb `2 2tTQb2/ iQ NyW Q7 HH BM/mbi`v@+QmMi`v T B`b
i?2B` BM/mbi`v@+QmMi`v 2tTQbm`2 /Bz2`b 7`QK i?2 2tTQbm`2 Q
TH2X JQ`2Qp2`- i?2+2B0MQR BMi i?2 2z2+i Q7 xQK#B2 +`2/Bi QM
/Bz2`b +`Qbb K `F2ib U2X;X- ?B;? pbX HQR }t2/ +Qbi b2+iQ`b- i` /
h?2`27Q`2- i?2 G h1 2biBK i2/ rBi? Qm` Ao TT`Q +? /Q2b MQi M2-
rBi? i?2 2biBK i2 Q7 i?2 h1 7`QK Qm` PGa bT2+B}+ iBQMX

AM bmK- Qm` 2pB/2M+2 bm;;2bib i? i i?2 +Q2{+B2Mi Bb #2ir22M

^kkaT2+B}+ HHv- i?2 }`bi bi ;2 Ub2Share/Zombies7`QK i?2 }`bi bi ;2BM BMbiB+mH `K `F2i rBi? i?2
K `F2iöb r2BhB 22/@R kly@ULSG ;`Qr??2V 2 il?SG ;`QrB?b K2 bm`2t/ 72 QK 1X
q2 Q#i BM / i #Qmii?2 LSG ;`Qri? 7`QK i?2 1*" / i r`2?Qmb2X

b2HBM2 PGa 2biBK i2b K `F i?2 HQr2` 2M/ M/ i?2 Ao 2biBK i2b i?

9XkXj o HB/Biv

AM i?Bb b2+iBQM- r2 7m`i?2` bb2bb i?2 p HB/Biv Q7 Qm` xQK#B2
i?2 B/2MiB}+ iBQM bbmK TiBQM b Q7 Qm` " `iBF Ao TT`Q +?X

AMbi`mK2Mi M/ wQK#B2 6B`K *H" mBBH/BMBQMX?2 i?2Q`2iB+ HBM
a2+iBQM k`bi 7m`i?2` +?2+Fi?2 TH mbB#BHBiv Q7 Qm` BMbi`mK2M

iBQM #v BMP2biB; iBM; r?2i?2` i?2 }`bi bi ;2 2biBK i2b b?Qr KQ`2
MF ?2 Hi? M/ xQK#B2 T`2p H2M+2 BM K `F2ib i? i `2 KQ`2 T`Q

aT2+B}+ HHv- r?2M Qm` BMbi`mK2Mi M/ xQK#B2 +H bbB}+ iBQ
b22 bi`QM;2` 2z2+i 7Q` K `F2ib i? i- BM //BiBQM iQ #2BM; +QM

/2T`2bb2/ M/fQ` KQ`2 mH-2Qp 2BMX?2 2z2+i b?QmH/ #2 KQ`2 T`QM
MFb 7 +2 KQ`2 H2MB2Mi bmT2`pBbQ`- 7Q` 2t KTH2 QM2 i? i/G

Qz LSGbX ++Q`/BM;Hv- r2 `2`mM i?2 }`bi bi ;2 Q7 i?2 Ao bT2+B}
xQK#B2 b? `2 QM Qm` " `iBF BMbi`mK2MiV b2T `i2Hv 7Q` /2T`2bb

?B;? M/ HQr mM+2`i BMiv K `F2ib- M/ +QmMi`B2b rBi? ?B;? M
bmT2`pBbBQMX

hQ` MF K `F2ib ++Q`/BM; iQ i?2B` ?2 Hi? i i?2 2M/ Q7 kyRR U
i?2 xQK#B2 b? `2 BM+`2 b2V- r2 + H+mH i2 i?2 +? M;2 BM p Hm2

H2p2H 7`QK kyyd UH bi T`2@+`BbBb v2 `V iQ kyRRX q2 i?2M bTHE
p Hm2 //2/ +? M;2b B MiQ /2T`2bb2/ UHQr ?2 Hi?V M/ MQM@/2T`

^{kj} ?B;?2` K `F2imM+2`i BMiv HQr2`bi?2 LSo Q7 i?2 }`Kbö QT2` iBM; T`Q}ib U
Q7 xQK#B2 + M/B/ i2bV b`BbF@ p2`b2 BMP2biQ`b/`Bp2 ?B;?2`/Bb+QmMi` i2
#H2 Qmi+QK2b biBHH HHQrb 7Q` ?B;? T vQz Qmi+QK2b- BM+`2 bBM; i?2 ii` +i
^{k96}Q` i?Bb M HvbBb- r2 2KTHQv Qm` T`272`2/ BMbi`mK2Mi bT2+B}+ iBQM-
`2H iBQM b?BTb mbBM; #Qi? K /2mb M/ .2 Ha+ MX

	>2 Hi?	IM+2`i BMiv
	U?B;?V UHQrV	UHQrV U?B;?V
S M2H , J `F2i *QM/BiBQM b a? `2 w Qk#B`22 w Qk#B`22 w Qk#B`22 w Qk#B`22		
hB2`@R kQ NM :`Qri? 9XRj RkX39	8Xde RRX3y	
	URXN8V U8XjkV	UkXe9V UjX8RV
P#b2`p iBQM b	R-yRN R-yeR	R-y83 R-ykk
_@b[m `2/	yXdjN yX8NR	yXe9d yXdR9

	amT2`pBbQ`v SQr2`bb2i *H bbB}+ iBQM
	U?B;?V UHQrV U?B;?V UHQrV
S M2H ", " MF amT2`pBbBQM a? `2 w Qk#B`22 w Qk#B`22 w Qk#B`22 w Qk#B`22	
hB2`@R kQ NM :`Qri? 9X3k R8XeN	8X9y R9X8d
	UkXyRV U8XykV UkX8dV UjX8NV
P#b2`p iBQM b	R-kRe 3e9
_@b[m `2/	yXe3N yXd3N
*QmMi`v@AM/mbi`v 61X	X
AM/mbi`v@u2 `61	X
*QmMi`v@u2 `61	X

h #H2,86B`bi ai ;2 aTHBbXi #H2 T`2b2Mib i?2 2biBK iBQM `2bmHib 7`QK i?2 }
 bT2+B}+ iBQM X AM S M2H - r2 bTHBi K `F2ib B Mi Q MQM @/2T`2bb2/ K `F2ib U
 UHQr ?2 Hi?V b r2HH b B Mi Q K `F2ib rBi? ?B;? M/HQr /2;`22 Q7 mM+2`i B Mi
 Q7 i?2 xQK#B2 b? `2 BM+`2 b2VX AM S M2H "- r2 bTHBi K `F2ib ++Q`/BM; iQ r?
 B Mi 2MbBiv k2mT2`pBbQ`v SQr2`bb2i *H bbB}+ iBQM? Qa`H Qr X QK#B`22m`2b i?2
 bb2i@r2B;?i2/ b? `2 Q7 k QK#B2 }@RkkyNm`2b i?2 hB2`@R` iBQ Q7 i?2 # MFb H
 }`Kb B Mi i?2 T `iB+mH `K G2MB:MQk2y N`2b i?2 MMm H HQ M ;`Qri? `i2 ii?2
 H2p2H Q7 i?2 +QmMi`v r?2`2 i?2 # MF Bb BM+Q`TQ` i2/X " MF `2H iBQM b?BTb
 .2 Ha+ MX ai M/ ` /2`Q`b +Hmbi2`2/ ii?2 BM/mbi`v@+QmMi`v H2p2H`2TQ`i2
 K yXy8<yKRX

"27Q`2 +QM/m+iBM; i?Bb bTHBi- r2 ++QmMi 7Q`i?2 7 +ii? ii?2`2
 ;QQ/b Bb HBF2Hv M iBQM H- r?BH2 Bi ;Q2b #2vQM/ M iBQM H #Q
 BM;Hv- r2 p2` ;2 i?2 p Hm2 //2/ +? M;2 7Q`i` / #H2 b2+iQ`b +`Q
 +QM/m+iBM; i?2 bTHBi- J B 2M2 M2 TQyR9 Q /BbiBM;mBb? #2ir22M i`
 M/ MQMi` / #H2 b2+bQ TbXi2 K `F2ib B Mi Q ?B;? M/ HQr mM+2`i B

^{k8}J B M M/ Umy)R9/2}M2b 7Qm`@/B;Bi L A*a BM/mbi`v bi` / #H2 B7 Bib BKTQ
 H2 bi 0Ry-yyy T2` rQ`F2`- Q` B7 iQi H 2tTQ`ib THmb BKTQ`ib 7Q` i?2 L A*a 7Q

bTHBi i?2K i i?2 K2/B M Q7 i?2B` +`Qbb@b2+iBQM H bi M/ `/@/2
UBM bTBHBi i?2K i i?2 K2/B M Q7 i?2B` +`Qbb@b2+iBQM H bi M/ `/@/2
S M2H hQ#H2+QM}`Kb i? i i?2 HBMF #2ir22M K `F2iöb 2tTQbm`
M/ Bib bm#b2[m2Mi +? M;2 BM i?2 xQK#B2 T`2p H2M+2 Bb BM/22
i? i `2 /2T`2bb2/ M/ K `F2ib i? i? p2 ?B;?2` mM+2`i BMivX
hQ bTHBi K `F2ib BMiQ ?B;? M/ HQr # MF bmT2`pBbQ`v BMi2Mb
qQ`H/ " MF " MF _2;mH iBQM M/ amT2`pBbBQM am`p2vX h?Bb / i
QM # MF `2;mH iBQM M/ bmT2`pBbBQM 7Q` R9j Dm`Bb/B+iBQMb-
q2 mb2 / i 7`QK i?2 7QHHRBM; irQ bm`p2v iQTB+b, ó bb2i+H bbE
BM+Hm/2b [m2biBQM bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q
bT2+B}+ iBK2T`NB/UBBV óamT2`pBbQ`v TQr2`b BM + b2b Q7 #
+Hm/2b [m2biBQM bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q
iQ +QMbiBimi2 T`QpBbBQM b iQ +Qp2VXi6QH Q+TQQ2TB+B H2H+Qb/2
v2bfMQ `2bTQM b2b b Rfy M/ +QKTmi2 i?2 K2 M T2` + i2;Q`v 7Q`
i?2 p `B #H2 +QMbi`m+iBQM bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q
q2 i?2M +QM/m+i irQ bTHBib BM r?B+? r2 b2T ` i2 K `F2ib rBi?
K2/B M p Hm2 Q7 Qm` # MF bmT2`pBbQ`v TQr2`b BM + b2b Q7 #
bmT2`pBbQ`v TQr2`b BM + b2bbQ2i# MF bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q
Q7 i?2 bb2i+H bbB}+ iBQM bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q
KQ`2 T`2p H2Mi BM +QmMi`B2b rBi? KQ`2 H2MB2Mi # MF bmT2`pB
h F2M iQ;2i?2`- Qm`2pB/2M+2 +QM}`Kb i? i i?2 `2H iBQM #2ir2
r2 F # MFb M/ Bib xQK#B2 T`2p H2M+2 Bb bi`QM;2` BM K `F2ib i?

LQMi` / #H2 BM/mbi`B2b `2/2}M2/ b i?2 `2i BH b2+iQ` M/ `2bi m` MibX
k eh?Bb `2bmHi Bb BM HBM2 rBi? i?2 2pB/2M+2 7`QK 2tBbiBM; bim/B2b QM i?2
B Mi2MbBiv M/ xQK#B2 H2M/BM; #2P` pNBQ2yi bQmm+2] mb ö2 # MFb iQ r`Bi2 Qz MQM@T2`7Q`
Ai Hv- " QM}K 2iUkyKK 7Q` SQ`im; HX

H2M/BM;- bmTTQ`iBM; i?2 TH mbB#BHBiv Q7 Qm` BMbi`mK2Mi M
" `iBF Ao TT`Q #QX7m`i?2` bb2bb i?2 B/2MiB}+ iBQM bbmKTiB
Ao TT`Q +?- r2 +QM/m+i b2i Q7 /B ;MQQHB b KBb? @ Q bMFBMK2 /B
UkyKyX q2 /Bb+mbb i?2b2 /B ;MQbiBT+T2iM bBMB M m2KKB`HB B Mi?2 K BM
+QM+HmbBQM b BM i?2 7QHHRBM;X

:QH/bKBi? @SBMUKyKyzi? Qrx i? i i?2 " `iBF Ao TT`Q +? Bb 2[m
mbBM; r2B;?i2/ p2` ;2 Q7 b2i Q7 BMbi`mK2Mib # b2/ QM +`Qbb@
b2/ QM iBK2@p `vBM; ;;`2; i2 b?Q+FbX AM Qm` b2iiBM;- i?2 B
ó2tTQbm`2ô iQ # MFb U M/ i?2B` `2bT2+iBp2 + TBi HBx iBQM V B
;;`2; i2 HQ M ;`Qri? b? Qöf b BmM#i`M Q7 BM+Q`tXQ` iBQM i iBK2
6B`bi- r2 T2`7Q`K _Qi2K#2`; /2+QKTQbBiBQM Q7 Qm` " `iBF A
#2`; r2B;?ib i2HH mb ?Qr b2MbBiBp2 i?2 Qp2` HH 2biBK iQ` Bb iQ
BM/BpB/m H BMbi`mK 2 #iib X bX Q i2Hi? Q7?2 bmK Q7 i?2 M2; iBp2 M/
_Qi2K#2`; r2B;05b6 `M1@16- `2bT2+iBp2HvX

h?2 2tBbi2M+2 Q7 M2; iBp2 _Qi2K#2`; r2B;?ib ` Bb2b i?2 TQbbB
b `BHv BKTHvV MQM+QMp2t r2B;?ib QM K V K2A @ b T B b B} b 2i?2KQ p2
" `iBF 2biBK i2 rQmH/ MQi? p2 G h1@HBF2 BMi2`T`2i iBQM b
K2Mi 2z2+ib UMQi2 i? i j r2BM M i Q #2 /B`2+iHv 2biBK i2/VX ?B;?2`
i?2[^] BM+`2 b2b i?2 HBF2HB?QQ/ Q7 XM2; iBp2 H H2B; B Mb Qm b2iiBM;
Bb bQK2 p `B iB[^]QM b Qm b?# MFbX " MFb /Bz2` rBi? `2bT2+i iQ i?2
/Bz2`2Mi K `F2ib- M/- a2 biBQrM 2 B Mz2+i Q7 xQK#B2 +`2/Bi QM *S
/2T2M/b QM K `F2i +? ` +i2`BbiB+bX

AM b2+QM/ bi2T- r2 i?mb T`Q#2 i?2 T ii2`Mb Q7 i?Bb ?2i2`Q;
/Bbi`B#miBQM Q7 i?2 Dmbi B/2MiB}^V X B; 2b i BK X Q r b U B X 2`X2` 2` B b
bQK2 /BbT2`bBQM `Q[^]m #/mi?# MFiB FBi? H `;2` _Qi2K#2`; r2B;?ib i
+HQb2 iQ i?2 Qp2` HH TQB Mi 2biBK i2X JQ`2Qp2` - MQM2 Q7 i?2 ?
_Qi2K#2`; r2B;?ib- KBiB; iBM; +QM+2`Mb #Qmi TQ X2MiB HHv M2;

h?B`/- r2 mb2 i?2 _Qi2K#2`; /2+QKTQbBiBQM iQ BMp2biB; i2 i?2
S M2H h Q 7 1 2 b X Q rbi? ii?2 _Qi2K#2^b; Vr2`B; ? Q` U2H i2/ rBi? i?2 p `B
BM i?2 # MF b? `2b +`Q bShake_hjb F2/i-b Uhp; ; 2biBM; i? i i?2 p `B iBQM
`2H iBQM b? BTb Bb /`BpBM; Qm` 2biBK i2bX S M2H . T`2b2Mib bn
rBi? i?2 ?B; ?2bi _Qi2K#2`; r2B; ?ib- b?QrBM; i? i Qm` Ao 2biBK i2
+ TBi HBx2/ H `; 2 # MFbX h?2b2 }M/BM; b `2 +QM bBbi2Mi rBi? i?2

6BM HHv- r2 +?2+F r?2i?2` i?2`2 Bb p `B iBQM i? i +QmH/ #2
`2bi`B+ h B Q M X b X Q rbi? ii?2`2 Bb MQ T`Q#H2K iB+ `2H iBQM b? BT
bBiBQM BM kyyN UBX2X- # MF b? `2b +`Qbb /Bz2`2Mi K `F2ibV M
B+ HHv- QmiTmi- BMi2`K2/B i2 +QM b mKTiBQM- r ;2b- M/ +QM b m

9XkX9 *QmMi2`7 +im H

AM 1m`QT2- TQHBiB+ H +QMbi` BMib H2/ iQ ?2bBi Mi BMi`Q/m+
BM i?2 7i2`K i? Q7 i?2 kyy3 ;HQ# H+}M`M+Bi- H y R V # B b U B 2 22/
iQ xQK#B2 H2M/BM; BM+ 2 Mi B p 2 H R U b + 2 B p ` / B- 2 y k- H M / H iiM2`
2i H X y k V X q2 + M mb2 Qm` Ao 2biBK i2 iQ /2i2`KBM2 i?2 2pQHmiB
i?2 ?vTQi?2iB+ H + b2 r?2`2 BKTQ`i Mi # MFb BM M22/ Q7 + TBi
rBi? ?B; ?2` + TBi H #mz2`X

6Q` i?Bb +QmMi2`7 +im H 2t2`+Bb2- bBKBH *? B M Q b Q B @ B j 2 i Q + P ? 2
Uk y R V 9 r2 ó`2+ TBi HBx2ô # MFb rBi? hB2`@R + TBi H `iBQ #2HQ

hB2` @ \$ ` i B X Q % ;
b,2009

r?2`2 r2 2KTHQv i?2X? = 2 N W Q M // R y W - `2bT2+iBp2HvX ++Q`/BM;Hv
+QmMi2`7 +im H p Hm2 Q7 Qm` " `iBF BMbi`mK2Mi b,

$$B_{hjt}^C = \sum_b^X m_{bhj; 2009} hB2` @ $ ` i B Q Q M : ` Q ; i ?$$

r?B+? HHQrb mb iQ + H+mH i2 i?2 +QmMi2`7 +im H xQK#B2 b? `2

$$a? `2 wQ_{hjt}^C \# B2 b `2 wQ_{hjt}^C \# B2 b a? `2 wQ_{hjt}^C \# B2 b `2 wQ_{hjt}^C \# B2 b \\ + b_B B_{hjt}^C B_{hjt} :$$

aT2+B}+ HHv- r2 ++mKmH i2 i?2 /Bz2`2M+2b 7Q` 2 +? BM/mbi`v@
i?2 +im H M/i?2 +QmMi2`7 +im H xQK#B2 b? `2 i? i `2 BM/m+2/ #
MF + TBi HBx iBQMX q2 b2i i?2 +QmMi2`7 +im H xQK#B2 b? `2
a? `2 wQ_{hjt}^C \# B2 b M+2 BM T` +iB+2 i?2 b? `2 Q7 xQK#B2 }`Kb + MMQi
+ H+mH i2 i?2 +QmMi2`7 +im H *SA ;`Qri? 7Q` 2 +? K `F2i b,

$$*SA :`Q_{hjt}^C i? *SA :`Q_{hjt}^C i? b_s a? `2 wQ_{hjt}^C \# B2 b `2 wQ_{hjt}^C \# B2 b$$

AM }M H bi2T- r2 + H+mH i2 i?2 r2B;?i2/ bmK UmbBM; 1m`Qbi i *
H2p2H +QmMi2`7 +im H *SA ;`Qri? iQ i?2 ;`2; i2 +QmMi2`7 +im H
6B;m`2HQib i?2 `2bmHib 7Q` i?Bb +QmMi2`7 +im H 2t2`+Bb2 7Q
bB;MB}+ Mi BM+`2 b2 BM i?2 xQK#B2 b 6B 2mUBXR X2 byQHkBi/QHkByR2
i?2 Q#b2`p2/ *SA ;`Qri? M/ i?2 i?BM / b?2/ HBM2b `2 +QmMi2`7 +
`2+ TBi HBx iBQM i?`2b?QH/b Q7 NW M/ RyW- `2bT2+iBp2HvX h
*SA ;`Qri? rQmH/ ? p2 #22M QM p2` ;2 yXkRTT ?B;?2` 7Q` i?2 NW
M/ yXjkTT ?B;?2` 7Q` i?2 RyW i?`2b?QH/6B2im22MMkR;km`M/. KydReX
b?Qr i?2 b2MbBiBpBiv Q7 i?2b2 +QmMi2`7 +im Hb iQ KQ`2 bi`BM;2
h?2`2 `2 irQ + p2 ib iQ Qm` +QmMi2`7 +im H 2t2`+Bb2X h?2 }`b
i? i r2 mb2 T `iB H 2[mBHB#`BmK M HvbBb rBi? 7Q+mb QM bm
?B;?2` # MF + TBi HBx iBQM M/- BM im`M- H2bb xQK#B2 H2M/BM
i?`Qm;? i?2 /2K M/ +? MM2HX i H2 bi BM i?2 K2/BmK@i2`K- KQ`2
rQmH/ HBF2Hv H2 / iQ ?B;?2` }`K B Mp2biK2Mi M/ ? QmBk2?M2k/ BM
2i HkY R dM/* ûHû`B2`- 2y R3 X?B+? rQmH/ Tmb? i?2 *SA ;`Qri? 7m`i?2

6B;m`2 dSA :`Qri? *QmMi2`7 +i?BHX;m`2 b?Qrb i?2 +im H *SA ;`Qri? BM Qm` b
irQ +QmMi2`7 +im H *SA ;`Qri? `i2bX h?2 +QmMi2`7 +im H BM~ iBQM `i2b `
i? i rQmH/ ? p2 T`2p BH2/ 7`QK kyRk iQ kyRe B7 r2 FHv@+ TBi HBx2/ # MFb 2M
?B;?2` hB2`@R `iBQX aT2+B}+ HHv- r2 +QMbB/2` i?2 + b2b r?2`2 # MFb rBi?
BM kyyN- `2bT2+iBp2Hv- `2`2+ TBi HBx2/ iQ i?2 `2bT2+iBp2 i?`2b?QH/ p Hm2
BM+Hm/2b i?2 `2bT2+iBp2 b? `2 Q7 K `F2ib i? i rQmH/ ? p2 #2+QK2 xQK#B2@7
#2ir22M i?2 +im H *SA ;`Qri? M/i?2 +QmMi2`7 +im H *SA ;`Qri?X

>2M+2- BM ;2M2` H 2[mBHB#`BmK 7` K2rQ`F- ` BbBM; # MF + TB
+QmMi2`7 +im H *SA ;`Qri? +QKT `2/ iQ Qm` T `iB H 2[mBHB#`Bm
h?2 b2+QM/ + p2 i `2H i2b iQ ?Qr # MF + TBi HBx iBQM Bb ` B
`2+ TBi HBx iBQM K2 bm`2 `2[mB`2b # MFb iQ BM+`2 b2 i?2B` 2[r
iQ `BbF@r2B;?i2/ bb2ib `iBQX aT2+B}+ HHv- `2+ TBi HBx iBQM
BM+`2 b2 i?2B` `BbF@r2B;?i2/ + TBi H `iBQ- HBF2 i?2 + TBi H
i?2 1m`QT2 M " MFBM; mi?Q`Biv- + M ? p2 mMBMi2M:/2QT+QMb2[m
2i HXy R/N # MFb i2M/ iQ `2bTQM/ iQ ?B;?2` `BbF@r2B;?i2/ + TBi H
HQR2`BM; i?2B` `BbF@r2B;?i2/ bb2ib UBX2X- #v /2+`2 bBM; i?2B
BM+`2 b2 BM i?2B` 2[mBiv + TBi HX h?Bb HQ M pQHmK2 `2/m+iB
HbQ i?`Qm;? i?2 /2K M/ +? MM2H /m2 iQ i?2 `2bmHiBM; /2+`2 b2
b H2b ;`Qri? Q7 z2+i2/ #Q``Qr2`bX Ai Bb HbQ MQi Q#pBQmb r?2
/B H # +F i?2B` HQ M bmTTHv KQ`2 bi`QM;Hv 7Q` xQK#B2 Q` MQM

>2M+2- Qm` +QmMi2`7 +im H 2t2`+Bb2 Bb KQ`2 TTHB+ #H2 iQ
`2[mB`2b + TBi H BM+`2 b2 BM #bQHmi2 i2`Kb- bm+? i? i i?2 BM
+QMbB/2` BM i?2 +QmMi2`7 +im H 2t2`+Bb2 Bb /`Bp2M #v M BM+`2
+ TBi H ` iBQX ;QQ/ 2t KTH2 7Q` bm+? T`Q;` K Bb i?2 amT2`p
S`Q;` K Ua* SV BM i?2 IXaX- r?B+? bi i2/ i?2 # MFbö + TBi H b?Q`

8 1[mBHB#`BmK S`2/B+iBQMb

AM i?Bb b2+iBQM- r2 /Q+mK2Mi 2KTb`B+ H 2pB/2M+2 +QMbBbi2Mi
7` K2rQ`F #Qmi i?2 BMM2` rQ`FBM;b Q7 i?2 xQK#B2 +`2/Bi +? MM
aT2+B}+ HHv- 2KTHQvBM; Qm` j# b2HB?M2 aT 2 + B B; ?iB`Qm K#B2 T
H2M+2 Bb bbQ+B i2/ rBi? UBV HQR2` /27 mHi M/ 2Mi`v` i2b- b r2
}`Kb M/ b H2b a`QriB QM 8XBV ?B;?2` p2` ;2 B/H2 B 2Q/ B 2IB p2 +
8Xkc b r2HH b- UBBBV HQR2` }`K K `FmTb M/a2Bj B2W82Q; 2 @MTn
Qp2` aB Mi B Q M 2 k 9 Qri? i M BM+`2 b2 BM i?2 b? `2 Q7 xQK#B2 }`K
bTBHHQp2` 2z2+ib 7Q` MQM @xQK#B2 }`Kb- i? i Bb- i?2b2 }`Kb ? p
M/ b H2b ;`Qri?- b r2HH b ?B;?2` #BM T xi2 + Q 5 Q X iA M K2 M M/
bi M/ `//2pB iBQM 7Q` Qm` 2[mBHB#`BmK T`2/B+iBQM Qmi+QK2 p

8XR +iBp2 6B`Kb- .27 mHi- 1Mi`v- M/ ;;;`2; i2 a H2b

AM i?Bb b2+iBQM- r2 i2bi i?2 T`2/B+iBQM Q7 i?2 xQK#B2 +`2/Bi +?
Bb bbQ+B i2/ rBi? HQR2` /27 mHi M/ 2Mi`v` i2b- b r2HH b ?B;
M/ ?B;?2` ;;;`2; i2 b H2b ;`Qri?X

h #H2b@Qrb i?2 2biBK iBQM `2bmHibX lbBM; Qm` KQbi +QMb2`p
H bi+QHmKM- i?2 2biBK i2 BM S M2H bm;;2bib i? i M BM+`2 b2 B
kXkTT UBx2X- i?2 Q#b2`p2/ xQK#B2 b? `2 BM+`2 b2 7`QK kyRk iQ k
H `;2` +? M;2 BM i?2 MmK#2` Q7 +iBp2 }`KbX JQ`2Qp2`- i?2`2bm

S M2H	+iBp2 6B`K	+iBp2 6B`K	+iBp2 6B`K	+iBp2 6B`K
a? `2 wQK#B2b	yXye9 UyXykjV	yXyd9 UyXyk8V	yXye8 UyXyRNV	yXyd8 UyXykyV
P#b2`p iBQMb	j-399	j-399	j-399	j-399
_@b[m `2/	yX9d8	yX8kN	yXek8	yXed8

S M2H "	.27 mHi	.27 mHi	.27 mHi	.27 mHi
a? `2 wQK#B2b	yXyRe UyXyydV	yXyRN UyXyyNV	yXyRd UyXyydV	yXyky UyXyy3V
P#b2`p iBQMb	j-eke	j-eke	j-eke	j-eke
_@b[m `2/	yX3k3	yX39k	yX3dk	yX338

S M2H *	1Mi`v	1Mi`v	1Mi`v	1Mi`v
a? `2 wQK#B2b	yXyk9 UyXyRyV	yXyke UyXyRkV	yXykR UyXyRyV	yXykR UyXyRRV
P#b2`p iBQMb	j-3k9	j-3k9	j-3k9	j-3k9
_@b[m `2/	yX3k8	yX39e	yX3d9	yX3N8

S M2H .	a H2b :`Qri?	a H2b :`Qri?	a H2b :`Qri?	a H2b :`Qri?
a? `2 wQK#B2b	yXR99 UyXydyV	yXR3j UyXydyV	yXRReR UyXyeNV	yXRNj UyXyedV
P#b2`p iBQMb	j-3N9	j-3N9	j-3N9	j-3N9
_@b[m `2/	yXkyy	yXk3N	yX9Ry	yX9Ne
*QmMi`v@AM/mbi`v	X	X	X	X
u2 `61	X			
AM/mbi`v@u2 `61		X		X
*QmMi`v@u2 `61			X	X

h #H2, d mK#2` Q7 +iBp2 6B`Kb- 6B`K .27 mHib- 6B`K 1Mi`v B b iH#2H 2 TQ 2ib 2Mib
2biBK iBQM`2bmHib 7` QKXa n 2 2B 2 2 B 2 2 M 2 M U p `B #H2 B b i?2 +? M; 2 B M i?2 M m K#
V- i?2 b? `2 Q7 }`K 2tBib US M2H "V- i?2 b? `2 Q7 }`K 2Mi`B2b US M2H *V- M/
.V X? `2 wQK#B2b m`2bi?2 bb2i@r2B; ?i2/ b? `2 Q7 xQK#B2 }tK1XB M `K B b B+mH `
+H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B/ 2 +p BM iM Q X K Q b B M i 2 B 2 b b V X 2
HH`2; `2bbBQM b +QMi`QH 7Q` i?2 bb2i@r2B; ?i2/ b? `2 Q7 HQR@[m HBiv }`Kb X
BM/mbi`v@+QmMi`v H2p2H M/ `2TQ < 2 X B M - 4 y 2 V Bi 2 2 K 2 B X T

i? i kXkTT xQK#B2 b? `2 BM+`2 b2 Bb bbQ+B i2/ rBi? 9X9#T M
2Mi`B2b M/ 2tBib- kd 2b? 2 2 b 2 B M 2 B M X b `2 +QM b B bi 2 Mi r Bi? i?2 2p B

^{kd}LQi2 i? i i?2 2Mi`v M/ /27 mHi p `B #H2b T`QpB/2/ #v 1m`Qbi i QMHv + Tim

#v"2`i` M/ 2Uk yM- r?Q b?Qr i? i BM/m+BM; # MFb iQ [mBi xQK#B2 H
BM+`2 b2 BM }`K 2Mi`v M/ 2tBi` i2bX

JQ`2Qp2`- S M2H . b?Qrb i? i kXkTT ?B;?2` xQK#B2 b? `2 Bb
?B;?2` ;;`2; i2 b H2b ;`Qri?X h?Bb }M/BM; T`QpB/2b 7m`i?2` 2pE
MQi/`Bp2M #v /`QT BM /2K M/ M/ bm#b2[m2Mi/2i2`BQ` iBQM BM
+? MM2H rQmH/QT`2/H2b ;`Qri? BM K `F2ib rBi? ?B;? xQK#B2 T`2p

8Xk * T +Biv liBHBx iBQM

AM i?Bb b2+iBQM- r2 M Hv x2 r?2i?2` i?2 xQK#B2 @BM/m+2/ +QM;
B/H2 T`Q/m+iBp2 + T +Biv BM i?2 z2+i2/ K `F2ibX wQK#B2 +`2/E
i?`Qm;? #Qi? i?2 bm`pBp H Q7 xQK#B2 }`Kb M/i?2B` Qp2`T`Q/m+i
T`B+2 M/- BM im`M- BM/m+BM; xQK#B2 M/ MQM@xQK#B2 }`Kb iC
KQ/2H BT2 M/Btb XQrb i? i i?Bb 2z2+i + M Qmir2B;? i?2 ?B;?2` BM/B
H2p2H Q7 xQK#B2 }`Kb U/m2 iQ i?2 BM+2MiBp2 iQ Qp2`T`Q/m+2 BM
iQ ?B;?2` ;;`2; i2 T`Q/m+iBQM M/ ?B;?2` p2` ;2 B/H2 + T +Bi

q2 Q#i BM BM7Q`K iBQM #Qmi + T +Biv miBHBx iBQM #v +Qm
/B;BibV 7`QK i?2 1löb ó"mbBM2bb M/ +QMbmK2` bm`p2vbXô h?2b2
`2 +QM/m+i2/ mbBM; `2T`2b2Mi iBp2 }`K b KTH2 ii?2 BM/mbi`v@
QM KQMi?Hvf[m `i2`Hv # bBb #v i?2 ó.B`2+iQ` i2 :2M2` H 7Q` 1+
7 B`bô U.: 1*6 A22/X2 bm`p2vb T`QpB/2 / i QM + T +Biv miBHBx iB
7mHH + T +BivV Q7 1m`QT2 M }`Kb QM [m `i2`Hv # bBbX q2 #mE
mbBM; i?2 7QHHRBM; b m`r2iv +mT2b BQ Mb vQm` +QKT Mv +m``2Mi

M iBQM Q7 T`Q/m+iBQM 7 +iQ`b B7 MQ Qi?2` 2Mi2`T`Bb2bfmMBib `2 BMpQH
+iBp2 }`Kb + M +? M;2 7Q` p `BQmb //BiBQM H`2 bQMbi? i `2 MQi + Tim`2/ :
h #H2 *QM} `Kb i? i Qm` `2bmHib `2 `Q#mbiiQ + H+mH iBM; }`K /27 mHi` i2b r
k³a22iitb,ff2+X2m`QT X2mfBM7QfbBi2bf/27 mHif7BH2Qf#K+Qr2BM7Q;KBiBQM/

	A/H2 * T +Biv	A/H2 * T +Biv	A/H2 * T +Biv	A/H2 * T +Biv
a? `2 wQK#B2b8Xy9k	eXeJN	9XNk9	eXeJN	
	UkX9eNV	UkXjNkV	UkX8jeV	UkX9d3V
P#b2`p iBQMb	k-9yN	k-9yN	k-9yN	k-9yN
_@b[m `2/	yXd3R	yX3k8	yXdNN	yX39j
*QmMi`v@AM/mbX`v 61	X	X	X	
u2 `61	X			
AM/mbi`v@u2 `61	X		X	
*QmMi`v@u2 `61		X	X	

h #H2,d* T +Biv liBHBx hBQM #H2 T`2b2Mib 2biBK iBQM `2bmVXbh7? QK aT2+
 /2T2M/2Mi p `B #H2 Bb i?2 B/H2 T`Q/m+iBp2 + T +Biv a? b`2`Q`2H2`2M+2Q7`7mHH`
 i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM1XT `jBK+Bb+HKb`FBj2/ b xQK#B2 B
 Bb HQR@[m HBiv M/T B/ /p Mi ;2Qm2+BMQ`7Q`xKQ`i2`b2U`b2`bVX`HH`2;`2bbBQM
 7Q`i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ `/2`Q`b `2+Hmbi2
 M/`2TQ`i2/ BM T`2M`y2y2F-x yXyTB < yTRX

U b T2`+2Mi ;2 Q7 7mHH + T +BivV\ô

h #H2bQ Qrb i?2 2biBK iBQM `2bmHib- r?2`2 A/2H22T`2M+2Q7`7mHH`
 + H+mH 100%@U+ T +Biv miBHBx iBQM b W Q7 7mHH + T +BivVX
 B}+ iBQMb- r2 }M/ i? i i?2 T`2p H2M+2 Q7 xQK#B2 }`Kb BM T`iE
 +Q``2H i2/ rBi? i?2 p2` ;2 B/H2 T`Q/m+iBp2 + T +Biv Q7 i?2 }`Kb
 2biBK i2b BM *QHmKM U9V BKTHvi? i kXkTT BM+`2 b2 BM i?2 b?
 rBi? R9Xe#T BM+`2 b2 BM i?2 B/H2 + T +BivX _2+ HH i? i xQK#
 bbQ+B i2/ rBi? 8Xj#T HQR2`h SA2`Q M2H`VX SmiiBM; i?2b2 irQ
 MBim/2b BMiQ T2`bT2+iBp2 b?Qrb i? i- T2` RTT BM+`2 b2 BM B/H
 BM *SA ;`Qri? Q7 @yXjeTT U@8Xj#TfR9Xe#TV- r?B+? HBM2b mTr
 i?2 S?BHHBTb +m`p2X 6Q` 2t KTH2- m> B2H+ 20QHi@ b QKiBM;M H / i
 >QQT2` 2k yKX2biBK i2 7Q` i?2 IXaX T`B+2 @S?BHHBTb +m`p2 M2
 2biBK i2 Q7 @yXj9 M/ #2ir22M @yXjyR M/ @yX99R- `2bT2+iBp2H

8Xj J `FmT M/ AMTmi *Qbib

AM i?Bb b2+iBQM- r2 M Hvx2 r?2i?2` i?2 xQK#B2 +QM;2biBQM`2b
BMTmi +QbibX GQR2` K `FmTb `2 i?2 2[mBHB#`BmK Qmi+QK2 Q7
BM K `F2ib rBi? ?B;? xQK#B2 b? `2X >B;?2` BMTmi +Qbib `2 i?2
?B;?2` /2K M/ 7Q` H #Q` M/ Bmi2`K2/B i2 BMTmib BM i?2b2 K `F2

h #H23Qrb i?2 2biBK iBQM`2bmHibX AM S M2H - i?2 /2T2M/2M
BM K `FmTb UT`B+2 Qp2` K`;BM H +QbibVX q22K2Q2m F2`K MF/mTb
q `xvMUFyvk M./2 GQ2+F2` UY RNXi? i Bb- r2 `2Hv QM QTIBK H BMT
+QM/BiBQMb Q#i BM2/ 7`QK bi M/ `/ +Qbi KBMBKBx iBQM iQ /2i2
Ur2 2tTH BM i?Bb TT`Q +?T BM/BX`BM BM2Hb " M/ *- i?2 /2T2M/
p `B #H2b `2 K i2`B H +Qbib M/ H #Q` +Qbib- K2 bm`2/ b K i2`E
i?2 1m`Qbi iöb H #Q` +Qbi BM/2t- `2bT2+iBp2HvX

h?2 2biBK iBQM`2bmHib +QM}`K i? i ?B;?2` xQK#B2 T`2p H2M
K `FmTb M/ ?B;?2` K i2`B H +QbibX AMi2`2biBM;Hv- i?2 TQbBiBp
2M+2 Q7 xQK#B2 }`Kb M/ H #Q` +Qbib QMHv 2tBbib 7Q` K `F2ib r
r?2`2B;? o + Bb v /mKKv 2[m H iQ QM2 7Q` BM/mbi`B2b rBi? M #Q
+ M+v iR i2X2 BMbB;MB}+ Mi +Q2{2B2QKb7B2}2bib i? i i?2 `2H iBp2
?B;?2` p2` ;2 H #Q` +Qbi 7Q` UbQK2V xQK#B2 K `F2ib Bb BM/22/
Q7 +iBp2 }`Kb M/ i?2 `2bmHiBM; ?B;?2` H #Q` b+ `+BivX

h?2 2biBK i2b BM i?2 Hh#H2BMTKMiQ7 kXkTT xQK#B2 b? `2 BM

^{kN}h?Bb TT`Q +? ? bi?2 /p Mi ;2 i? i Bi QMHv`2[mB`2b }`Kbö }M M+B H bi i2
bbmKTiBQMb QM /2K M/ M/ QM ?Qr}`Kb 2 GQ22F2X UBQRVHXQ2BM;2; i2 }`K
K `FmTb BM i?2 `2bT2+iBp2 K `F2i mbBM; }`Kbö im`MQp2` b r2B;?iX
^{iy}h?2 1m`Qbi iöb H #Q` +Qbi BM/2t Bb /2bB;M2/ iQ + Tim`2 i?2 H #Q` +Qbi T`2
i?2 H #Q` +Qbi #v i?2 MmK#2` Q7 ?Qm`b rQ`F2/X AKTQ`i MiHv- i?2 H #Q` +Qbi B
BM/mbi`v +H bbB}+ iBQMb- r?B+? H2 /biQ bB;MB}+ Mi`2/m+iBQM BM i?2 Mm
^{iR}h?2 DQ# p + M+v `i2 Bb + H+mH i2/ 7`QK 1m`Qbi iöb DQ# p + M+v bi iBbiB+
Q7 DQ# p + M+B2b b T2`+2Mi ;2 Q7 i?2 bmK Q7 i?2 MmK#2` Q7 Q++mTB2/ TQ

S M2H	J `FmT	J `FmT	J `FmT	J `FmT
a? `2 wQK#B2b	yXydd UyXykjV	yXydR UyXyk8V	yXyde UyXykjV	yXydj UyXykeV
P#b2`p iBQMb _@b[m `2/	j-keR yXRjj	j-keR yXkdk	j-keR yXR8d	j-keR yXkNe

S M2H "	J i2`B H *Qbi	J i2`B H *Qbi	J i2`B H *Qbi	J i2`B H "
a? `2 wQK#B2b	yXy8j UyXykkV	yXy8R UyXykjV	yXy93 UyXykjV	yXy9e UyXykjV
P#b2`p iBQMb _@b[m `2/	j-dyR yXN9j	j-dyR yXN8R	j-dyR yXN98	j-dyR yXN8j

S M2H *	G #Q` *Qbi	G #Q` *Qbi	G #Q` *Qbi	G #Q` *Qbi
a? `2 wQK#B2b	yXyR8 UyXykkV	yXyye UyXyk9V	yXyy9 UyXyk9V	yXyy3 UyXykdV
>B;? o + M+v	yXyyk UyXyy9V	yXyyj UyXyy9V	yXyyd UyXyy9V	yXyyj UyXyy9V
a? `2 wQK#B2b >B;? o + M+v	yXyN8 UyXyjeV	yXRk9 UyXy9jV	yXRRy UyXy9jV	yXRj3 UyXy8kV
P#b2`p iBQMb _@b[m `2/	Nkk yXk8N	Nkk yXjey	Nkk yXjNd	Nkk yX8yy
*QmMi`v@AM/mbi`v`61 u2 `61	X	X	X	X
AM/mbi`v@u2 `61		X		X
*QmMi`v@u2 `61			X	X

h #H2,3J `FmTb M/ AMTmi`v`61 QBiB X#H2 T`2b2Mib 2biBK iBQM `2bjvXi b 72QK aT2
/2T2M/2Mi p `B #H2b `2 i?2 im`MQp2`@r2B;?it2/1+?QM;S BM2HK VFm T2 BMQK bi`v
K i2`B H +Qbi UK i2`B H BMTmi +Qbifim`MQp2`- S M2H "V- M/ i?2 BM/mbi`v H
BM/2t- S M2H *V- `2bT;2+iBp 2HvX/mKKv 2[m H iQ QM2 7Q` BM/mbi`B2b rBi? #Q
p + M+v `ai2X2 wQK#B2b m`2b i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM T
t 1X }`K Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ B2B/iB/QMjX;K Qmb
7Q` KQ`2 /2i BHbVX HH `2;`2bbBQMb +QMi`QH 7Q` i?2 bb2i@r2B;?i2/ b? `2 C
`2 +Hmbi2`2/ i i?2 BM/mbi`v@+QmMi`v H2p2H M/y 2yR-42/XB B<TyK2FK?2b2bX

bbQ+B i2/ rBi? Re#T /2+`2 b2 BM K `FmTb- Ry#T BM+`2 b2 BM
BM+`2 b2 BM i?2 H #Q` +Qbi BM/2t 7Q` K `F2ib rBi? ?B;? DQ# p +
2z2+i Q7 M BM+`2 b2 BM i?2 xQK#B2 b? `2 @M2`BA #H/2S:SKR;`Qri
`2bT2+iBp2HvV bm;;2bi i? i i?2 M2; iBp2 2z2+i Q7 i?2 xQK#B2 +`
/QKBM i2b Bib TQbBiBp2 2z2+i QM BMTmi +Qbib- Qp2` HH Tmb?B
*QMbBbi2Mi rBi? i?2b2 }M/BMT; 2 2 M/ B Qm B M;SMA / i 7`QK 1m`Qb

M/ BMTmi@QmiTmi i #H2b 7`QK i?2 qQ`H/ AMTmi@PmiTmi . i # b
 +`2/Bi K2+? MBbK z2+ib T`B+2b HQM; i?2 bmTTHv +? BMX 6B`bi
 BM+`2 b2 BM bmTTHB2` BM/mbi`B2b /2+`2 b2b T`B+2b 7Q` ;QQ/b
 iQK2` BM/mbi`B2bX a2+QM/- r2 b?Qri? i ?B;?2` xQK#B2 T`2p H2
 BM/mbi`v H2 /b iQ ?B;?2` T`B+2b 7Q` ;QQ/b bQH/ iQ i?Bb BM/mbi`
 :Bp2M Bib TQbBiBp2 2z2+i QM BMTmi +Qbib M/ Bib M2; iBp2 2z
 +`2/Bi +? MM2Hi?mb ?2HTbiQ 2tTH BMi?2`2+2Mir2 F2MBM; Q7 i
 T`Q/m+i T`B+2 BM~ iBQM /Q+mK2Mi2/ BM i?2 v H-Q`y-Q-HB#2B+m`2 Ub
 2i HkY R N2 H L2;` Q 2kiy HkX

8X9 aTBHHQp2`b

AM i?Bb b2+iBQM- r2 T`2b2Mi 2pB/2M+2 +QMbBbi2Mi rBi? M2; iB
 iQ MQM@xQK#B2 }`Kb- MQi?2` T`2/B+iBQM Q7 i?2 xQK#B2 +`2/B
 Q7 xQK#B2 +`2/Bi H2 /b iQ KQ`2 +iBp2 }`Kb M/ M 2H2p i2/ ;;`2;
 BM M2; iBp2 T`B+2 H)2KbmX2KQB2 M/ MQM@xQK#B2X Pm` 2KT
 +QM} `Kb i? i MQM@xQK#B2 } `Kb BM K `F2ib rBi? ?B;? xQK#B2 T`2
 T`Q}i #BHBiv- M/ b H2b ;`Qri?- M/ ?B;?2` BMTmi +QbibX
 h FBM; /p Mi ;2 Q7 Qm` } `K@H2p2#H H2- Q2E7QBHKQ
 i?2b2 bTBHHQp2` 2z2+ib #v 2biBK iBM; i?2 7QHHRBM; `2;`2bbBC

$$Y_{ihjt} = \beta_1 LQM @ w_{ihjt} QK#B2 + \beta_2 LQM @ w_{ihjt} QK#B2^2 w_{ihjt} QK#B2 + \beta_3 i_{ihjt}; \quad U8V$$

r?2`i2Bb } `K- +QmMi`M- BM/mbi`tv- vM/`X Pm` /2T2M/2Mi p `B #H2
 } `K K `FmT- 1"Ahfb H2b- K i2`B H +Qbi- M/ b H2b ;`Qri?X q2 BM
 v2 `}t2/ 2z2+ib iQ #bQ`# BM/mbi`v@+QmMi`v bT2+B}+ b?Q+FbX F
 i? i Bb- r?2i?2` MQM@xQK#B2 } `Kb i? i QT2` i2 BM K `F2ib rBi? ?

	J `FmT	1"Ahfa H2b	J i2`B H *Qbi	a H2b :`Qri
LQM@wQK#B2	yXyej	yXy3e	yXykj	yXyey
	UyXyydV	UyXyUyXyykV	UyXyydV	
LQM@wQK#B2	yXkj8	yXRN3	yXyd9	yXR8j
a? `2 wQK#B2b	UyXy99V	UyXyUjyXyRNV	UyXyjkV	
P#b2`p iBQMb	9-kRR-ejj	8-NRy-Re8	9-e8j-9Ry	8-Nkk-N
_@b[m `2/	yX8e8	yXR8d	yX8Rd	yXyjj
AM/mbi`v@*QmMi`v@u2 `61 X		X	X	
6B`K@G2p2H *QM i`QHb	X	X	X	

h #H2,NJ `FmTb- 1"Ahfa H2b- J i2`B H *Qbib- M/ a H2b :`Qri? 6B`K@G2p2H
h?Bbi #H2 T`2b2Mib 2biBK iBQM `2b bVXib 72QKT2T2/2M+iBQ #HL2b `2 }`Köb K
1"Ahfb H2b- K i2`B H +Qbi UK i2`B H BMTmi +Qbil Qm @ Q Q26#B2QB M/ B i2 b Q`Qri
p `B #H2 2[m HiQ QM2 B7 }`K Bb +H bb Bx27 `2 MQM@xQK#B2 b2iB M b2i@r2B;?i2
b? `2 Q7 xQK#B2 }`Kb BM T `iB1+x6B` K@H2ip2H +QM i`QHb BM+Hm/2 M2i rQ`i?-
bb2ibV- M/i?2 A*` iBQX }`K Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBi
`i2b U b22iBQM QXKQ`2 /2i BHbVX ai M/ ` /2` `Q`b `2 +Hmbi2`2/ i i?2 BM/mb
`2TQ`i2/ BM T `2Mi2yXyRX < yXy8 < yXRX

T2`7Q`K /Bz2`2MiHv i? M MQM@xQK#B2 }`Kb BM K `F2ib rBi? HQ
h?2 }`bi +QHm #M2M7 Qrb i? i MQM@xQK#B2 }`Kb BM K `F2ib rBi?
T`2p H2M+2 ? p2 ?B;?2` K `FmTbi? M xQK#B2 }`Kb BM i?2 b K2 K
rBi? Qm` `2bmHib i i?2 BM/mbi`v@+QmMi`v H2p2H- K `FmTb Q7 M
r?2M i?2 b? `2 Q7 xQK#B2 }`Kb +iBp2 BM i?2 b K2 K `F2i Bb ?B;?
7Q` i?2 1"Ah K `;BM U*QHmKM kVX h?2 `2bmHib BM *QHmKM UjV +
i? i 7 +2 M BM+`2 b2 BM i?2 xQK#B2 b? `2 BM i?2B` `2bT2+iBp2
K i2`B H +Qbib `2H iBp2 iQ MQM@xQK#B2 }`Kb BM MQM@xQK#B2
MQBbv K2 bm`2 Q7 H #Q` +Qbib i i?2 }`K@H2p2HVX 6BM HHv- *G
xQK#B2 +`2/Bi Bb bbQ+B i2/ rBi? HQR2` b H2b ;`Qri? 7Q` BM/BpB
} `Kb ? p2 iQ b? `2 ;Bp2M /2K M/ H2p2HX

h?2b2 `2bmHib +QM }`K i? i i?2`2 Bb xQK#B2 +QM i ;BQM 7`QK x
BM K `F2ib rBi? bi`QM; `Bb2 BM xQK#B2 +`2/BiX h? i Bb- ?2 Hi
bmz2` /2+`2 b2 BM i?2B` T`Q}i #BHBiv /m2 iQ ?B;?2` T`B+2 T`2b
b `2bmHi- BMBiB HHv ?2 Hi?v MQM@xQK#B2 }`Kb KB;?i im`M B
?B;? T`2p H2M+2 Q7 Qi?2` xQK#B2b BM i?2B` K `F2ibX

JQ`2Qp2`- i?Bb 2pB/2M+2 bm;;2bib i? i i?2 Q#b2`p2/ ;;`2; i2 2z
bbQ+B i2/ rBi? M BM+`2 b2 BM i?2 xQK#B2 b? `2 + M i H2 bi T `i
bTBHHQp2` 2z2+ib iQ MQM@xQK#B2 }`Kb U b T`2/B+i2/ #v i?2 xQK
bQH2Hv + mb2/ #v +QKTQbBiBQM H 2z2+ib UBX2X- /m2 iQ KQ`2 x
K `F2ib i? i 2tT2`B2M+2 M BM+`2 b2 BM i?2 xQK#B2 T`2p H2M+2V
b TH +2#Q i2bi 7Q` i?2 }`K@H2p2H #2HmN i2KTT2Q2M?2/ B?M` 2
Q7 HQR@[m HBiv }`Kb b BM/2T2M/2Mi p `B #H2 UBMbi2 / Q7 i?2
KmiBM; i?2 /p Mi ;2Qmb Bmi2`2bi ` i2 +`Bi2`BQM#X2h 23Q2bmHib
i? i i?2 bTBHHQp2` 2z2+ib QM MQM@xQK#B2M`K?2/Q?MQiQQ+HQR@
[m HBiv }`Kb BM+`2 b2b BM K `F2iX h?Bb 2pB/2M+2 bm;;2bib i? i
} `Kb Bb BM/22/ + mb2/ #v M BM+`2 b2 BM i?2 b? `2 Q7 +im H xQK
} `Kb `2+2BpBM; bm#bB/Bx2/ +`2/BiX JQ`2Qp2`- i?2b2 `2bmHib T`
M2; iBp2 +Q``2H iBQM #2ir22M i?2 `Bb2 Q7 xQK#B2 F22/BQ M/ *SA
/2i2`BQ` iBM; p2` ;2} `K T2`7Q`K M+2 BM bT2+B}+ K `F2i U2X;X

e h2biBM; i?2 J2+? MBbK

AM i?Bb b2+iBQM- r2 T`QpB/2 7m`i?2` 2pB/2M+2 BM b2T2Q2MQ7 i?
eXR?Qrb i? i Bib 2z2+ib `2 KQ`2 T`QMmM+2/ BM ?B;? +QKT `2/ iC
a2+iBQM?Qxb i? i i?2 2z2+i Q7 xQK#B2 +`2/Bi QM T`B+2b Bb /`Bp2F
MQMi` / #H2 ;QQ/b M/ #v bmT` M iBQM H K a`F2iBQM Me H j/k #H2 ;Q
i?2 iBK2 /vM KB+b Q7 i?2 xQK#B2 +`2/Bi K2+? MBbKX

eXR >B;? pbX GQR 6Bt2/ *Qbi AM/mbi`B2b

Pm` KQ/2H bm;;2bib i? i i?2 2z2+i Q7 xQK#B2 H2M/BM; QM *SA ;`
BM K `F2ib +? ` +i2`Bx2/ #v ?B;? }t2/ +QbibX h?2 BMimBiBQM B
} `Kb 2tT2+i2/ # MF`mTi+v +Qbib bbQ+B i2/ rBi? bmbi BMBM; ?

>B;? 6Bt2/ *QbibGQr 6Bt2/ *Qbib

*SA A/H2 * T +SA A/H2 * T +Biv

a? `2 wQK#B2b	yXyke	eXekNyXyyd	kXN3N
	UyXyy3VUjXRRR	UyXyy3V	UjXd93V
P#b2`p iBQMb	R-388	3d8	k-yk8 R-8j9
_@b[m `2/	yXde3	yXdNd	yX3j3 yX3yk
*QmMi`v@AM/mbXv 61	X	X	X
AM/mbi`v@u2 `6X	X	X	X
*QmMi`v@u2 `61X	X	X	X

h #H2 R SA :`Qri? *Qbi ai`m+im`2h2`BH Bi`H2 T`2b2Mib 2biBK iBQM `2bmHib 7
iBQM h?2 /2T2M/2Mi p `B #H2 Bb i?2 MMm H *SA;`QriQ Xa?2 `2BMQ-K#BQM V 7`
K2 bm`2b i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM }TK iBb+mH b`B}F2ibi
xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B/ /p M2+2BQM BMK Q`2b/i2i iBbUv2 22 mb
i?2 `iBQ Q7 H #Q` 2tT2Mb2b iQ iQi H +Qbib iQ T`Qtv 7Q` i?2B` /2;`22 Q7 }t2/
+QHmKMb `2TQ`ii?2 `2bmHib 7Q` }`Kb BM K `F2ibi? i? p2 M #Qp2 K2/B M p
i?2 H bi irQ +QHmKMb `2TQ`ii?2 `2bmHib 7Q` i?2 K `F2ib #2HQR i?2 K2/B MX
bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ ` / 2` `Q`b `2 +Hmbi2`2/ i
`2TQ`i2/ BM T `2Mi2`K2RX<yX78<yKRX

`2bmHiBM; ?B;? QT iBK H T`Q/m+iBQM b+ H2X

6Q` i?Bb M HvbBb- r2 mb2 i?2 ` iBQ Q7 i?2 }`Kbö H #Q` 2tT2Mb2
i?2 BM/mbi`B2bö }t2/ +Qbib 2tTQbm`2X h?2 B/2 Bb i? i Bi Bb KQ`2
i? M iQ /Dmbi K i2`B H +Qbib M/ Qi?2` QT2` iBM; +Qbib- r?B+? B
;Bp2M i?2 `2H iBp2Hv ?B;? }`BMH+2QyW

h #H2 +QM }`Kb i?Bb KQ/2H T`2/B+iBQM X aT2+B}+ HHv- i?2 `2bm
M BM+`2 b2 BM i?2 xQK#B2 T`2p H2M+2 QM B/H2 + T +Biv M/ *S
7Q` BM/mbi`B2b rBi? M #Qp2 K2/B M p2` ;2 ` iBQ Q7 }t2/ +Qbib

eXk h` / #H2 pbX LQMi` / #H2 :QQ/b

AM i?Bb b2+iBQM- r2 2tTHQBi /Bz2`2M+2b BM i?2 K `F2ibö ;2Q;`
i?2 xQK#B2 +`2/Bi K2+? MBbKX aT2+B}+ HHv- Bib K2 bm`2/2z2+i
T`QMmM+2/ r?2M i?2 xQK#B2 b? `2 K2 bm`2 +QKT`Bb2b i?2 T`2
K `F2iX hQ i?Bb 2M/- r2 i F2 /p Mi ;2 Q7 i?2 7 +i i? i- r?BH2 i?2
MQMi` / #H2 ;QQ/b Bb HBF2Hv M iBQM H- Bi ;Q2b #2vQM/ M iBQM

LQMi` / #H`2 / #H`2mHH a KTH2

S M2H , AM/mbi`v@*QmMi`v`SA2 bm`2SA *SA				
a?`2 wQK#B2b	yXyj8	yXyR3	yXyk9	
	UyXyyNV		UyXyy3V	UyXyydV
P#b2`p iBQMb	R-989	k-R3R	j-33y	
_@b[m`2/	yXd9d	yX3yd	yXde9	
*QmMi`v@AM/mbi`v 61	X	X	X	
AM/mbi`v@u2`61	X	X	X	
*QmMi`v@u2`61	X	X	X	

S M2H ", AM/mbi`v J2 bm`2*SA *SA *SA				
AM/mbi`v a?`2 wQK#B2b	yXyje	yXReR	yXyk3	
	UyXyjjyV		UyXy8kV	UyXyeRV
P#b2`p iBQMb	R-989	k-R3R	j-33y	
_@b[m`2/	yX8yk	yX883	yX8jk	
*QmMi`v@AM/mbi`v 61	X	X	X	
*QmMi`v@u2`61	X	X	X	

h #H2 R RSA :`Qri? h` / #H2 M/ LQMi` / #H2h:CB /ib #H2 T`2b2Mib 2biBK iBQM`
 7`QK aT2+B}+ iBQM U2T2M/2Mi p`B #H2 Bb i?2 MMm H *SA t`QriQ X i2 UBM~
 a?`2 wQK#B2b/AM/mbi`v a?`2 wQK#B2b?2 bb2i@r2B;?i2/ b?`2 Q7 xQK#B2 }`Kb B
 BM/mbi`v@+QmMi`v T B`T M/ B2M/2biBp2HvX }`K Bb +H bbB}2/ b xQK#B2 B7
 M/ T B/ /p Mi ;2Qmb B Mi2`2biB Q7QK#B2 /2/i BHbVX *QHmKM URV`2TQ`ib i
 MQMi` / #H2 b2+iQ`b- *QHmKM UkV 7Q`i` / #H2 b2+iQ`b- M/ *QHmKM UjV 7Q`
 M/ aM y R9iQ B/2MiB7v i` / #H2 M/ MQMi` / #H2 b2+iQ`bX HH`2;`2bbBQMb +
 b?`2 Q7 HQR@[m HBiv }`KbX ai M/`/2`Q`b`2 +Hmbi2`2/ i i?2 BM/mbi`v@+Q
 BM/mbi`v H2p2H BM S M2H "X q2`2TQ`i i?2 bi M/ </y2XyQ`b yBM 8<2MR X2b2bX

hQ i2bi i?Bb T`2/B+iBQM- Jr2 M BM 7UyR9QQ /BbiBM;mBb? #2ir2
 i` / #H2 M/ MQMi` / #H2# b2+iBQ bX i?2 2biBK iBQM`2bmHib Q7 Q
 bT2+B}+ iBQM X *QHmKM URV b?Qrb i?2`2bmHib 7Q` BM/mbi`B2
 *QHmKM UkV 7Q` b2+iQ`b T`Q/m+BM; i` / #H2 ;QQ/b- M/ *QHmKM
 JQ`2Qp2`- BM S M2H - r2 2KT h Q v 2wQK#B2M /2 i? i + Tim`2b i?2
 xQK#B2 T`2p H2M+2 i i?2 BM/mbi`v@+QmMi`v H2M2Mbir`vBa?2`BM S
 wQK#Br2B+? K2 bm`2b i?2 xQK#B2 b?`2 i i?2 BM/mbi`v@H2p2H U
 BM/mbi`v`2 +QMbB/2`2/ iQ #2 BM i?2 b K2 K`F2i- rBi?Qmi 7m`i
 h?2`2bmHib BM S M2H b?Qri? i i?2 M2; iBp2 +Q`2H iBQM #2i
 M/ i?2 *SA ;`Qri? Bb bB;MB}+ Mi 7Q` #Qi? i` / #H2 M/ MQMi` / #H2

i?2 xQK#B2 b? `2 i i?2 BM/mbi`v@+QmMi`v H2p2HX h?2 2z2+i- ?Q
#H2 i? M 7Q`i` / #H2 b2+iQ`bX S M2H " b?Qrb i? i- r?2M K2 bm`2
BM+`2 b2 BM i?2 xQK#B2 b? `2 QMHv bB;MB}+ MiHv z2+ib i?2 *SA
h?Bb 2pB/2M+2 +QM}`Kb i?2 xQK#B2 +`2/Bi K2+? MBbK M/`2B
b2HBM2 PGa`2bmHib- r?2`2 r2 K2 bm`2 i?2 xQK#B2 b? `2 i i?2
HH b2+iQ`b- +QMbiBimi2 HQR2` #QmM/ 7Q` i?2 2z2+i bBx2 Q7 xQ

eXj hBK2 .vM KB+b

hQ M Hv x2 i?2 /vM KB+b Q7 i?2 xQK#B2 +`2/Bi K2+? MBbK- r2 //
wQK#B2Hb iBp2 iQ i?2 `2bT2+iBp2 /2T2M/2Mi p `B #H2 UBX2X- *SA
Qm` # b2HBM2 bT2+B}+ iBQ#H2 HBM/2+m2Hii` BM2 xQK#B2 +`2/Bi +
TT2 `biQ #2 b?Q`i@ iQ K2/BmK@i2`K T?2MQK2MQM- r?B+? T `iB
h?Bb iBKBM; HBM2b mT rBi? Qm` 2pB/2M+2 QM /27 mHi `i2b Q7 x
v2 `b 7i2` i?2 BMBiB H xQK#B2B;?m VXB M+`2 b2 Ub22

h?2`2 `2 irQ TQi2MiB H `2 bQMb 7Q` i?2 2z2+ib Q7 i?2 xQK#B2
bQK2 iBK2 iQ `2p2`b2- QM2 i i?2 2ti2MbBp2 M/ QM2 i i?2 BMi2M
6B`bi- /QrMr `/ /DmbiK2Mi Q7 i?2 xQK#B2@+`2/Bi@BM/m+2/
i?`Qm;? }`K 2tBib UBX2X- i i?2 2ti2MbBp2 K `;BMV + M #2 HQM
TQHB+B2b i? i 2M #H2 xQK#B2 H2M/BM; #2++QK2M2Mi k?M d?2/ Ub
" M2`D22 M/ >-Q7R3MM2fkyRNQTT 2i+kHky+? `v 2i-kHkk M/
"2+F2` M/ ApkyKBM ?B;? xQK#B2 T`2p H2M+2 +`2 i2b M2; iBp2 b
?2 Hi?v }`Kb U#H22M/h #H2 *K-Ry mbBM; M 2+QMqKB+ bHQR/QrMX
TQHB+v K F2`b ? p2 M BM+2MiBp2 iQ bi #BHBx2 i?2 2+QMqKv #
T` +iB+BM; `2;mH iQ`v 7Q`#2 ` M+2 iQr `/b # MFbX h?Bb + M +`2
BM+`2 bBM;Hv /B{+mHi iQ Tmb? i?2 `2bmHiBM; H `;2 MmK#2` Q7 x
a2+QM/- r?2M 7 +BM; xQK#B2b BM i?2B` BM/mbi`v- }`Kb M22/iQ
rBi? K BMi BMBM; i?2B` +m``2Mi T`Q/m+iBQM /m`BM; i?2 iBK2 i?2B

i?2 /DmbiK2Mi +Qbib bbQ+B i2/ rBi? /QrM@b+ HBM; /m`BM; i?2
b+ HBM; ; BM 7i2`r`/bX :Bp2M i?2 ?B;? HBF2HB?QQ/ i? i MQM
iQ 2tBi- pB #H2 }`Kb KB;?i i?mb /2+B/2 ; BMbi BKK2/B i2Hv /QrM
Bb bmTTQ`i2/ #v i?2 HBi2` im`2 i? i bim/B2b }`Kb ö H #Q` /DmbiK
b?Q+Fb- r?B+? b?Qrb i? i UBV ;Bp2M /DmbiK2Mi +Qbib- }`Kb `2bT
iQ i?2 QTIBQM p Hm2 Q7 r BiBM; M/ ; i?2`BM; KQ`2 Bmp7Q`K iBQM
qBDM#2`;2M M/kqBVj-HMKUUBBV }`Kb `2 H2bb HBF2Hv iQ /Dmbi B7 i
b i2KTQ` `v` i?2` i? M T2`K M2Bi Q 2 2 H2X;X-

d _2 H 1z2+ib

AM i?Bb b2+iBQM- r2 /Bb+mbb i?2 `2 H 2z2+ib Q7 i?2 xQK#B2 +`
BM; i?2b2 T`2/B+iBQMb `2[mB`2b ;2M2` H 2[mBHB#`BmK KQ/2H
T`QpB/2 2KTb`B+ H 2pB/2M+2 bm;;2biBM; i? i xQK#B2 +`2/Bi BM+
HQ+ iBQM- M/ `2/m+2b Bmp2biK2Mi- p Hm2 //2/- M/ T`Q/m+iBpB
6B`bi- r2 M Hvx2 Bmp2biK2Mi M/ + TBi H KBb HHQ+jViBQM mb
AM S M2Hh #B12-R2 }M/ i? i M BM+`2 b2 BM i?2 xQK#B2 b? `2 Bb
HQR2` p2` ;2 M2i Bmp2biK2MiMUTQ HB+kMHRVX kXkTT BM+`2 b2 BM
xQK#B2 }`Kb BM ;Bp2M K `F2i BKTHB2b R8#T H?Br2 `2/2i+B BQ 2bi
Q7 Bmp2biK2Mib BM xQK#B2 K `F2ib + M #2 `2bmHi Q7 UBV i?2 2
K `F2ib M/ i?mb H +F Q7 T`Q}i #H2 Bmp2biK2Mi QTTQ`imMBiB2b
b r2HH b MQM@xQK#B2 }`Kb- iQ BM+`2 b2 i?2B` + TBi H 2tT2M/B
2{+B2M+v Q7 + TBi H i? i? KT2`b Bmp2biK2Mi +iBpBivX

^{ik}q2 K2 bm`2 M2i Bmp2biK2Mi mbBM; K /2mb }`K@H2p2H/ i M/ ;;`2; i2 }`Kb
}t2/ bb2ib UBX2X- i?2 +? M;2 Bb b2i iQ x2`Q B7 M2; iBp2V iQ i?2 K `F2i@H2p2
^{ij}h?2 M2i Bmp2biK2Mi` iBQ` M;2/ QM p2` ;2 #2ir22M yW M/ kW BM i?2 H bi/

S M2H	L2i AMp2biK2Mi	* TBi H JBbo	HHQ+ iBQM
a? `2 wQK#B2b	yXye3 UyXyk3V	yXR9k UyXyejV	yXRyN UyXy9yV
P#b2`p iBQMb	j-9e9	k-Nde	9-yky
_@b[m `2/	yXjNd	yXNky	yX933

S M2H "	1KTHQvK2Mi :`Qri?	G #Q` JBb	HHQ+ iBQM	G #Q` S`
a? `2 wQK#B2b	yXyyk UyXyR3V	yXRRj UyXy8eV	yXyRN UyXyyNV	
P#b2`p iBQMb	j-3Ne	k-Nde	j-3Nk	
_@b[m `2/	yX9Nd	yXNy8	yXN93	
*QmMi`v@AM/mbi`v 01	X	X	X	
AM/mbi`v@u2 `61	X	X	X	
*QmMi`v@u2 `61	X	X	X	

h #H2 RkAMp2biK2Mi- 1KTHQvK2Mi- M/ 6 +iQ` JBb BHG#H2BQ2Mib 2biBK iE
`2bmHib 7`QK aT2VX} AMBSM2H - i?2 /2T2M/2Mi p `B #H2b `2 M2i BMp2biK2
;`Qri?BM }t2/ bb2ib M/ b2i iQ x2`Q B7 M2; iBp2V- + TBi H KBb HHQ+ iBQM U
iBQM Q7 HQ;UJ_SEVV- M/ i?2 p Hm2 //2/ ;`Qri?X h?2 /2T2M/2Mi p `B #H2b l
;`Qri?- H #Q` KBb HHQ+ iBQM UK2 bm`2/ b i?2 bi M/ ` / /2pB iBQM Q7 HQ;UJ
Up Hm2/ //2/fMmK#2` Q7a2K`THQvK2Mib 2bi?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#
T `iB+mH `Kt`H2i i`K Bb +H bbB}2/ b xQK#B2 B7 BiBb HQR@[m HBiv M/ T B
`i2b Ubb2iBQM QXKQ`2 /2i BHbVX HH `2;`2bbBQMb +QMi`QH 7Q` i?2 bb2i@r
}`KbX ai M/ ` /2`Q`b `2 +Hmbi2`2/ i i?2 BM/mbi`v@+QmMi`v H2py2Hy RM/ `2TQ`
K yXy8<yXRX

1KTHQvBM; i?2 }`K @H2p2H i2bV7`QK QTM2} K }? iBQM; U xQK#B2 T
H2M+2 HQR2`b i?2 BMp2biK2Mi +iBpBiv Q7HMQM@XQY#BKM`KVXUS
aBKBH `Hv- *QHm#M2U`SR y2H " b?Qrb i? i KQ`2 T`Q/m+iBp2 }`Kb
K `F2ib BMp2bi H2bb +QKT `2/ rBi? T`Q/m+iBp2 }`Kb BM MQM@xQ
q2 HbQ }M/ 2pB/2M+2 bmTTQ`iBM; HQR2` HHQ+ iBp2 2{+B2M+
7QH HQB2? M/ E H2yMQM:QTBM i? 2Hy RvX M/ i` +F i?2 /BbT2`bBQM Q
K `;BM H `2p2Mm2 T`Q/m+i Q7 + TBi H UJ_SEV +`Qbb K `F2ibX h
;Bp2M i?2 J_SE Bb /BKBMbb?BM; UBX2X- /2+`2 bBM; `2im`Mb iQ
}`Kb b?QmH/ QTIBK HHv 2[m i2 Bi rBi? i?2B` #Q``QrBM; `i2X AM i
/BbiQ`iBQMb- i?2 J_SE b?QmH/ i?mb #2 2[m i2/ +`Qbb Qi?2`rBb
/BbT2`bBQM Q7 i?2 J_SE +`Qbb }`Kb BM T `iB+mH `K `F2i Bb
+ TBi H KBb HHQ+ iBQM bBM+2 ;;`2; i2 QmiTmi+QmH/ #2 BM+`2

}`Kb rBi? HQr J_SE iQ }`Kb rBi? ?B;?2` J_SEX

hQ + H+mH i2 }`Kb ö J_SE- r2 /2+QKTQb2 JS_E B MiQ i?2 p Hm2 C
 (VMPK_{ijt}) M/ i?2 B Mp2`b2 @ K,`FmT U

$$MRPK_{ijt} = \frac{P_{ijt} (Q_{ijt}) Q_{ijt}}{K_{ijt}} = P_{ijt} \frac{Q_{ijt}}{K_{ijt}} \left(1 + \frac{Q_{ijt}}{P_{ijt}} \frac{P_{ijt}}{Q_{ijt}} \right) = \frac{K_{ijt} P_{ijt} Q_{ijt}}{K_{ijt} Q_{ijt}} \frac{1}{Q_{ijt}}$$

r?2`P_{ijt} Q_{ijt} B b iQi H b H2b UT`B+2 K_{ijt} K_{ijt} b {mT Mii B_{ijt} v BM /i?2 Q miTmi
 2H biB+Biv Q7 + TBi HX hQ 2biBK i2 }`Kb ö K `FmT M/ QmiTmi 2H
 i?2 T`Q+2/m`2 Q mT H2M/2 BM

h?2`2bmHib BM *QHmKM UjV BM S M2H 7m`i?
 i?2 xQK#B2 b? `2 Bb bbQ+B i2/ rBi? M BM+`2 b2 BM i?2 J_SE /B
 bi M/ `//2pB iBQM Q7 HQ;UJ_SEVX h?Bb 2pB/2M+2 bm;;2bib i? i?
 BM K `F2ib z2+i2/ #v xQK#B2 +`2/Bi Bb + mb2/ #v +QK#BM iBQM
 M/ KBb HHQ+ iBQM Q7 + TBi HX *QHmKM UjV BM S M2H 7m`i?
 T`2p H2M+2 Bb bbQ+B i2/ rBi? HQr2` ;`Qri? BM p Hm2 //2/ UQ
 >2M+2- r?BH2 xQK#B2 +`2/Bi ii2Mm i2b i?2 ;;`2; i2 b H2b `2/m
 M2; iBp2 /2K M/ b?Q+F- i?2 +QM+m`2Mi `2/m+iBQM BM T`B+2b
 bbQ+B i2/ rBi? ?B;?2` xQK#B2 T`2p H2M+2 `2/m+2b i?2 :.S +QM
 >2M+2- Qm` `2bmHib bm;;2bi i? i i?2 ;HQ# "HM B`D2B MMxQK#B2 J M M
 ky R3KB;?i #2 +QMi`B#miBM; 7 +iQ` iQ i?2 Q#b2`p2/ b2+mH `bHC

ⁱ⁹ M 2t KTH2 7Q` /BbiQ`iBQM /m2 iQ xQK#B2 H2M/BM; Bb i? i xQK#B2b #2M2
 MQM@xQK#B2b + M QMHv #Q``Qr i`2;mH ` ` i2bX b `2bmHi- i?2 J_SE Q7 xQ
 xQK#B2b M/ `2 HHQ+ iBM; + TBi H 7`QK xQK#B2b iQ MQM @xQK#B2b rQmH/ i?
ⁱ⁸ h #H2 *XS M2H T`QpB/2b `Q#mbiM2bb +?2+F 7 QMIU`B H m2 BM/2i V2/r2 mb2
 Q7 i?2 p Hm2 //2/ ;`Qri?X h?2 `2bmHib `2 [m HBih B p2H`v B B K B H b K S H M2H "
 M2; iBp2 2z2+i Q7 `Bb2 BM xQK#B2 +`2/Bi QM*T#QH m2 i B p2i v M /2K2 r2 m Q H H Qr
 T`Q/m+iBp2 H2bV kfj HQ;U2KTHQvK2MXV Rfj HQ;U}t2/ bb2ibV

$a_2 + QM / - r_2 \quad M \quad H v x_2 i^? 2 \quad BKT \quad + i \quad Q_7 \quad x Q K \# B_2 \quad + \quad ` 2 / B i \quad Q M \# B_2 \quad R H Q v K_2$
 $S \quad M_2 H \quad " \quad b^? \quad Q r b \quad i^? \quad i \quad M \quad B M + \quad ` 2 \quad b_2 \quad B M \quad K \quad ` F_2 i \ddot{o} b \quad x Q K \# B_2 \quad T \quad ` 2 p \quad H_2 M + 2$
 $2 K T H Q v K_2 M i ; \quad ` Q r i^? \quad X \quad h^? 2 \quad ` 2 \quad ` 2 \quad i r Q \quad Q T T Q b B M ; \quad 2 z_2 + i b \quad Q_7 \quad x Q K \# B_2 \quad + \quad `$
 $P M_2 \quad i^? 2 \quad Q M_2 \quad ? \quad M / - \quad \# v \quad B i b \quad p_2 \quad ` v \quad M \quad i m \quad ` 2 - \quad x Q K \# B_2 \quad + \quad ` 2 / B i \quad T \quad ` 2 p_2 \quad M i b \quad H \quad v$
 $B M ; \quad i^? 2 b_2 \quad } \quad ` K b \quad P \quad M \quad i^? 2 \quad ? \quad M / - \quad x Q K \# B_2 \quad + \quad ` 2 / B i \quad ? \quad K T_2 \quad ` b \quad M \quad 2 \{ + B$
 $Q_7 \quad H \quad \# Q \quad ` 7 \quad ` Q K \quad x Q K \# B_2 \quad i Q \quad M Q M @ x Q K \# B_2 \quad } \quad ` K b \quad M / \quad ` 2 / m + 2 b \quad i^? 2 \quad p$
 $x Q K \# B_2 \quad } \quad ` K b - \quad T Q i_2 M i B \quad H H v \quad H Q r_2 \quad ` B M ; \quad i^? 2 \quad H H Q + \quad i B p_2 \quad 2 \{ + B_2 M + v$
 $i^? 2 b_2 \quad b T B H H Q p_2 \quad ` b - \quad x Q K \# B_2 \quad + \quad ` 2 / B i \quad M_2 ; \quad i B p_2 \quad H v \quad z_2 + i b \quad i^? 2 \quad 2 K T H Q v$
 $i^? \quad i \quad ` 2 \quad + i B p_2 \quad B M \quad K \quad ` F_2 i b \quad r B i^? \quad ? B ; \quad ? \quad x Q K \# B_2 \quad T \quad ` 2 p \quad H_2 M + 2 \quad X \quad 1 K T H$
 $+ Q M \quad } \quad ` K \quad i^? 2 b_2 \quad M_2 ; \quad i B p_2 \quad b T B H H Q p_2 \quad h b \quad \# B_2 \quad S \quad X \quad M Q \quad H H v \quad K \quad M M \quad ` K \quad V Q_7$
 $h^? 2 \quad B M b B ; M B \quad } + \quad M i \quad ` 2 b m H i \quad Q_7 \quad M \quad B M + \quad ` 2 \quad b_2 \quad B M \quad i^? 2 \quad x Q K \# B_2 \quad b^? \quad ` 2$
 $i^? m b \quad \# 2 \quad 2 t T H \quad B M_2 / \quad \# v \quad i^? 2 b_2 \quad i r Q \quad Q T T Q b B M ; \quad 2 z_2 + i b \quad Q M \quad 2 K T H Q v K_2 M i$
 $x Q K \# B_2 \quad + \quad ` 2 / B i - \quad r^? \quad B + \quad ? \quad b_2 \quad 2 K \quad i Q \quad Q z b_2 \quad i_2 \quad + \quad ? \quad Q i^? 2 \quad ` X \quad q^? \quad B H_2 \quad x Q K \# B_2 \quad + \quad `$
 $x Q K \# B_2 \quad } \quad ` K b - \quad i^? 2 \quad ` 2 \quad \# v \quad F_2 \quad 2 T B M ; \quad 2 K T H Q v K_2 M i \quad m T \quad B M \quad i^? 2 b_2 \quad } \quad ` K b - \quad B i$
 $B M \quad M Q M @ x Q K \# B_2 \quad } \quad ` K b \quad \# v \quad ? \quad K T_2 \quad ` B M ; \quad i^? 2 \quad H \quad \# Q \quad ` \quad ` 2 \quad H H Q + \quad i B Q M \quad 7 \quad C$
 $A M \quad i^? B b \quad r \quad v - \quad x Q K \# B_2 \quad + \quad ` 2 / B i + \quad M \quad T Q i_2 M i B \quad H H v \quad H Q r_2 \quad ` i^? 2 \quad H H Q + \quad i B p$
 $q_2 \quad 7 Q \quad ` K \quad H H v \quad M \quad H v x_2 \quad i Q \quad r^? \quad i \quad 2 t i_2 M i \quad x Q K \# B_2 \quad b^? \quad ` 2 \quad B M + \quad ` 2 \quad b_2 \quad B b$
 $H \quad \# Q \quad ` \quad K B b \quad H H Q + \quad i B Q M \quad \# v \quad / 2 i_2 \quad ` K B M B M ; \quad i^? 2 \quad K \quad ` F_2 i b \ddot{o} \quad / B b T_2 \quad ` b B Q M$
 $Q_7 \quad H \quad \# Q \quad ` \quad U J _ S G V - \quad K_2 \quad b m \quad ` 2 / \quad b \quad i^? 2 \quad b i \quad M / \quad ` / / 2 p B \quad i B Q M \quad Q_7 \quad H Q ; U J _ S$

$$MRPL_{ijt} = \frac{Q_{ijt} (Q_{ijt}) Q_{ijt}}{Q_{ijt}} = P_{ijt} \frac{Q_{ijt}}{Q_{ijt}} \left| \frac{Q_{ijt}}{Q_{ijt}} \right| \left| \frac{Q_{ijt}}{Q_{ijt}} \right| = \frac{L_{ijt}}{L_{ijt}} \frac{Q_{ijt}}{Q_{ijt}} \frac{1}{Q_{ijt}} :$$

^{i e.} $2 b + \quad ` B T i B p_2 H v - \quad Q m \quad ` / \quad i \quad + Q M \quad } \quad ` K b \quad i^? \quad i \quad B M / 2 2 / \quad 2 K T H Q v K_2 M i ; \quad ` Q r i^? \quad B b \quad b H B ; \quad ?$
 $\quad } \quad ` K b + Q K T \quad ` 2 / \quad i Q \quad H Q r @ [m \quad H B i v \quad M Q M @ x Q K \# B_2 \quad } \quad ` K b X$
^{i d} $h^? \quad B b \quad ` 2 b m H i \quad B b + Q M b B b i_2 M i \quad r \quad \# B \quad i^? \quad H_2 \quad Q \quad 2 b y \quad M \quad X \quad b^? \quad Q_7 \quad } \quad M / \quad M_2 ; \quad i B p_2 \quad b T B H H Q p_2 \quad ` 2$
 $Q_7 \quad x Q K \# B_2 \quad H_2 M / B M ; \quad Q M \quad 2 K T H Q v K_2 M i \quad i \quad M Q M @ x Q K \# B_2 \quad } \quad ` K b \quad B M \quad i^? 2 \quad + Q M i_2 t i \quad Q_7$

6QHHQrBTMB;M i? 2kiy r2 K2 bm`2 i?2 HL#QrBiM Tm2-}`Köb /2~ i2/
r ;2 #BH*QHmKM Uk#HQ-7Sk M2H " +QM}`Kb i? i ?B;?2` xQK#B2 T
bbQ+B i2/ rBi? ?B;?2` J_SG /BbT2`bBQM- i? i Bb- HQr2` H #Q`
6BM HHv- i?2 `2bmHib Bm#HQHFskM2 H j"V?G7?HB;?i i? i i?2 7 +iQ`
HQ+ iBQM /m2 iQ xQK#B2 +`2/Bi /` ;b /QrM H #Q` T`Q/m+iBpBiv-
//2/ #v i?2 MmK#2` Q7 2KTHQvr22i UjHvX AM T `iB+mH ` - xQK#B2
M/ i?2 `2bmHiBM; 7 +iQ` KBb HHQ+ iBQM bBKmHi M2QmbHv H2
HHQ+ iBp2 2{+B2M+vX "Qi? 2z2+ib `2/m+2 H #Q` T`Q/m+iBpBivX
Pp2` HH- i?2 2pB/2M+2 BM i?Bb b2+iBQM bm;;2bib i? i- r?BH2 x
#BHBxBM; 2z2+i BM i?2 b?Q`i@i2`K- Bi? b M /p2`b2 BKT +i QM i

3 *QM+HmbBQM

h?2 HQr@;`Qri? HQr@BM~ iBQM 2MpB`QMK2Mi i? i T`2p BH2/ BM
/2#i+`BbBb M/ i?2 *QpB/@RNT M/2KB+ #2 `b bi`BFBM;`2b2K#H
BM i?2 7i2`K i? Q7 Bib +`BbBb BM i?2 2 `Hv RNNybX aKBKH `iQ i?
BM M 2MpB`QMK2Mi +? ` +i2`Bx2/ #v r2 FHv@+ TBi HBx2/ # MFb
7QHHQr2/ + MQMB+ H /2K M/@bB/2 i?2Q`v M/ HQr2`2/ BMi2`2bi
K bbBp2 [m MiBi iBp2 2 bBM; T`Q;` Kb iQ 2M+Qm` ;2 KQ`2 BMp2bi

ⁱ³IbBM; i?2 r ;2 #BHH BMbi2 / Q7 2KTHQvK2Mi ++QmMib 7Q` /Bz2`2M+2b BM i
^{iN}_2H i2/2vi` M/ 2iUkHyX b?Qrbi? i M2i 2KTHQvK2Mi M/ p Hm2 //2/ T2`rQ`F2
MF@/2T2M/2Mi b2+iQ`b 7QHHQrBM; 6`2M+? /2`2;mH iBQM i? i`2/m+2/ bm#

BM; i? i i?Bb rQmH/ H2 / iQ bm`;2 BM BM~ iBQMX >Qr2p2`- /2k
}`K 7mM/BM; +Qbib- BM~ iBQM /B/ MQi TB+F mT b 2tT2+i2/- r?B+
óKBbbBM; BM~ iBQM Tm xH2-3kYB2 - 2X;X-

AM i?Bb T T2`- r2 T`QTQb2 M/ i2bi MQp2H bmTTHv@bB/2 +? I
H2M/BM; bm#bB/Bx2/ +`2/Bi iQ MQM@pB #H2 }`Kb ? b /BbBM~ i
BM; M 2tTH M iBQM 7Q` i?2 T2`bBbi2Mi HQR BM~ iBQM `i2b BM
+QMbi` BMib H2/ iQ ?2bBi Mi Bmi`Q/m+iBQM Q7 `2+ TBi HBx iB
i?2 kyy3 ;HQ# H }M M+B H +`BbBb- r?B+? H2/ iQ xQK#B2 H2M/BM
7m2HBM; i?2 bm`pBp H Q7 MQM@pB #H2 }`Kb- xQK#B2 H2M/BM;
/QrMr `/ T`2bbm`2 QM T`B+2b M/ BM~ iBQMX

q2 i2bi i?Bb xQK#B2 +`2/Bi +? MM2H mbBM; M2r BM~ iBQM M/ }
RXR KBHHBQM }`Kb BM Rk 1m`QT2 M +QmMi`B2b +`Qbb e8 BM/m
2tT2`B2M+2/ `Bb2 BM xQK#B2 }`Kb bm#b2[m2MiHv ? p2 HQR2` }`K
miBHBx iBQM- K `FmTb- M/ BM~ iBQM- ?B;?2` BMTmi +Qbib b r2
M/ H #Q`- r?B+? `2bmHib BM HQR2` T`Q/m+iBpBiv- BMp2biK2Mi-
Pm` }M/BM;b b?Qri? i +2Mi` H # MF i? iBKTH2K2Mib TQHB+v K
T2`bBbi2Mi xQK#B}+ iBQM Q7 i?2 2+QMqKv rBi? i?2 Q#D2+iBp2 G
KB;?i 2M/ mT rQ`FBM; ; BMbi Bib QrM Q#D2+iBp2bX *QMp2`b2H
TQHB+v KB;?i #2 KQ`2 2z2+iBp2 BM iBK2b Q7 r2 F2MBM; }M M+B
i `;2i2/ # MF `2+ TBi HBx iBQM T`Q;` KX

6BM HHv- Qm` `2bmHib /` r ii2MiBQM iQ i?2 Q7i2M@M2;H2+i2/
7`B+iBQM b QM BM~ iBQMX h?2 BM+HmbBQM Q7 i?2b2 7`B+iBQM b
pB2r- M BKtQ`i Mi `2 Q7 7mim`2 `2b2 `+?X

_272`2M+2b

+? `v - oX oX- hX 1Bb2`i- *X 1m7BM;2`- UkyRX >B`b+2 H 1z2+ib
i?2 aQp2`2B;M .2#i`*`BbBb BM 1m`QT2, 1pB/2M+2 7`QK2avM7B+
6BM M+B H jRm k3NeX

UkyR3#V, K2 aiQ`v- .Bz2`2Mi SH +2\ SQbi@*`BbBb _2+ TBi H
C T M M/ 1mRQdR9dX

UkyRNV, óq? i2p2` Ai h F2b, h?2 _2 H 1z2+ib Q7 IM+QMp2MiB
h?2 _2pB2r Q7 6BM MjH jHæi nj9B2Bx

+? `v - oX oX- aX G2Mxm- MURykM;ówQK#B2 G2M/BM; M/ SQH
qQ`FBM; S T2`

+F2`#2`;- .X- EX * p2b- M/ :XUkyR2`V, óA/2MiB}+ iBQM S`QT2`iB
S`Q/m+iBQM 6mM+iBQM QMiBk2QB k9RR k98RX

HH2M- 6X M/ .XUky29V, ó*QKT2iBiBQM M/ 6BQM+MBHQ7 #BM2v
*`2/Bi M/ " MFBM;8j 93yX

M/`2rb- .UkyRNV, ó" `2 FBM; i?2 a? +FH2b, wQK#B2 6B`Kb- q2 F
_2bi`m+im`BM; BQ1mBQT S- d2`

M/`2rb- .X- *X *`Bb+mQHq- UkySRxV Hóh?2 :HQ# H S`Q/m+iBpBiv
h2+?MQHQ;v .Bp2`;2M+2 M/ Sm#HB+ SQHB+qQ`FBMKS T2H S2`

M;2HBMB- SX- 6X GQiiB- X S bb H +[m UkyW/R:V, aQ;?B _2 H 1z2+
Q7 " MF amT2`pBbBQM, 1pB/2M+2 7`QK QM@FBM2S MF AMbT2+i

" H/mxxB- SX- 1X " ` M+ iB- M/ 6X aURPRMV;26B M+B H J `F2ib-
*Qbi Q7 6mM/BM;- M/ 6B`Kbö .2+BbBQM b,CQ2b`MQ MbQ7`QKMrQ #
AMi2`K2/BjèB QMR8X

" M2`D22- _X M/ "X >U7kyR3W, óh?2 _Bb2 Q7 wQK#B2 6B`Kb, * m
[m2M+2AaZm `i2`HvX_2pB2r

UkykkV, ó*Q`TQ` i2 wQK#B2b, M iQKiv+QM GB7-2 \$Q+HBdô
3yjX

" `i? AAA- JX CX M/ oX UkyKRW, óh?2 *Qbi *? MM2H Q7 JQM2i `v
bBQM"-16_ J +`Q2+QMqKB+Fe-MRNN Hk9yX

" `iBF- hXCRNNRV, óq?Q "2M2}ib 7`QK ai i2 M/ GQ+ H 1+QMqKB
+B2hV1X ITDQ?M AMbiBimi2X

"2+F2`- "X M/ oX ApUbkykMv, óq2 F *Q`TQ` i2 AMbQHp2M+v _mH2
 .`Bp2` Q7 wQK#B2 G2M/T2Mb-dM/ S`Q+R2RBM8Re kyX

"2;2M m- CX- aX "B;BQ- CX J D2`QpBix-UMy/kRX,oB2Z`@h?2Q`v G
 " MFbqQ`FBM; X T2`

"2`i` M/- JX- X a+?Q`- M/ .X hU2kykdV, ó" MFBM;.2`2;mH iBG
 AM/mbi`v ai`m+im`2, 1pB/2M+2 7`QK i?2 6`2M+h??2 M Q BMM_H 7Q7` H
 6BM Me+2- 8Nd ek3X

"H iiM2`- GX- GX 6`BM? - M/ 6Xy_k2#2H6Q?2M GQbb2b hm`M AMi
 h?2 *Qbi Q7 IM/2`+ TBi H B 22K2`NB+bM61+QMqKB+ _2pB2r U6Q`i?

"HQQK- LX- JX 6HQ2iQiiQ- LX C BKQpB+?- AX a TQ`i @1Fbi2M-
 UkyR3V, ó_2 HHv IM+2`i BM1"mQMBQIK22B8-vR yj2r F6ye8X

"Q#2B+ - 1X- JX *B++ `2HHB- M/ AXUk yFN2/2MFB2iQBMF "2ir22M C
 *Qbi M/ S`B+2 AM~ iBQM BMQ?2BIMh; X T2` -ô

"Q7QM/B- JX- GX * `TBM2HHB-UMy/R3X a 2ři`2/Bi amTTHv /m`BM; a
 .2#i *`BbBQm`M H Q7 i?2 1m`QT2 M 1+QV6Q K B e dbNQ4B iBQM

"QM7BK- .X- :X *2`[m2B`Q- >X .2;`vb2- MkyakX P M6 P M @ aBi2 AMbT2
 wQK#B2 G2M/2M2-62Mi a+B2M+2 UX7Q`i?+QKBM;V

"`m+?2- JX M/ :X GHUQ#B9V, óS`2p2MiBM; w QK#B2r Q2M6/BM;M6+ B
 aim/B2b- Nkj N8eX

* # HH2`Q- _X CX- hX >Qb?B- M/ XU EYy EVb?ówTQK#B2 G2M/BM;
 .2T`2bb2/ _2bi`m+im`BM2BM+CMT1 MQ M Q K B+3 _ RpB92rddX

?2p HB2`- CX X M/ .X aX a+JPRN7b2/BM6 TBi H@J`F2i AKT2`72
 *QmMi2`+v+HB+ H J `FmTb, h?2Q2vB MM1 pBQ2MQ+2B6y_j_2pBZr

*?Q/Q`Qr@_2B+Uky.R9V, óh?2 1KTHQvK2Mi 1z2+ib Q7 *`2/Bi J `F
 6B`K@H2p2H 1pB/2M+2 7`QK i?2 kyZ6@j2N H B M Qm+`BM HH*QB7b1B+Q M
 RkN- R 8NX

*?QT` - uX- EX am#` K MB M- M/ SUX ykXRV,Má" BMF *H2 MmTb- * TB
 iBQM- M/ G2M/BM;;, 1pB/2M+2 22_2pB2 AQ17B B M Mj+9B 9Raj km9 B 2bX

*?`BbiB MQ- GX CX- JX aX 1B+?2M# mK- UM y R X Vh`ó#MM2i`bi M/BM
 i?2 :`2 i _2+2bK2QBM- M 1+QMqKB+ C Qm`M Hd-JR-R`yQ2dQMQKB+b

ÇB?{F- JX- X .2KB` ;=É@EmMi- JX aX J `iLM2x S2`L - M/ X
 *?2` ;?HQURkV, ó" MF _2;mH iBQM M/ amT2`pBbBQM `QmM
 IT/ i2-çQ`H/ " MF qQ`FBM; S T2`

*QMbi<M+BQUkyR8V, óIM/2`bi M/BM; AM~ iBQM .vM KB+b M/ JQ
 aT22+? i i?2 C +FbQM >QH2 1+QMQR+H8QNB+v avKTQbBmK

*Q`M2ii- JX JX- CX CX J+Lmii- SX 1X ai` ? M- MUkyRH2V; dMBB M@
 mB/Biv _BbF J M ;2K2Mi M/ *`2/Bi amTTHv BQm?M 6BQ7M6BBM HM+
 1+QMQR+R- kNd jRkX

*öHö`B2`- *X- hX EB+F- M/ BXyRi2p2M2b BM i?2 *Qbi Q7 " MF 1[
 M/ i?2 amTTHv Q7 -" RvFN *R2/BX

/2 HK2B/ - GkYR8V, ó6B`Kbö " H M+2 a?22ib M/ a2+iQ` HAM~ i
 .m`BM; i?2 6BM M+1B+ QMQR+H8QNB+ B2p2jRb jjX

.2 GQ2+F2`- CX- CX 12+F?Qmi- UkyRNM; z`h?2 _Bb2 Q7 J `F2i SQr
 i?2 J +`Q2+QMQR+ AZKTHB2+HB CQm`öM H-QRj8+Q/RQK89X

.2 GQ2+F2`- CX M/ 6X q UkyRkVB óJ `FmTb M/ 6B`K@G2p2H 1tT
 K2`B+ M 1+QMQR+Ry k2 pB2r dRX

.2 J `+Q- 6UkyRNV, ó" MF G2M/BM; M/ i?2 1m`QT2 M@QpM`2B;M
 Q7 6BM M+B H M/ Zm MiBi9+Rp28 M 3HkXbBb

.2H L2;`Q- JX- JX G2Mx - :X S`BKB+2`B- M/UXykyk#, kQ?iBöb IT
 qBi? i?2 S?BHBT TqQ`m Bp2;`S T2`

:B MM2iiB- JX M/ X aBkQRmjqP óPM i?2 _2 H 1z2+ib Q7 " MF " BH
 1pB/2M+2 7`QK IC2TBM-M 1+QMQR+ CQm`M H8-JRj8Q2+QMQR+

:BH+?`Bbi- aX- _X a+?Q2MH2- CX aBK-U MyR1dX/w óFA`MD- 2BQM .vM H
 .m`BM; i?2 6BM M+ B2H B+BM Bb+QMQR+Ry d2 pB2r3kjX

:QH/bKBi? @SBMF? K- SX- AX aQ`FB My-kyW/, >óX`àiBFiAMbi`mK2Mib,
 q?2M- q?v- M/ >Q2`B+ M 1+QMQR+Ry2 pB2r kek9X

:QTBM i?- :X- X E H2KHB@³x+ M- GX E `# `#QmMBb- M/ *X oBH
 UkyRdV, ó* TBi H HHQ+ iBQM M/ T`Q/ m?2Bzpb i vi B`MH a CQm`1mHC
 1+QMQR+Rjkb RNR8 RNedX

:`QTT- _X- X :m2iiH2`- M/ dUkkykYB, óSm#HB+ " MF :m `Mi22b M
 iBp2 1{+B2Qm+M H Q7 JQM2i `R R+Q MjQK8Xb

:`QTT- _X- hX JQbF- aX PM;2M -UMyR M Vq,Bó" MFb _2bTQM b2 iQ >B;
Bi H _2[mB`2K2Mib, 1pB/2M+2 6`QK Zm hb72@_l2 pi b2 rQ 7t62 MB M2-10
aim/B2k- kee kNNX

:mBbQ- GX- GX SBbi 72``B- M/ U6Ky y8-V Bpó AMBb m` M+2 rBi?BM i?
CQm`M H Q7 SQHBiBRjHRy+QMRyK3dX

> x2HH- CX- CX >2``2MQ- 1X L F Km` - M7 QXi a+2QKBM;QM óh?2 aH
Q7 i?2 S?BHHBTb *m`p2, 1pB/2M+2 7i2Q K v XCaXma iMi 2bX07 1+QM QK

>2HK2`bbQM- hX- GX JBM; `2HHB- "X JQbF- X SB2ib+?- "X _ p M.
CX q2M/2H#Q`M-U2kiy HRV, ó*Q`TQ` i2 wQK#B}+ iBQM, SQbi@S M
1m`Q `26BM M+B H ai #BHRXiv _2pB2r

>QH/2M-Uakxy9V, óh?2 *Qbib Q7 S`B+2 ai #BHBiv, .QrMr `/ LQKBM
1m`QT12+QM QKdBR- R3j ky3X

>QK ` - hX M/ aX CX p M qBDM#Rd;2,Mó" MF _2+ TBi HBx iBQM M
_2+Qp2`v 7i2`6BM MC+QmHM`HB Q27b6BM M+B-Hjka NRie`k32X B iBQM

>QQT2`- SX- 6X aX Jbb?FBM-UkykyX,aónS`BQ bT2+ib 7Q` AM~ iBQM
S`2bbm`2 1+QM QKv, Ab i?2 S?BHHBTb *m`p2 .2_/2Q2 Bb?AB M mbi
1+QM QKdBR+bke ekX

>bB2?- *X@hX M/ SX CX yH2M Q JBB HHQ+ iBQM M/ J Mm7 +im`B
M/ AM/B?2óZm `i2`Hv CQm`M H R791+RQMJRB93X

>mHD F- AX- _X J `iBM- .X JQ++2`Q- M/kýXySV Méh?Q J +`Q2+QM Q
AKT +i Q7 LSGb BM 1m`Q `a21*_Q r61Q HB 2-bRL33iX

Ap b?BM - oX M/ .X a+?U`ybr 2B,Mó" MF G2M/BM; /m`BM; i?2 6BM M
kyy3CQm`M H Q7 6BM M+ B dH jR Q Mj3XB+b

CBKöM2x- :X- aX PM;2M - CX@GX S2v/Uky Md VC,Xóal m`QM`m/2MiB H
B+v- *QmMi2`+v+HB+ H" MF * TBi H "mz2`b- M/ *`2/Bi amTTHv,
.vM KB+ S`QpBbBQMBMÇ Qnt`2MBK QM iS QóHBiB k8H KR QdM QRKddX

E H2KHB@Px+ M- aX- "X aQ`2Mb2M- *X oBHH2; b@a M+?2x- oX
aX u2bB Wiky RNV, ó>QriQ *QMbi`m+i L iBQM HHv _2T`2b2Mi iBp
i?2 P`#Bb :HQ# H . i # b2, L2r6 +ib M/ ; ;`aQ iE BAM,T BT-2`iBQM b

EmHF `MB- LX- aX _Bi /?B- aX oBD- UkyER Vq, H5/1Q-2F`i?BM; wQK#B
qQ`FBM; X T2`

G2pBMbQ?M- CX M/ UkySyjiVBM1biBK iBM; S`Q/m+iBQM 6mM+iBQ
iQ *QM i`QH 7Q` IMQ#2p2B p r#Q72 b +Q MQ-KcBy+ pRrd / B92RbX

GBm- 1X- X JB M- MUKy lakm7, B6GQr AMi2`2bi _ i2b- J `F2i SQR2`-
iBpBiv :`Q1i+QM QK2 N B X

J+:Qr M- JX X- .X M/`2rb- M/ oX UByHHQ, óAMbQH p2M+v _2;BK2
6B`Kb M/ * TBi H _2 H H B MB SMT-2`

UkyR3V, óh?2 q HFBM; .2 /\ wQK#B2 6B`Kb M/ S`Q/m+iBpBiv S
*QmMi` B 2 Q-10 QKB+ SjQ H B & v d j e X

JB M- X M/ X Uk y B 9V, óq? i 1tTH BMb i?2 kyyd kyyN .`QT BM
1+QM QK2 B B+kRNd kkkjX

JB/`B; M- oX M/ uX Uky R 9V, ó6BM M+2 M/ JBb HHQ+ iBQM, 1pB
G2p2H . iK26 B+ M 1+QM QK B r y 92 p B R r983X

PHH2v- :X aX M/ X USR FN 2 be V, óh?2 .vM KB+b Q7 S`Q/m+iBpBiv E
KmMB+ iBQM b 1[mBTK2+QM QK 2 b i B * - ô CQm`M H Q7 i?2- 1+QM QK
Rkej RkNdX

S22F- CX M/ 1X _ Q b 2 M y y 2 M, óIMM im` H a2H2+iBQM , S2`p2`b2 A
JBb HHQ+ iBQM Q7 *` 2K Bi B+MM 1+ QMM Q K B N 8 - 2p B 29 R R e e X

S2i2`b- JXkykyV, ó>2i2`Q;2M2Qmb J `FmTb- :`Qri?- M/ 1M/Q;2M
1+QM QK2 B B+k y j d k y d j X

a+?Bp `/B- 6X- 1X a2ii2- M/ :XUky #2KHV B6M B2/Bi JBb HHQ+ iBQM .
1m`QT2 M 6BM M+ B Q M Q K B B b G Q j m - J N R 9 k j X

h vHQ`- UkyyyV, óGQr AM~ iBQM- S bb@h?`Qm;?- M/1im2 S @B+BM
T2 M 1+QM QKB + 9 2 R B 2 N R 9 y 3 X

p M qBDM#2`;2M- aX M/ hXUky B R i j V 2 K ó A K T 2`72+i AM7Q`K iBQM- G
/DmbiK2Mi- M/ i?2 :`2 i J Q v 2 Q `i/B Q + Q M Q K B e 8 S R 2 N b k j N X

q?Bi2/- hX JX M/ CXUky k Q V, óh?2 JBb HHQ+ iB?QMC Q 7 m 6 B M H Q 7 2
6BM M d e- k j 8 N k 9 y d X

AMi2`M2i TT2M/Bt

ówQK#B2 *`2/Bi M/ U.Bb@VAM~ iBQM, 1pB/2M+2 7`QK

oB` H oX +? `v

J ii2Q *`QbB;M MB

hBK 1Bb2`i

*?`BbiB M 1m}M;2`

C Mm `v kykj

ai`m+im`2

h?Bb QMHBM2 TT2M/Bt Bb bi`m+im`2`2b2Mib H QK QX 2H Q7 i?2 xQ
H2M/BM; +?TM/B?Qrb ?Qr r2 Q#i BM }`K@H2p2HKG`E n+Tb27QH
M/ q `xv MubFKTT2M/BT`*2b2Mib //BiBQM T2M#BT`2b2Mib //B@
iBQM H };mT2M/BT`2b2Mib i?2 Ao /B ;MQbiB+ Q2b/ibKQm? @BM M/FB MK
2i HUXy kyXTT2M/BtBb+mbb2b i?2 bm`p2v / i +QHH2+i2/ 7Q` i?2 #
i2MbBiv M HV2M/BT`2b2Mib i?2 bmTTHv +T2M/BT`2b2Mib i?2 Qm`
`2bmHib `2 MQi 2tTH BM2/ #v Hi2`M iBp2 bmTTHv @bB/2 +? MM2

TT2M/Bt JQ/2H

AM i?Bb TT2M/Bt- r2 T`2b2Mi Qm` 7` K2rQ`F iQ M Hvx2 i?2 `2H
H2M/BM; M/ Ba2+ iBQM`2b2Mib KQ/2H r?2`2 xQK#B2 H2M/BM; z
bmTTHv #v + mbBM; iQQ K Mv }`Kb iQ T`Q/m+2 i Mv ;Bp2M TQBMi
K `;BM 2z2+XBQM 2ti2M/b i?2 2ti2MbBp2 K `;BM KQ/2H iQ HHQr xC
HbQ z2+i i?2 /2+BbBQM Q7 BM/BpB/m H }`Kb #Qmi i?2B` T`Q/m+
iBK2- i?mb //BM; M B Mi2MbBp2 K `;BM 2z2+iX

XR 1ti2MbBp2 J `;BM JQ/2H

aBM+2 Qm` Q#D2+iBp2 Bb iQ +? ` +i2`Bx2 i?2 2z2+i Q7 xQK#B2 +`
xQK#B2 +`2/Bi b M 2tQ;2MQmb 7Q`+2 BM Qm` KQ/2H i? i T`2p2M
/27 mHiBM;- M/ 7Q+mb Qm` M HvbBb QM Bib 2z2+i QM T`Q/m+i T
hQ i?Bb 2M/- r2 `2Hv QM M 2ti2MbBp2 i?2Q`2iB+ H HBi2` im`
+ TBi HBx2/ # MFb + M ? p2 M BM+2MiBp2 iQ 2ti2M/ /p Mi ;2Qm
Ub22- 2Xm X?2 M/ GHYR#QK ` M/ p M qBD My#Rd22M m 2kyHX
M/ +? `v 2i- klykX h?Bb HBi2` im`2 ? b ?B;?HB;?i2/ U i H2 biV in

H2M/BM; 7`B+iBQMb, pQB/ M+2 Q7 `2;mH iQ`v +Qbib M/ `BbF@
xQK#B2 H2M/BM; Qmi+QK2- i?2b2 irQ 7`B+iBQMb QT2` i2 BM /Bz2
wQK#B2 +`2hB`2xpQB/ M+2 Q7 `2;mK2iQ`MBQKi0 b 7Qm` M2+2bb `v
/B2MibX 6B`bi- i?2 # MF M22/b iQ #2 bm{+B2MiHv r2 F bm+? i?
T`Q# #BHBiv i? i i?2 # MF 7 HHb #2HQR KBMBKmk`2;mH iQ`v +
BM+m`b `2;mH iQ`v +Qbib r?2M Bi 7 HHb #2HQR i?2 `2;mH iQ`v +
`2bmHi Q7 + TBi H b?Q`i7 HH- i?2 `2;mH iQ` `2bi`B+ib # MF #2
+ TBi HBx iBQMX h?B`/- i?2 # MF ? b T`22tBbiBM; 2tTQbm`2 iC
HBF2HB?QQ/ Q7 MQi #2BM; #H2 iQ K22i Bib /2#i T vK2MibX 6Qm
#Q``Qr2` rBi? 7mM/b i /p Mi ;2Qmb i2`Kb- i?2 # MF + M U i H2 bi
i?2 T`Q# #BHBiv i? i i?2 }`K /27 mHib QM Bib Qmibi M/BM; /2#i T v
AM bmK- i?2 T`QpBbBQM Q7 +?2 T +`2/Bi iQ i?2 BKT B`2/ #Q``Q
i?2 # MF ? b iQ `2+Q;MBx2 HQbb2b QM i?2 #Q``Qr2`öb 2tBbiBM;
rQmH/ HQr2` i?2 # MFöb + TBi H H2p2H M/ BM+`2 b2 i?2 HBF2H
T`QpB/BM; +`2/Bi rBi? /p Mi ;2Qmb i2`Kb iQ xQK#B2 }`Kb Ui?mb-
i?2B`HQ M T vK2MibV- # MF + M ó#mviBk2`h?iQM BM2ki?KjXBi`2+Q
T`QpB/2b 2KT B`B+ H 2pB/2M+2 7Q` i?Bb /`Bp2` Q7 xQK#B2 H2M/BM
MFb `2 HHQ+ i2 +`2/Bi iQ /Bbi`2bb2/ }`Kb rBi? mM/2` @`2TQ`i2/
h?2BbF@b`B`?BMBbK ? bi?`22 M2+2bb `v BM;`2/B2MibX 6B`bi-
r2 F bm+? i? i i?2`2 Bb MQM@M2;HB;B#H2 T`Q# #BHBiv Q7 #2+C
iQ xQK#B2 }`K vB2H/b ?B;?2` 2tT2+i2/ `2im`M BM i?2 # MFöb bQ
QmibB/2 Bmp2biK2Mi QT iBQMb UBX2X- HQ M iQ }`K BM /Bz2
`2[mB`2b i? i i?2 xQK#B2 HQ M ? b ?B;?2` T vQz B7 bm++2bb7mH

^{9y}JQ`2Qp2`- i?2 xQK#B2 HQ Mb M22/ iQ BM+Hm/2 bm#bB/v iQ K F2 +QM iBMm
TQbBiBp2 LSoX

Q7 i?2 xQK#B2 HQ M Bb KQ`2 ?B;?Hv TQbBiBp2Hv +Q``2H i2/ rBi?
T`22tBbiBM;TQ`i7QHBQU2X;X- #2+ mb2 i?2 # MF ? b K i2`B H T
}`K- Q`- KQ`2 ;2M2` HHv- i?2 # MF Bb ?B;?Hv 2tTQb2/ iQ i?2 b2+i
QT2` i2bVX h?B`/- i?2 # MFöb /2#i Bb MQi 7 B`Hv T`B+2/ UBX2X-
`BbFVX 6Q` 2t KTH2- i?2 # MF Bb T`Qi2+i2/ #v ;Qp2`MK2Mi ;m ` M
wQK#B2 H2M/BM; #2? pBQ` i?2M Q`B;BM i2b 7`QK i?2`2bmHiBM
B+ HHv- # MF rBi? /2#i MQi TT`QT`B i2Hv T`B+2/ 7Q` `BbF ? b M
i? i HHQr i?2 # MF iQ ób?B7iô //BiBQM H`2im`Mb BM bQHp2M+v
BM BMbQHp2M+v bi i2bX T`BK2 `BbF@b?B7iBM; QTTQ`imMBiv 7
BM+`2 b2 Bib 2tTQbm`2 iQ r2 F}`Kb UxQK#B2bV iQ r? B-6QBi H`2 /
2t KTH2QT` 2iUkYWR T`QpB/2b 2KTB`B+ H 2pB/2M+2 7Q` i?Bb /`Bp2
a2imT`2 /2}M2 M 2[mBHB#`BmK rBi? M/ rBi?Qmi xQK#B2 +`2/Bi U
b M 2tQ;2MQmb 7Q`+2V M/ i?2M +QKT `2 2[mBHB#`BmK [m MiBi
BKT2`72+i +QKT2iBiBQM KQM;}`Kb iQ` #7`HK2i`Q`Ej`BX BH` iQ
hBK2 Bb /Bb+`2i2 M/ i?2 2+QMqKv Bb TQTmH i2/ #v H` ;2- #n
i? i T`Q/m+2 bBM;H2 ;QQ/X 6B`Kb `2 B/2MiB+ H BM bBx2 M/ +
2Mi` MibX i 2t+? ?2i`2m; BM+mK#2Mi }èKQiMMiB H 2Mi` Mi}`KbX
h?2 T`Q#H2K Q7}`Kb t iBb +? 7Q2iHQRbX 6B`bi-}`Kb UBM+mK#2M
2Mi` MibV T v }tX/ aQ`bQM/- BM+mK#2Mi}`Kb bBKmHi M2QmbHv
}`Kb /` r i?2B` T`Q/m+? ?KQ MmMB7Q`K /p biUP;#ixi BQ MKbö T`Q}ib `2
(p c)yit l - r?2c2Bb i?2 U2tQ;2MQmbV K `;BM H +QbiX .2T2M/BM; C

^{9R} xQK#B2 HQ M rBHH ? p2 /p Mi ;2Qmb Ubm#bB/Bx2/V i2`Kb #2+ mb2 Bi +C
i? i i?2 #Q``QrBM;}`K óM2;QiB i2bô rBi? i?2 # MFX h?2 T`iB+BT iBQM +QMbi
MF iQ BM+Hm/2 bm{+B2MiHv H` ;2 p Hm2 i` Mb72` BM i?2 xQK#B2 HQ M bm
7`QK M2; iBp2 iQ TQbBiBp2 LSo 7Q` i?2 xQK#B2}`KX

$i^2 B^T Q / m + i B Q M - T Q i^2 M i B H^2 M i^M i \}^K b K B ; ? i^2 M i^2 i^2 K^F 2 i$
 $/ 27 m H i X \}^K i^? i K F 2 b M^2 ; i B p^2 T^Q \} i b B b 7 Q^+ 2 / i Q / 27 m H i X$
 $h^? 2^2 B b M^2 t Q ; 2 M Q (p) \neq 2 K M / - r^? 2 p^2 B b i^? p^2 ; 2 T^B + 2 b^2 i \neq$
 $B M + m K \# 2 M i \}^K b X h^? B b ; ;^2 ; i^2 / 2 K M / B b b i B i^2 / b i^i B M ; r B i^? i^?$
 $i^? i b^2 i b i^? 2 H Q r^2 b i T^B + 2 X$

G 2 K K R X 6 B^K b + ? Q Q b^2 r^? 2^2

$$p_t = t \frac{m_t}{2} \quad U R V$$

$S^Q Q \bar{a} X T T Q b B / 2 M i B + H \}^K b b^2 i T^B + 2 b b \neq \bar{a} \bar{a} i^2 M^2 Q m^2 H v x i i B Q M Q 7 i^? 2 T^Q$
 $T^K 2 i^2^B M b B M ; H^2 b^? Q i ; K 2 X h^? 2 K^ ; B M X H^? 2 b^2 Q b^? T Q M H v + Q B Q M Q B / M /$
 $/ 2 K M / B (p) = t p_t - r^? 2^2 \frac{1}{2} (m_t + 1) + c X h^? 2 2 t T^2 + i^2 / T^Q E (m_t) + B^1 Q M H B b T^Q \# H^2 K$
 $B b b B K B H^i Q " 2^i^M / T^B + 2 @ b^2 i i B M ; K Q / 2 H r B i^? M^2 t Q ; 2 M Q m b + T + B i v +$
 $T^Q / m + i B Q M X q 2 p_t H p K i^? \frac{1}{2} X : B p^2 M i^? 2 Q M^2 b^? Q i M i m^2 Q 7 i^? 2 ; K^2 - r^2 + M B ;$
 $b m \# b +^B T i b Q T i B K H H v / 2 p b_i \neq 2 p_i \neq Q K \# 2 + m b^2 B i + M ; 2 i^? B ; ? 2^T^B + 2 Q M i^? 2$
 $/ 2 K M / ; B p^2 M i^? i Q i^? 2^}^K b + M M Q i \frac{1}{2} B M m^2 + 2 K +^2 B i Q M i B K^K H v / 2 p B i^2 b 7^Q K$
 $p_i = p_i > p \# 2 + m b^2 B i + M m M / 2^+ m i b H B ; ? i H v i^? 2 T^B + 2 M / 2 t T^2 + i^i Q b^2 H H B i b$
 $6 B^i K Q T i B K H H v / 2 p b_i \neq 2 p_i \neq 2 K m b^2 B i + M ; 2 i^? B ; ? 2^T^B + 2 Q M i^? 2 \square 2 b B / m H / 2$

$6 B^K b b^2 i T^B + 2 b F M Q r B M ; i^? i i^? 2 B^2 t T^2 + i^2 / T^Q / m + i B Q M B b R f$
 $i^? 2 T^B + 2 i \# v B M + m K \# 2 M i \}^K b B b b m + ? i^? i i^? 2 i Q i H^2 t T^2 + i^2 / T^Q /$
 $i i^? 2 T^B + 2 A i B b M Q i Q T i B i K i Q \neq Q r^2^B i b T^B + 2 b B i r B H H^2 M / m T$
 $H Q r^2^T^B + 2 B i b^2 M i B^2 2 t T^2 + i^2 / T^Q / m + i B Q M X i Q i B M + H^2 Q 2 M Q b C$
 $T^B + 2 b B i + M B M +^2 b^2 T^Q \} i b \# v B M +^2 b B M ; 2^? 2 m^2 t T^Q + 7 2 / ? p m$

^{9k}: $B p^2 M = \frac{P}{i} p_{it} = m_{it} - i^? B b H H Q + i B Q M^m H^2^2 b^2 K \# H^2 b H B K B i Q^? / 2^ \# Q Q F b m b$
 $K m H i B T H^2 \}^K b b^2 i i^? 2 b K^2 H Q r^2 b i T^B + 2 - i^? 2 / 2 K M / B b b T H B i 2 p^2 M H v K Q M ; i$
^{9j}: $A 7_t B b H^ ; 2 2 M Q m ; ? - i^? 2 K^ ; B M H^2 p^2 M m^2 B b ;^2 i^2^i^? M i^? 2 K^ ; B M H +$
 $B M +^2 b^2 T^Q \} i b \# v H Q r^2^B M ; i^? 2 T^B + 2 M / - B M i m^M - B M +^2 b B M ; i^? 2 [m M i B i$

T`Q/m+iBQM +QMbi` BMi- }`Kb +? (p_t; 2c)=T`Q bBiBp2 K `FmT

7i2` i?2 T`B+2 Bb b2i- }`Kb H2 `M i?2 `2 HBx iBQM Q7 i?2B` T`
 i? i;2M2` i2 M2; iBp2 T`Q}ib `2 7Q`+2/ iQ /27 mHiX AMpQFBM; i?
 K bb Q7 /27 mHXBM/}i`Kb K bb Q7 bm`pBpBM; BM2mK#2Mi }`Kb

$$X_t = m_t \int_0^{\frac{1}{p_t c}} di = \frac{m_t l}{p_t c} \quad S_t = m_t \int_0^{\frac{1}{p_t c}} di = m_t \cdot 1 \cdot \frac{l}{p_t c} : \quad U \text{ kV}$$

SQi2MiB H 2Mi` Mi }`Kb i? i;2M2` i2 T`Q}ib 2Mi2` i?2 K `F2iX h?2

$$E_t = e \int_0^{\frac{1}{p_t c}} di = e \cdot 1 \cdot \frac{l}{p_t c} : \quad U \text{ jV}$$

hQi H T`Q/m+iBQM Q7 2Mi` Mib M/ bm`p

$$N_t = (e + m_t) \frac{1}{2} \cdot 1 \cdot \frac{l}{p_t c} : \quad U \text{ 9V}$$

1[mBHB#`BmK rBi?Qmi xQK#B2 +`2/Bi U
 `BmK rBi? xQK#B2 H2M/BM; U1[wVX

.2}M BiBp2M i?2 /2K M/ T` ; BM H--Qb2[mBHB#`BmK
 rBi?Qmi xQK#B2 +`2/Bi U 1[mV rBm#2M iQ/m NiBQM? i? i i?2 T`Q/m+i
 T`B+2 Bb ; Bp2M#iv H T`Q/m+iBQM Bb M/pi2M MmK#2` Q7 BM+mK#2M
 7QH hQr= m_t + E_t X_t X

h?2 2[mBHB#`BmK rBi?Qmi xQK#B2 +`2/Bi U1[LV Bb ;Qp2`M2/ #v

⁹h?2 T`B +B2 /2i2`KBM2/ BM i2`Kb Q7 +Qbi b i?2 MmK2` B`2X AM Qm` 2MpB`Q
 7Q`K Q7` B;B/Biv QM i?2 +Qbi bB/2X

T`B+2 Q7 i?2 ; Q Q 2 7 Q 7 H a 2 + Q M / - i Q i H T`Q / m + i B Q M B b i?2 b m K Q 7
 Q 7 }`K b i? i 2 M i 2` i?2 K `F 2 i M / T`Q / m + i B Q M Q 7 B M + m K # 2 M i }`K b
 B M + m K # 2 M i }`K b` 2 i i?2 b m K Q 7 B M + m K # 2 M T H`K b 2 M i B K M i }`K b i i B K
 t K B M m b / 2 7 m H i B M ; t X 6 Q`K i B K 2 ,

$$p_t = \frac{m_t}{2}$$

$$m_{t+1} = m_t + e \frac{1}{p_t} \frac{l}{c} \frac{z^t}{m_t l} \frac{1}{c}$$

$$N_t = (e + m_t) \frac{1}{2} \frac{1}{p_t} \frac{l}{c}$$

A M b i 2 / v b i + 1 i 2 m M / / 2 7 m H i b ` 2 2 t + i H v Q z b 2 i # v 2 M i ` v X 6 Q`K H H

$$p = \frac{m}{2} \frac{M}{\frac{l}{c}} = e \frac{1}{\frac{l}{c}}$$

$$m = \frac{e(c+l)}{l + \frac{e}{2}} \quad p = \frac{2l + e(c+l)}{2l + e} \quad N = \frac{e+m}{2} \frac{1}{p} \frac{l}{c}$$

r? 2` @m > 0 - @p > 0 - @p > 0 - M @p > 0 X

h? 2 2 [m B H B # ` B m K r B i? x Q K # B 2 + ` 2 / B i B b + ? ` + i 2 ` B x 2 / # v 7 Q m
 Q 7 i?2 ; Q Q / 7 Q 7 H a 2 + Q M / - i Q i H T`Q / m + i B Q M B b i?2 b m K Q 7 i
 }`K b i? i 2 M i 2` i?2 K `F 2 i T H m b i?2 T`Q / m + i B Q M Q 7 b m ` p B p B M ; }`K
 Q 7 x Q K # B 2 }`K b X h? B` / - / 2 7 m H i b ` 2 b n z + x a T 2 x B Q K # B 2 v` K b b m
 i? i - B M i?2 T`Q / m + i B p B i v / B b i` B # m i B Q M - # M F b r B i? x Q K # B 2 H 2 M
 x 2` Q z - Q H B p 2 - H 2 / B M ; i Q M m K # 2` Q 7 ó z X p 2 Q m }`K b i 2 [2 m B M i Q K # 2
 }`K b t i + 1 ` 2 i?2 b m K Q 7 B M + m K # 2 M T H`K b 2 i M B K M i }`K b K B M B K 2

/27 mHiBM; }`KtbX 6QBK2HHv,

$$\begin{aligned}
 p_t &= \frac{m_t}{2} & U &= 8V \\
 m_{t+1} &= m_t + e \left(\frac{l}{p_t c} - \frac{m_t l}{p_t^2 c} \bar{Z} \right) & U &= eV \\
 N_t &= (e + m_t) \frac{1}{2} \left(1 - \frac{l}{p_t c} + \frac{\bar{Z}^2}{2m_t} \right) & U &= dV
 \end{aligned}$$

.2}MBiBQM p2M i?2 /2K M/ T : Kt2i2+QbK `;BM Hc+QM/i xQK#B2
 }`KZ- M 2[mBHB#`BmK rBi? xQK#B2p_t`2MBinUK#2MiBv r#BBQM
 bm+? i? i i?2 T`Q/m+i T`B-RV BQi; BpT`Q/#v+iBQM dAZ; B p2M`#v
 T`2p2Mi2/ 7`QK /27 mHiBM;- M/ i?2 MmK#2m_tQ = BM+Em K#2Mi }`Kb
 AM bi2 /v bi+1i2 m U M/ /27 mHib `2 2t +iHv Qzb2i #v 2Mi`vVX

$$\begin{aligned}
 p &= \frac{m}{2} \quad M / \frac{m l}{p c} \quad \bar{Z} = e \left(1 - \frac{l}{p c} \right) \\
 m &= \frac{e \left(\frac{c l}{l + \frac{e}{2} + \frac{\bar{Z}}{2}} \right) + \bar{Z} \left(\frac{c}{2} \right)}{\frac{2l + e(c+l) + \bar{Z}c}{2l + e + \bar{Z}}} \\
 N &= (e + m) \frac{1}{2} \left(1 - \frac{l}{p c} + \frac{\bar{Z}^2}{2m} \right)
 \end{aligned}$$

AMbB;?hbX K BM BMbB;?iBbi? ii?2 2[mBHB#`BmK rBi? xQK#B2 H
 HQR2` T`B+2b M/ ?B;?2` ;;`2; i2 T`Q/m+iBQM +QKT `2/ rBi? M 2[
 H2M/BM;X 6Q`K HHv- r2 ? p2 i?2 7QHHRBM; T`QTQbBiBQM X

S`QTQbBRBQM i?2 2[mBHB#`BmK rBi? xQK#B2 +`2/Bi- BM bi2 /v bi
 i?2`2 `2 KQ`2 BM+mK#2Mi }`Kb- i?2 T`B+2 M/ K`FmT `2 HQR2`
 +QKT `2/ rBi? i?2 bi2 /v bi i2 BM M 2[mBHB#`BmK rBi?Qmi xQK#B

6B;m`2 ,XR 2bTQM b2b iQ SQbBiBp2 wQK#B2 H?B/B ;an?Q +F?Qrb ?Qr 2[mBHB#`
 [m MiBiB2b M/ T`B+2b`2bTQM/ iQ \bar{z} \bar{x} K?M 2 M/ B M+22 Hb2 MB2b BM/B+ i2 M 2[m
 rBi? HQR xQK#B2 +`2/BiX h?2 #H +F / b?@/Qi HBM2b BM/B+ i2 M 2[mBHB#`B
 T` K2i2`b =0205-e=1 -c=0:3- =13 - \bar{z}^L =0:5- M \bar{z}^H =0:9X

S`QQZXi2 i? \bar{z} B σ -p = p Mm = m X q2 HbQ ? p2 i? i,

$$m \quad m = \frac{l(c + \frac{e}{2})}{(1 + \frac{e}{2} + \frac{z}{2})(1 + \frac{e}{2})} \bar{z} \quad 0 \quad M/p \quad p = \frac{l(c + \frac{e}{2})}{(1 + \frac{e}{2} + \frac{z}{2})(2l + e)} \bar{z} \quad 0$$

:Bp2M i?2 2[mBHB#`BmK +QM/BiBQM b 7Q` 1[L M/ 1[w- Bi i?2M 7QHHQrb i? i K
 HQR2` BM 1[w +QKT`2/ rBi? 1[LX □

h?2b2`2bmHib + M #2 b?QrM ;` T?B+ HHv mbBM; bBKTH2 MmK
 i iBp2Hv BHHmbi` i2 i?2 /vM KB+b ;2M2` i2/ #v i? B B ;mK 2rQ`F /2b

6B;m`2 ,X&i2 /v ai i2 1[mBHB#`BmK S`B+2b b wQK#B2 *`2/Bi *? M;2b 1ti2Mb
JQ/2Hh?Bb };m`2 b?Qrb ?Qr 2[mBHB#`BmK bi2 /v bi i2 [m MiBiB2bX M?T`B+2b`2
T ` K2i2`b =0205-e=1 -c=0:3- =13- MZ^L 2(y-R)X

b?Qrb ?Qr M 2+QMqKv BM bi2 /v bi i2 rBi? MQ xQK#B2 H2M/BM
T2`K M2Mi BM+`2 b2 BM xQK#B2 H2M/BM; iQ M 2+QMqKv rBi? HQ
HBM2V M/ M 2+QMqKv rBi? ?B;? xQK#B2 H2M/BM; U#H +F / b?@
1[w bi2 /v bi i2b- r2 Q#b2`p2 i? i UBV T`B+2b M/ 2Mi`v `2 HQR2`
#2Mib- M/ T`Q/m+iBQM `2 ?B;?2` b x QK#B 2H2XQ/BM,QBM i+2 2/vb2b
bi i2 2[mBHB#`BmK [m MiBiB2b M/ T`B+2b h? B bM; Q Hb 2+ iBM+M 2Q 2
bi i2 2[mBHB#`B +QM}`Kb i?2 BMbB;?ib /Bb+m b2/ #Qp2X

6B;m`2 bXQrb ?Qr i?2`2H iBQM b?BT #2ir22M xQK#B2 H2M/BM;
p `v i?2 }t2/l+XQb?2 };m`2 b?Qrb i? i- 7Q` ?B;? xQK#B2 T`2p H2M

6B;m`2 ,Xj2MbBiBpBiv rBi? `2bT2+ii2iQbBp2 J `;BM JQ?2BHX};m`2 b?Qrb ?Qr
2[mBHB#`BmK bi2 /v bi i2 T`B+2b Z2X ThQ M/TiQ K2i2#2b`2-M:3- =13- M/
Z2[0;1]X h?2 };m`2 b?Qrb i?2 +QHH2+iB-QM:0;0:05[00B]XB#`B 7Q`

T`B+2 bbQ+B i2/ rBi? M BM+`2 b2 BM xQK#B2 H2M/BM; Bb KQ`2`
M HviB [Ⓢ]HH0-BZ> 2l eX

AMTmi +Qb P2X7` K2rQ`F /2b+`B#2/ #Qp2 + M #2 / Ti2/ iQ M Hv
xQK#B2 H2M/BM; QM BMTmi +QbibX aT2+B}+ HHv- +QMbB/2` M
T`B+2 Bb 2tQ;2MQmb- i?2`2 Bb M 2LQ=2MQimLbr 0 20 2B H i?Q 7TBM+2mi
Q7 BMTmi M/ K `;BM H +Qbi MQ` 2i2? T`KBM; i?2 }tK/b+Q2i ii?2
T`B+2 Q7 i?2 BMTmi- FMQrBM; i? i i?2B` 2tT2+i2/ T`Q/m+iBQM Bb
i?2 irQ 2[mBHB#`BmK /2}MBiBQM b i F2 i?2 T`Q/m+i T`B+2 b ;Bp2
+QM/BiBQM 7Q` i?2 B M 2T+mi X Qb?i2 BMimBiBQM 7Q` i?Bb 2tT`2bbB
BMimBiB QM K K6B`Kb b2i i?2 K `;BM H b Q b?Q7 BM 2mQi H /2K M/
7Q` i?2 BMTmi 2[m Hb Bib bpxT A HB bi2i 22 TQBb+2Qr i? i- BM i?Bb 2M
M BM+`2 b2 BM xQK#B2 H2M/BM; H2 /b iQ /2+`2 b2 BM i?2 UMQ
i?2 UMQr 2M/Q;2MQmbV K `;BM H +QbiX

Xk AMi2MbBp2 J `;BM JQ/2H

AM i?Bb b2+iBQM- r2 2ti2M/ i?2 2ti2MbB p2 Ki B QMM 7`HK2QQ}FK7` QK
iQ /2+B/2 ?Qr Km+? i?2v T`Q/m+2- i?2`2#v //BM; M BMi2MbBp2 k
7` K2rQ`FX

a2imTXQM bB/2` i?2 7` K2rQ` Fa/Bi Br QK b 2XQBM 2T i?2 BMi2MbBp2 K
2ti2MbBQM i` +i #H2- r2 bbmK2 i? i}`Kb +QM bB/2` i?2 K `F2i T`B
/2K M/ Bb ;B D2M #v t p t- M/- BM 2[mBHB#` p,mBk- b m2+ T`iB+i2i?2
;;`2; i2 T`Q/m+iBQM 2[m Hb /2K M/ i i?Bb T`B+2X

*QM bB/2` HbQ 2tQ;2MQ mb?B +B +BM M 2BM Mi2`T`2i2/ b QT2` iB
}M M+B H H2p2` ;2X q2 bbmK2 i? i 7Q` #Qi? BIM B m K#2iMB #M /22/Mi
Qp2` i?2 B M; i2` M H ++Q`/BM; iQ /B(i) XB #miBQM

G2i #2 i?2 UMQr 2M/Q;2MQ mbHv +?Qb2MM T`i Q Kra +?BQ2Mr B+ H2 C
bbmK2 i? i}`Kb ö K tBKmK QmiTmi [m MiBiv Bb 2[m HiQ RX AM M
#2ir22M i?2 T`Q/m+iBQM /2+BbBQM M/ T`Q/m+iBQM-Q m i+Q K2V- r
//BiBQM H T`Q/m+iBQM M 222M i Q #2 B-M+m``2/ iQ +QM iBMm2 T`Q

q⁰< 0-q⁰⁰ 0-q(0) 1- Mq(1) 0X h? i Bb- i?2 HBF2HB?QQ/i? i i?2 //BiBQ
+Qbib `Bb2 BM+`2 b2b rBi? i?2 +?Qb2M T`Q/m+iBQM b+ H2X A7 i
`Bb2- i?2 LSo Q7 +QM iBMmBM; i?2 T`Q/m+iBQM T`Qi+0 B X 2X`-Mb
7Q` HH }`Kb VX AM i?2 7QH HQR BM;- r2 `272` iQ i?Bb bi i2 b i?2 ó#

>Qr2p2`- rBi? T`Q-#} #B H B i v?P UB X2X- ?B;?Hv H2p2`2/ }`KbV `2+
+`2/Bi BM i?2 # / bi i2X h? i Bb- i?2v `2 ó# BH2/ Qmiô #v i?2B` #
Q7 bm{+B2MiHv H `;2 bm#bB/v i? i H2ib i?2 }`K #`2 F 2p2M UB X2
T vBM; i?2 //BiBQM H T`Q/m+iBQM 2tT2M/Bim`2 M/ +QM iBMmBM
#v Bib # MF BM i?2 # / bi i2- }`K biQTb T`Q/m+BM;X *QM b2[m2MiH
Bi /27 mHib- M/ BM+m`b i?2X#hM E 7m F i i +? +QQ K#B2 +`2/Bi TQi2MiB
}`Kb rBi?P 7`QK BM+m``BM; i?2 # MF`mTi+v +Qbi +`2 i2b M BM+2M

$7Q \cdot i^2 b^2 \} \cdot K b U b^2 H^2 - M^2 X M X k y M^2 Q \cdot b B K B H \cdot \cdot B b F @ i F B M ; K Q / 2 H b$
 $++ Q \cdot / B M ; H v - i^2 K t B K B x i B Q M T \cdot Q \# (P, Q) B \cdot Q B p^2 M K \# v, i^2$

$$\max_{y_{it} \in [0;1]} (M_t y_{it} - I) q(y_{it}) - (1 - q(y_{it})) (1 - z); \quad U \ 3 \ V$$

$r^2 \cdot M_t = p_t - c B b i^2 K \cdot F m T X q B i^2 q(y_{it}) - \# i^2 B H B K i^2 b T \cdot Q / m + i B Q M r Q$
 $b^2 K H^2 b b H v - B M r^2 B + ? + b^2 i^2 \} \cdot K \cdot 2 + 2 B p^2 b i^2 Q X i^2 B i^2 i^2 B K^2 b$
 $T \cdot Q \# \# B H B i^2 y - i^2 // B i B Q M H T \cdot Q / m + i B Q M 2 t T^2 M / B i m^2 b \cdot B b^2 X q$
 $Q m i \# v B i b \# M F - r^2 B + ? ? T T^2 M b B B i^2 T^2 Q \# 2 \# B X^2 B Q T \cdot Q \} i X q B i^2 T \cdot$
 $1 - z - i^2 \} \cdot K B b M Q i^2 b + m^2 / - 7 B H b - M / B M X m^2 b i^2 \# M F \cdot m T i + v +$
 $h F B M ; i^2 \} \cdot b i @ Q \cdot / 2 \cdot + Q M / B i B Q M B U \theta P^2 v T^2 + 1 \cdot U^2 T \cdot Q / m + i B Q$
 $v B^2 H / b$

$$M_t q(y_{it}) + (M_t y_{it} - I + (1 - z)) q^0(y_{it}) = 0; \quad U \ N \ V$$

$> 2 M + 2 - i^2 Q T i B K H T \cdot Q / m + i B Q M i^2 + (P, Q) B \cdot Q \cdot 7 m^2 M + i B i^2 M i^2 Q Z$
 $T \cdot Q \# \# B H B i v Q^7 \# 2 B M ; \cdot 2 b + m^2 / \# v x Q K \# B^2 \cdot 2 B / B T B M + B^2 / B Z \cdot i^2 M i^2 E$
 $Q^7 i^2 T \cdot Q / m + i B Q M b + N M^2 B i^2 Q \cdot K b T^2 v B^2 Q / b$

$$\frac{\partial y}{\partial z} = \frac{q^0(y_{it})}{2M_t q^0(y_{it}) + (M_t y_{it} - I + (1 - z)) q^{00}(y_{it})} > 0; \quad U \ R \ y \ V$$

$r^2 B + ? b^2 Q r b i^2 i^2 ? B ; ?^2 \cdot H B F^2 H B ? Q Q / Q^7 \cdot 2 + 2 B p B M ; x Q K \# B^2 + \cdot 2$
 $T \cdot Q / m + i B Q M b + H^2 + ? Q B^2 \cdot 2 P, Q \cdot 7 m T \cdot r K / r B X \cdot J Q \cdot 2 Q p^2 \cdot - i^2 B K T H B + B i /$
 $i B Q M Q^7 i^2 T \cdot Q / m + i B i Q M B i^2 (P, Q) B \cdot Q \cdot 7 r B i^2 \cdot 2 b T i^2 v B^2 Q / b$

$$\frac{\partial y}{\partial I} = \frac{q^0(y_{it})}{2M_t q^0(y_{it}) + (M_t y_{it} - I + (1 - z)) q^{00}(y_{it})} > 0; \quad U \ R \ R \ V$$

aBKBH `Hv- 7Q`l 2]0;K] fB?2 K tBKBx iBQM T`Q#H2K #2+QK2b,

$$\max_{y_{it} \in [0;1]} (M_t y_{it} - l) q(y_{it}) - (1 - q(y_{it})); \quad U R k V$$

r?2`2 i?2 6P* rBi? `2p B2+;iBi Q2 M #v

$$M_t q(y_{it}) + (M_t y_{it} - l + z) q'(y_{it}) = 0; \quad U R j V$$

LQi2 i? i- BM i?B/Q 2bbM Qi z2+i i?2 }`Kbö T`Q/m+iBQM +?QB+2bX
2MiB iBQM Q7 i?2 T`Q/m+iB Q W b Bi H 227` Q2+B 2Q U b

$$\frac{\partial \mathcal{L}}{\partial l} = \frac{q'(y_{it})}{2M_t q'(y_{it}) + (M_t y_{it} - l + z) q''(y_{it})} > 0; \quad U R 9 V$$

h?2 BMimBiBQM mM/2R N vBM RU/ BX U b 7QHHRb X;Bp2B;?`Kb M
BM+2MiBp2 iQ BM+`2 b2 i?2B` QmiTmi [m MiBiv bBM+2 i?Bb ` Bb2
HQR2`b i?2 HBF2HB?QQ/ Q7 i?2 ;QQ/ bi i2 Q+ (M y_{it} ` BIM ;BM Bi B2M+`2
;QQ/ bi i2X h?Bb #2M2}i Q7 +?QQbBM; ?B;B? ? B m i B m 2 [m Mi B Q v #?
ivT2b Q7 }`Kb UB X 2X + #Q H Q K b M / B P / Q p ? 2 + Q b i Q 7 ? B ; ? 2 ` T ` Q / m
b+ H2 B b i? i Bi BM+`2 b2b i?2 HBF2HB?QQ/ Q7 i?2 # / bi i2 Q++m
b2p2`2 7Q` }`K b Pr Bi ? 2 v T Qi 2 Mi B H H v # 2 M 2 } i 7 ` Q K x Q K # B 2 + ` 2 / Bi -
2tT2+i2/ # MF`mTi+v +QbibX >2M+2- BM+`2 bBM; i?2 QmiTmi [m
}`Kb BM i?2 # / bi i2X *QM b2 [m 2MiHv- Bi ?QH/b i? i

$$\frac{\partial \mathcal{L}}{\partial l} = \frac{q'(y_{it}) q''(y_{it})}{(2M_t q'(y_{it}) + (M_t y_{it} - l + (1 - z)) q''(y_{it}))^2} > 0; \quad U R 8 V$$

>2M+2- M BM+T n b 22BM?2 T`Q/m+iBQM b+ H2 KQ`2 bi`QM;Hv mTr
+`2/Bi H 2 p 2 H ? B ; ? 2 ` - r ? B + ? H b Q / B ` 2 + i H v 7 Q H H R Q v b M / Q U X Q K T ` B
aBKBH `Hv- M B M m 2 ? B B B ? 2 Q mi T mi [m Mi B iv K Q ` 2 bi ` B M ; H v m T

H `;2`X

b BM i?2 2ti2MbBp2 K `;BM KQ/2H- bmTtTiQ 222i B b BrM Q 7+ ? T2`B
BM+mK#2Mi }`Kb eMQ 7 K Qbi2 MiB H 2Mi` MibX h?2 T`Q#H2K Q7 2Mi`
iQ i?2 QM2 Q7 i?2 BM+mK#2Mib- rBi? irQ /Bz2`2M+2bX 6B`bi- }`K
K `F2i `2 M2p2` # BH2/ Qmi BM il?2([I]) X ih?2 B b p2MnK 7 iBQM + Tim`2
7 +ii? i# MFb QMHv T`QpB/2 xQK#B2 +`2/Bi iQ }`Kb iQ r?B+? i?2v
`2H iBQM b?BTb M/ r?B+? `2 i?mb bQK2r? i K im`2 M/ H`2 /v B
TQi2MiB H 2Mi` Mib ? p2 iQ b K biQ B2Mi2b2ii?2TK+ QF2iX >2M+2- i?2b
2Mi2` QMHv B7 i?2v 2tT2+iiQ K F2 TQbBiBp2 T`Q}ib M2i Q7 i?Bb :
T`Q/m+iBQM (+) ? Q B +2TQi2MiB H 2Mi` Mi }`K-rB? B b H 2 p2 2M22` b i?2
K `F2i B7 M/ QMHv B7

$$(M_t y_{it}(I) - I) q(y_{it}(I)) (1 - y_{it}(I)) > K: \quad U \text{ Re } V$$

*QM/BiB Q M B K T H B 2 b i? i TQi2MiB H 2Mi` Mi }`K 2Mi2`b i?2 K `F
H2p2` ;2 #2HQM;b iQ b2iIrE? B +? r2 /2MQi2

1[mBHB#` B 2T K #2 i?2 iQi H MmK#2` Q7 }`Kb BM i?2U B X Q 2 K Q B M - B n M K T @
#2Mib M/ M2r 2Mi` MibVX :Bp2M i? i }`K /27 m(y_{it}) (1rBz)?BT7 Q# #B
l 2 ([, I] M/ rBi? T`Q#1# B (y_{it}) B B 72 [0; ^] - i?2 H r Q7 H `;2 MmK#2`b B K T H
i?2 7` +iBQM Q7 BM+mK#2Mi }`Kb i? i /27 mHi BM 2 +? T2`BQ/ Bb,

$$X_t = m_t \int_0^{Z_t} [1 - q(y_{it}(I))] dG(I) + (1 - z_t) \int_0^{Z_t} [1 - q(y_{it}(I))] dG(I) \quad F_t; \quad U \text{ R } dV$$

r?2`y_{it} /2MQi2b i?2 QTibK H T`Q/m+iBQM +?QB+2 Q7 2Mi2` Mi }`Kb
[0; ^] - My_{it} i?2 QTibK H T`Q/m+iBQM +?QB+2 Q 2 B [M] X m J G # 22M i p 2 }`Kb r

$i^2 \gamma + iBQM \quad Q \gamma \quad b m \quad p B p B M; \quad B M + m K \# 2 M i b \quad B b,$

$$S_t = m_t \int_0^Z q(y_{it}(I)) dG(I) + \int_0^Z q(y_{it}(I)) dG(I) + z \int_0^Z [1 - q(y_{it}(I))] dG(I) \quad F_t: \quad U \quad R \quad 3 \quad V$$

$6 B M \quad H H v - i^2 i Q i \quad H \gamma + iBQM \quad Q \gamma \quad b m \quad p B p B M; \quad 2 M i \quad M i b \quad B b,$

$$E_t = e \int_{I_E} q(y_{it}(I)) dG(I) \quad F_t: \quad U \quad R \quad N \quad V$$

$> 2 M + 2 - ; ; \gamma; \quad i^2 T \quad Q / m + iBQM \quad B b ; \quad B p 2 M \quad \# v,$

$$N_t = m_t \int_0^Z q(y_{it}(I)) y_{it}(I) dG(I) + \int_0^Z q(y_{it}(I)) y_{it}(I) dG(I) + z \int_0^Z [1 - q(y_{it}(I))] y_{it}(I) dG(I) \\ + e \int_0^{I_E} q(y(I)) y(I) dG(I): \quad U \quad k y \quad V$$

$++ Q \quad / B M; \quad H v - i^2 b i^2 \quad / v \quad b i \quad i^2 \quad 2 [m B H B \# \quad B m K \quad B b \quad + ? \quad + i^2 \quad B x 2 / \quad \# v \quad i$

$$p = m \int_0^Z q(y(I)) y(I) dG(I) + \int_0^Z q(y(I)) y(I) dG(I) + z \int_0^Z [1 - q(y(I))] y(I) dG(I) \\ + e \int_0^{I_E} q(y(I)) y(I) dG(I); \quad U \quad k \quad R \quad V \\ m \int_0^{I_E} [1 - q(y(I))] dG(I) + (1 - z) \int_0^Z [1 - q(y(I))] dG(I) = e \int_{I_E} q(y(I)) dG(I); \quad U \quad k \quad k \quad V$$

$r^2 \gamma \quad M m \quad / 2 M Q i^2 \quad i^2 \quad 2 [m B H B \# \quad B m K \quad p \quad H m 2 b \quad 7 Q \quad i^2 \quad + \quad b 2 \quad r^2 \quad 2 \\ r B i^2 > 0 X \quad h^2 \quad } \quad b i + Q M / B i B Q M + Q K 2 b \quad 7 \quad Q K \quad i^2 \quad 7 \quad + i \quad i^2 \quad i B B \quad M m 2 \quad [\quad m B H B \\ i^2 \quad i i^2 \quad ; ; \gamma; \quad i^2 T \quad Q / m + iBQM \quad 2 [m \quad H b \quad / 2 K \quad M / \quad i i^2 B b \quad T \quad B + 2 X \quad h^2 \quad b 2 + \\ B M \quad b i^2 \quad / v \quad m_{t+1} \quad z \quad m_t = m \quad M / \quad / 27 \quad m H i b \quad \gamma^2 \quad 2 t + i H v \quad Q z b 2 i \quad \# v \quad 2 M i \quad v X \\ h Q \quad Q \# i \quad B M + H Q b 2 / \quad @ 7 Q \quad K \quad b Q H m i B Q M b \quad 7 Q \quad i^2 \quad 2 [m B H B \# \quad B m K \quad [m \\ i^2 \quad I \quad B b \quad m M B 7 Q \quad K H v \quad / B \quad [\quad] \quad B \quad \# M \quad i^2 / q(Q) \quad p = 21 \quad y \quad r B i^2 (0; 1] X \quad 6 \quad Q K \quad i^2$

}`Kbö 6P*b- r2 i?2 M ;2i,

$$y = \min \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right); 1 \quad M/q(y) = \begin{matrix} \approx \\ \cdot y \end{matrix} \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) \quad \text{By7} = \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) \\ \text{By} = 1$$

BI72 (f, l]- M/

$$y = \min \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right); 1 \quad M/q(y) = \begin{matrix} \approx \\ \cdot y \end{matrix} \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) \quad \text{By} = \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) \\ \text{By} = 1$$

BI72 [0; f] Q` i?2 }`K Bb TQi2MiB H 2Mi` MiX LQil22i(f, l]- 7Q2 }`K r
T`Q/m+iBQM +QMbi` BMi Bb #BM/BM; B7

$$I_{Iz} := (2 - 1)(p \cdot c) + (1 - z); \quad U \text{ kjV}$$

M/ 7Q` }`KlrB[0; f] B7

$$I_{I_{nz}} := (2 - 1)(p \cdot c) + ; \quad U \text{ k9V}$$

:Bp2M i?2 QTIBK H T`Q/m+iBQM +?QB+2 Q7 TQi2MiB H 2Mi` M
iBQM H 7Q(y)K 7QM/BiBQM#2+QK2b

$$\frac{p \cdot c}{2} \left(1 + \frac{l}{p \cdot c} \right) \quad l \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) \quad \frac{1}{2} \left(1 + \frac{l}{p \cdot c} \right) > K; \quad U \text{ k8V}$$

bbmKBM; MQM#BM/BM; T`Q/m+iBQM +QMbi` BMiX >2M+2- TQi2
B7 M/ QMHv B7 *QM Bb B Q Mbu2/X * Q M/BiBQM UQQib,

$$I_{1;2} = p \cdot c + \frac{2^p}{(p \cdot c) (+ K)}; \quad U \text{ keV}$$

6Q` `2 bQM #H2 T` K2i2` ` M;2b- i?2 }`bV BQ iQ 7v*Q;M2BiBQM M

A XRe

6B;m`2 ,X~~9~~i2 /v ai i2 1[mBHB#`BmK S`B+2b b wQK#B2 *`2/Bi *? M;2b AMi2M
JQ/2H~~X~~?Bb };m`2 b?Qrb ?Qr 2[mBHB#`BmK bi2 /v bi i2 [m MiBiB2~~X~~ AM T? B+2b`2
H bi T M2H- xQK#B2b U`B;?i tBbV `2 i?2/ b?2/ HBM2- MQM@xQK#B2b UH27i t
`~~2~~=1 -c=0:1- =2:1- =0:1- =3:4-K =0:5- =0:45-[^]=0:095- MI/2 [0;0:1]X

> 2 M+2- *QM/~~B~~BiQM~~U~~H i2b B MiQ

$$l < l_E := p \quad c + \quad 2^p \frac{\quad}{(p \quad c) (\quad + K):} \quad U \quad kdV$$

M M HQ;Qmb +QM/BiBQM + M #2 Q#i BM2/ BM + b2 Q7 #BM/BM;

AMbB;? ~~6~~~~B~~X m`2 [~~X~~ 9H Bi iBp2Hv BHHmbi` i2b- mbBM; bBKTH2 MmK2
2[mBHB#`BmK [m MiBiB2b BM i?2 B Mi2MbBp2 K `;BM KQ/2H +? M
`2b+m2/ #v xQK#B2 +`2/Bi BM + b2 Q7 7 BHm`2 BM+`2 b2bX HH `2
KQ/2H +QM iBMm2 iQ ?QH/ BM i?2 B Mi2MbBp2 K `;BM 7` K2rQ`FX

A XRd

6B;m`2 ,X82MbBiBpBiv Q7 T`B+2 rBi? `2bT2+i iQ A AMi2M?bBp2; m`2; BMQrQ/2H
?Qr 2[mBHB#`BmK bi2 /v bi i2 T`B+2z- 2kT Q Bz 2 Q M? bMx 2 5 Q 2M 5 Q 7K 2i2`b `2
e=1 -c=0:1- =2:1- =0:1- =3:4-K =0:5- M/=0:45X h?2 };m`2 b?Qrb i?2 +QHH2+iBQM Q7
7Q`2 ["; 0:1+ "]" -" 2f0;0:03;0:05g X^ Bb bm+? i? i BM 2 +? + b2 8W Q7 }`Kb `2 xQK#B2bX

AMi2`2biBM;Hv- //BM; i?2 BMi2MbBp2 K `;BM 2z2+ib `2p2 Hb
7`QK MQM@xQK#B2 iQ xQK#B2 }`Kb b `2bmHi7`QKi?2 T`2p H2M+
i?2 2tT2+i2/ +Qbib bbQ+B i2/ rBi? +?QQbBM; ?B;?2` QmiTmi [m
MF`mTi+v +QbibV- xQK#B2 +`2/Bi BM+2MiBpBx2b i?2 z2+i2/ }
;;`2; i2 bmtTHv i?`Qm;? i?2 BMi2MbBp2 K `;BMX

i i?2 b K2 iBK2- i?`Qm;? i?2 T`2pBQmbHv /2b+`B#2/ 2ti2MbBp2 K
BM/m+2b #Qi?- xQK#B2b M/ MQM@xQK#B2 }`Kb- iQ T`Q/m+2 H2b
; i2 bmtTHv Ur?B+? Bb + mb2/ #v i?2 bm`pBp H Q7 xQK#B2 }`Kb M
i?2 `2bmHiBM; HQr2` 2[mBHB#`BmK T`B+2X Pp2` HH- xQK#B2 +`2/
#mi rBi? bvKK2i`B+ 2z2+ib QM i?2 BM/BpB/m H T`Q/m+iBQM b+ M
}`KbX Ai? b bi`B+iHv M2; iBp2 2z2+i QM i?2 T`Q/m+iBQM b+ H2 C
HQr2` 2[mBHB#`BmK T`B+2- M/ irQ QTTQbBM; 2z2+ib QM i?2 T`Q
TQbBiBp2 /m2 iQ i?2 BM+2MiBp2 iQ Qp2`T`Q/m+2 M/ M2; iBp2 /m2
6m`i?2`KQ`2- b BM i?2 2ti2MbBp2 K `;BM KQ/2H- i?2 M2; iBp2

6B;m`2 ,Xa2MbBiBpBiv Q7 B/H2 + T +Biv rBi? `2bT2+i iQ A AMh2BbBp2 J ` ;
};m`2 b?Qrb ?Qr 2[mBHB#`BmK bi2 /v bi i2 T` B+ 27Q`2/BTzQ M2/MQb+0T M02bB0/7
T` K2i2`be=`2-c=0:1- =2:1- =0:1- =3:4-K=0:5- M/=0:45X h?2 };m`2 b?Qrb i?2
+QHH2+iBQM Q7I24 r;B#B#]-B2 f00:03;0:05g X^ Bb bm+? i? i BM 2 +? + b2 8W Q7 }`K
xQK#B2bX

M/ xQK#B2 H2M/BM; Bb bi`QM;2` BM BM/mbi` B2B2?m` 2VXBx2/ #
h?2 BMimBiBQM Bb i? i xQK#B2 +`2/Bi HQr2`b }`Kbö 2tT2+i2/ # MF
bmbi BMBM; ?B;? }t2/ +Qbib # b2 M/ i?2 `2bmHiBM; ?B;? QTIBK
AM Qm` KQ/2H- 2 +? }`K + M +?QQb2 iQ T`Q/m+2 i KQbi M Qmi
r?B+? + M #2 BMi2`T`2i2/ b i?2 T`Q/m+iBQM + T +BivX "v +QKT `
+?QB+2 Q7 2 +? }`K rBi? i?2 TQi2MiB H QmiTmi Q7 R- r2 + M K2 bn
BM i?2 2+QMqKv b

$$\text{Idle Capacity} = \frac{m_0^R (1 - y(l))dG(l) + e_{IE}^R (1 - y(l))dG(l)}{m + eE}$$

h?2 HQr2` @H27B,TmM2HKBm i? ii?2 p2` ;2 B/H2 + T +Biv BM+`2 b2
+`2/BiX h?Bb `2bmHi bm;;2bib i? i 7Q` K `F2ib rBi? ?B;? xQK#
T`Q/m+iBQM H2p2H 7Q` MQM@xQK#B2 }`Kb b +QMb2[m2M+2 Q

}`Kb- M/ i?2 `2bmHiBM; HQR2` 2[mBHB#`BmK T`B+2- + M Qmir2B
Qp2`T`Q/m+2 BM MiB+BT iBQM Q7 TQi2MiB HHv #2BM; bmTTQ`i2
h?2 /2+QKTQbBiBQM Q7 i?2 B/H2 + T +Biv`2bmHi BMiQ i?2 +? M
}`Kb BM i?2 HQR2` @`BB?mT2M QM Q Kb i?Bb BMimBiBQM, B/H2 + T
rBi2 7Q` MQM@xQK#B2 }`Kb M/7/Q`x2K#B2B`iKbX
6BM BB,ym`2bXQrb i? i i?2 TQbBiBp2`2H iBQMb?BT #2ir22M B/H
H2M/BM; Bb bi`QM;2` BM BM/mbi`B2bX+? ` +i2`Bx2/ #v ?B;?2`

TT2M/Bt " J `FmT 1biBK iBQM

hQ Q#i BM }`K@H2p2HK `FmTb- r2 7QHHQ.r2i 62Q 2+Q 22/m/2qT`xvMQ@
bFk yR/k r?B+? `2HB2b QM i?2 BMbB;?i i? i i?2 QmiTmi 2H biB+Bi
7 +iQ` Bb QMHv 2[m H iQ Bib 2tT2M/Bim`2 b? `2 BM iQi H `2p2Mr
+Qbi Q7 T`Q/m+iBQMX IM/2` Mv 7Q`K Q7 BKT2`72+i +QKT2iBiBQM
/`Bp2b r2/;2 #2ir22M i?2 BMTmiöb `2p2Mm2 b? `2 M/ Bib QmiTmi
AM T `iB+mH ` - i?Bb TT`Q +? `2HB2b QM bi M/ `/ +Qbi KBMBKE
BMTmi 7 +iQ`b 7`22 Q7 /DmbiK2Mi +QbibX hQ Q#i BM QmiTmi 2H
? b iQ #2 2biBK i2/X K DQ` +? HH2M;2 Bb TQi2MiB H bBKmHi M
#2 /2i2`KBM2/ #v T`Q/m+iBpBiv b?Q+Fb- r?B+? KB;?i #2 +Q` `2H i2
hQ +Q` `2+i i?2 K `FmT 2biBK i2b 7Q` mMQ#b.2` 62Q 2+Q 22/m+MBpB
q `xvMUFyR/k7QHHQrb i?2 +QMi`QH 7mM+iBQM Q` T`Q 2` #2T; Q +?
2i HUXyR8 # b2/PCIM 2v M/ R R N le MG 2pBMbQ?M NwysVX` BMBb
TT`Q +? `2[mB`2b T`Q/m+iBQM 7mM+iBQM rBi? b+ H ` >B+Fb@
+? M;2b BM T`Q/m+iBpBiv /Q MQi z2+i i?2 T`QTQ`iBQM Q7 7 +iQ`
TQQH2/ iQ;2i?2` #v iBK2@BMP `B Mi +QKKQM T`Q/m+iBQM i2+?M
H2p2HX

>2M+2- r2 +QMbB/2` i?2 + b2 r?2} 2KKNB M B K B 22 B Q/2 +QMi2KTQ`
T`Q/m+iBQM +Qbib ;Bp2M i?2 7QHHQrBM; T`Q/m+iBQM 7mM+iBQM

$$Q_{ijt} = Q_{ijt} (\text{ijt} ; V_{ijt} ; K_{ijt}); \quad U " RV$$

r?2`Qijt Bb i?2 QmiTmi [m MiBiv T`Q/mQijt(/) #Vjt i2?2 M Q B i Q;H2 BMTmi
7 +iQijt-i?2 + TBi H biQ+F Ui`2 i2/ b /vM KB+ BMijt m? B M K @Q/m+i
bT2+B}+ >B+Fb@ M2mi` H T`Q/m+iBpBiv F 2`U2X RNDH2H Qb BM 2 i? i
rBi?BM v2 `i?2 p `B #H2 BMTmi + M #2 /Dmbi2/ rBi?Qmi 7`B+iBQ

biQ+F BMpQH p2b 7`B+iBQM bX

b r2 bbmK2 i? i T`Q/m+2`b `2 +Qbi KBMBKBxBM;- r2 ? p2 i?2 7

$$L(V_{ijt}; K_{ijt}; i_{jt}) = P_{ijt}^V V_{ijt} + r_{ijt} K_{ijt} + F_{ijt} \quad i_{jt} (Q(\cdot) \bar{Q}_{ijt}); \quad U''_k V$$

r?2`P^V B b i?2 T`B+2 Q7 i?2 p BB #?22nBbM T m Q b F_{ij} Q B b i? B i} t2- +Qbi-
M/ijt B b i?2 G ;` M;2 KmHiBTHB2`X h?2 }`bi Q`/2` +QM/BiBQM rB
BM T/mB b i?mb ;Bp2M #v,

$$\frac{\partial Q_{ijt}}{\partial V_{ijt}} = P_{ijt}^V \quad i_{jt} \frac{\partial Q}{\partial V_{ijt}} = 0: \quad U''_j V$$

JmHiBTHwBMO #v M/`2 `` M;BM; i2`Kb vB2H/b M 2/tb 2On BTQm 7Q
2H biB+Biv,

$$i_{jt} \frac{\partial Q}{\partial V_{ijt}} V_{ijt} = \frac{1}{i_{jt}} \frac{P_{ijt}^V V_{ijt}}{Q_{ijt}}: \quad U''_9 V$$

b i?2 G ;` M;2 KmHiBTHB2`Hm2 Q7 i?2 Q#D2+iBp2 7mM+iBQM b
+QMbi` BMib- Bi Bb /B`2+i K2 bm`2 Q7 i?2 K `;BM H +QbibX q2
= P= - r?2P2B b i?2 T`B+2 7Q` i?2 QmiTmi ;QQ/- r?B+? /2T2M/b QM
TQR2`X am#biBimiBM; K `;BM H +Qbib 7Q` i?2 K `FmTfT`B+2` iBQ
7Q` i?2 K `FmT,

$$i_{jt} = \frac{v}{i_{jt}} \frac{P_{ijt} Q_{ijt}}{P_{ijt}^V V_{ijt}}: \quad U''_8 V$$

>2M+2- i?2`2 `2 irQ BM;`2/B2Mib M22/2/ iQ 2b,i BKbi2tIT?2MK/ B iFm` 2
b? `2 Q7 i?2 p `B P# Q2 =P^V M_{ijt} mir?B+? Bb `2 /BHv Q#b2`p #H2 BM i?2
QmiTmi 2H biB+Biv Q7 i?2 X `B #H2 BMTmi-

hQ Q#i BM M 2biBK i2 Q7 i?2 QmiTmi 2H biB+Biv Q7 i?2 p `B #
2biBK i2 T `K2i`B+ T`Q/m+iBQM 7mM+iBQM 7Q` 2 +? BM/mbi`v U

6Q` ;Bp2M BmB/Mb Qm-M2 v QMbB/2` i?2 i` MbHQ; T` Q/m+⁹⁸ BQM 7m

$$Q_{ijt} = v_1 V_{ijt} + k_1 k_{ijt} + v_2 V_{ijt}^2 + k_2 k_{ijt}^2 + !_{ijt} + i_{jt} : \quad U" eV$$

r?2`2 HQR2` + b2b /2 M Qi T Hi B; p X B` i?2 HQ; Q7 i?2 `2 HBx2/ }` Köb
 UBx2X- /2~ i2/ v_{ijt} m` iM2 p2 Q; VQ7 i?2 p `B #H2 BMTmi 7 +iQ` UBx2X-
 M/ Qi?2` QT2` iBQM Hk_{ijt} tT2 M HbQ mQ7 bi?2 + TBi H biQ+F UBx2X- i
 !_{ijt} = ln(i_{jt})- M_{ijt} Bb i?2 mM MiB+BT i2/ b?⁹⁷ Q Q F 2 Q p 2 m i T m 7 Q H H Q r # 2
 T` +iB+2 M/ /2~ i2 i?2 b2 p `B #H2 b r Bi? i?2 `2H2p Mi BM/mbi`v@
 q2 7QHHQR i?2 HBi2` im`2 M/ +QMi`QH 7Q` i?2 bBKmHi M2Biv
 T`2b2Mi BM i?2 2biBK" iB-Q M /Q`2 H i X Q U M +QMi`QH 7mM+iBQM TT`Q
 H r Q7 KQiBQM 7Q` T` Q/m+iBpBiv- iQ 2biBK i2 i?2 QmiTmi 2H biB
 h?Bb K2i?Q/ `2HB2b QM bQ@+ HH2/ irQ@bi ;2 TT`Q +?X AM i
 i?2 2tT2+i2/ Q_{ijt} m V T m i /U?2 mM MiB+BT i2/ b?_{ijt} Q V F b 2 i Q n Q m 2 T m b B M ;
 MQM@T ` K2i`B+ T` QD2+iBQM Q7 QmiTmi QM i?2 BMTmib M/ i?2

$$q_{ijt} = i_{jt} (v_{ijt} ; k_{ijt}) + i_{jt} : \quad U" dV$$

⁹⁸h?2 hGS6 Bb +QKKQM i2+?MQHQ;v bT2+B}+ iBQM i? i BM+Hm/2b ?B;?2` Q
 i? M- 2X;X- *Q##@.Qm;H b T`Q/m+iBQM 7mM+iBQM X h?2 /2T `im`2 7`QKi?2 b
 7mM+iBQM Bb BKTQ`i Mi 7Q` Qm` Tm`TQb2X A7 r2 r2`2 iQ `2bi`B+i i?2 QmiTm
 BMTmi mb2 BMi2MbBiv r?2M M HvxBM; ?Qr K `FmT /Bz2`b +`Qbb }`Kb- r2 rQn
 i2+?MQHQ;v iQ p `B iBQM BM K `FmTb- M/ TQi2MiB HHv #B b Qm` `2bmHibX
 MQM@xQK#B2 }`KbVX

⁹⁶QHHQ.2BQ2+F2` U_{ijt} R M X r2 /Q M Qi +QMbB/2` i?2 BMi2`v+ MBQi Q i 2 B M B X i B 2 2 M
 i?2 TQi2MiB H BKT +i Q7 K2 bm`2K2Mi2` `Q` BM + TBi HiQ +QMi KBM i2 i?2 T`
 QmiTmi 2H biB+BivX

^{9d}.2 G Q 2 + F 2 ` M / q U_{xy} R M b F Q rbi? ir?2M `2HvBM; QM `2p2Mm2 / i UBMbi2 / Q7
 QMHv i?2 K `FmT H2p2H Bb TQi2MiB HHv z2+i2/ #mi MQi i?2 2biBK i2 Q7 i?2 +
 }`K@H2p2H +? ` +i2`BbiB+b Q` ?Qr K `FmTb +? M;2 Qp2` iBK2X

$h^2 b^2 + QM / bi ; 2 T^{\backslash} Q p B / 2 b 2 bi BK i 2 b 7 Q^{\backslash} H H T^{\backslash} Q / m + i B Q M 7 m M + i$
 $H r Q 7 K Q i B Q M 7 Q^{\backslash} T^{\backslash} Q / m + i B p B i v ,$

$$\dot{v}_{ijt} = g_t(\dot{v}_{ijt-1}) + \ddot{v}_{ijt} \quad U"3V$$

$q^2 + M + Q K T m i^2 T^{\backslash} Q / m + i B p B i v 7 Q^{\backslash} 2 M = p (H ; m ; Q ; 7 k_2) - m b B M ;$
 $\dot{v}_{ijt} = b (v_1 v_{ijt} + k_1 k_{ijt} + v_2 v_{ijt}^2 + k_2 k_{ijt}^2) X " v M Q M T^{\backslash} K 2 i^{\backslash} B + H H (v)^2 ; 2 b b B$
 $Q M B i d_{ijt-1}(-) - r^2 \cdot 2 + Q p^2 \cdot i^2 B M M Q p i B Q M i Q - T^{\backslash} (Q / m + i B p B i v ; B p 2 M$
 $h^2 B b ; B p 2 b \cdot B b^2 i Q i^2 7 Q H H Q r B M ; K Q K 2 M i + Q M / B i B Q M b - r^2 B + ?$
 $i^2 T^{\backslash} Q / m + i B Q M 7 m M + i B Q M T^{\backslash} K 2 i^2 \cdot b ,$

$$\begin{array}{ccc}
 0 & 0 & 11 \\
 \begin{array}{c} \text{E} \\ \text{@} \end{array} \ddot{v}_{ijt} & \begin{array}{c} V_{ijt} \\ k_{ijt} \\ V_{ijt}^2 \\ \text{@} \\ k_{ijt}^2 \end{array} & \begin{array}{c} 1 \\ \text{A} \\ \text{A} \end{array} = 0; \\
 & & U"NV
 \end{array}$$

$r^2 \cdot 2 r^2 m b^2 bi M / \cdot / : J J i^2 + ? M B [m^2 b i Q Q \# i B M i^2 2 bi BK i 2 b Q 7 i$
 $M / \cdot 2 H v Q M \# H Q + F \# Q Q i b i^{\backslash} T T B M ; 7 Q^{\backslash} i^2 bi M / \cdot / 2^{\backslash} Q^{\backslash} b X h^2 2 b$
 $i^2 7 + i i^? i i^2 + T B i H bi Q + F B b b b m K 2 / i Q \# 2 / 2 + B / 2 / T 2^{\backslash} B Q /$
 $M Q i \# 2 + Q^{\backslash} \cdot 2 H i^2 / r B i^? i^2 B M M Q p i B Q M B M T^{\backslash} Q / m + i B p B i v X q^2 \cdot 2 H$
 $i Q B / 2 M i B 7 v i^2 + Q 2 \{ + B 2 M i b Q M i^2 + m^{\backslash} \cdot 2 M i p \cdot B \# H 2 B M T m i b B M$
 $2 t T 2 + i^2 / i Q^{\backslash} \cdot 2 + i i Q b^? Q + F b i Q T^{\backslash} Q / m + i B p B i v X$
 $h^2 Q m i T m i^2 H bi B + B i B 2 b \cdot 2 + Q K T m i^2 / m b B M ; i^2 2 bi BK i 2 / + C$
 $7 m M + i B Q M ,$

$$\dot{v}_{ijt} = b_{v1} + 2 b_{v2} v_{ijt} ; \quad U"RyV$$

$r^2 B + ? H H Q r b m b i Q + H + m H i^2 X^? 2 K \cdot F m T Q 7 \} \cdot K$
 $6 Q^{\backslash} i^2 K B b H H Q + i B Q M 2 B 2 b 7 B ; K i H v / 2 p B i 2 7^{\backslash} Q K i^2 T^{\backslash} Q + 2 / m$

BM i?Bb b2+iBQMX aT2+B}+ HHv- 7Q` i?2b2 i2bib- r2 BM+Hm/2 i?2
K i2`B H +Qbib BM K /2mbV M/ H #Q` BMTmib b b2T ` i2 7 +iQ`b
2H biB+Biv 2biBK iBQM UBMbi2 / Q7 +QMbB/2`BM; i?2K b bBM;
bmK Q7 *P:a M/ Qi?2` PS1sVX q2 i?2M 2biBK i2 i?2 K `FmTb # b2/
BMTmib- r?B+? HHQrb mb iQ HbQ /2i2`KBM2 i?2 K `;BM H `2p2Mr
iQ i?2 J_SEX

TT2M/Bt * //BiBQM H h #H2b

	*SA	*SA	*SA	*SA
a? `2 wQK#B2b	yXyR	yXyR3	yXy9	yXyR
	UyXyy3V	UyXyydV	UyXyyNV	UyXyydV
P#b2`p iBQMb	j-3jj	j-3jj	j-3jj	j-3jj
_@b[m `2/	yX8R8	yXdRy3898	yXd9N	
*QmMi`v@AM/mbX`v 61	X	X	X	
u2 `61	X			
AM/mbi`v@u2 `61	X		X	
*QmMi`v@u2 `61		X	X	

h #H2 *X RSA :`Qri? qBi?Qmi 1ti`2K2 J `Fib?B bi #H2- r2 `2/Q i?2 M HvbBb 7`C
 " Q7 #H2 #mi /`QT 2ti`2K2 K `F2ibrBi? H2bbi? M @8yW Q`KQ`2 i? M Y8yW MM
 /2T2M/2Mip `B #H2 Bbi?2 MMm H *SA ;`Qri? iQ Xa?BM~wiBQMBm`2K i?2
 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM TX`iB+kbB`+H`F2B}2/ b xQK#B2 B7
 HQR@[m HBiv M/ T B/ /p Mi ;2Qmb BMB2 M iX KiQ b2U22 BHbVX HH`2;`2bbBQM
 7Q`i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ ` /2`Q`b `2 +Hmbi2
 M/ `2TQ`i2/ BM T `2M`y2y2R-X yXyTB < yTRX

	.27X OR	.27X Ok	.27X Oj	.27X O9	.27X O8
	*SA	*SA	*SA	*SA	*SA
a? `2 wQK#B2b	yXyRR	yXyRy	yXyRy	yXykj	yXyRN
	UyXyy9V	UyXyy9V	UyXyy9V	UyXyRyV	Uy
P#b2`p iBQMb	j-33y	j-33y	j-33y	j-33y	j-33y
_@b[m `2/	yXd89	yXd89	yXd89	yXde9	Xde9
*QmMi`v@AM/mbX`v 61	X	X	X	X	
AM/mbi`v@u2 `6X	X	X	X	X	
*QmMi`v@u2 `61X	X	X	X	X	

h #H2 *XkSA :`Qri? Hi2`M iBp2 wQK#B2 *H hb?B)g-iiBQ2M`2b2Mib 2biBK iBQM`
 7`QK aT2+B}+XBRM U2T2M/2Mip `B #H2 Bbi?2 MMm H *SA ;1Q@iA?i22UBM~ iB
 wQK#B2bbm`2bi?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }iKbBM }`K BbB+Hm bB`K2/F2i
 b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B/ /p Mi ;2Qmb BMi2`2bi` i2 +`Bi2`BQM Q7 i?2 xQK#B2 +H bbB}+
 URV + H+mH i2b K2/B M p Hm2b 7Q`H2p2` ;2 M/A*` iBQ ii?2 BM/mbi`v@v2`
 i?2 A*` iBQ +`Bi2`BQM iQ /2}M2 }`K b HQR@[m HBivX *QHmKM UjV +QMbB/2
 /2}M2 }`K b HQR@[m HBivX *QHmKM U9V + H+mH i2bi?2 A*` iBQ mbBM; 1"A
 U8V /Dmbibi?2 /p Mi ;2Qmb BMi2`2bi` i2 +`Bi2`BQM Q7 i?2 xQK#B2 +H bbB}+
 +`Qbb +QmMi`B2bX aT2+B}+ HHv- iQ + H+mH i2 i?2 BM/mbi`v@v2`2bi` i2 7
 i?2 *SA ;`Qri? BMh+QmMi`viQ 7`QK i?2 }`Köb BMi2f`2biQ +2H+mH i2 i?2 /Dmbi2
 #2M+?K `F BMi2`2bi` i2- r2 bm#i` +ii?2 1l@H2iQ`H`CSAi? Q#2M7`QK`F`i2X HH
 `2;`2bbBQMb +QMi`QH 7Q`i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX a
 BM/mbi`v@+QmMi`v H2p2H M/ `2TQ`i2/ BM T `2M`y2y2R-X yXyTB < yTRX T

	HiX OR *SA	HiX Ok *SA	HiX Oj *SA	HiX O9
a? `2 wQK#B2b	yXyRN UyXyydV	yXykj UyXyRyV	yXyk8 UyXyydV	yXyke UyXyyd
P#b2`p iBQMb _@b[m `2/	j-33y yXde9	j-33y yXde9	j-33y yXde9	j-33y yXde9
*QmMi`v@AM/mbi`v@u2 `61X	X	X	X	
AM/mbi`v@u2 `61X	X	X	X	
*QmMi`v@u2 `61X	X	X	X	

h #H2 *Xj*SA :`Qri? Hi2`M iBp2 wQK#B2 a? `2 H2Bbm`2HXT`2b2Mib 2biBK iB
`2bmHib 7`QK aT2V B}h? 2B/QM2UM/2Mip `B #H2 Bbi?2 MMm H*SA;`Qri? `i2 UBM
tX }`K Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ TaB+iBp MQX;2 Qmb B
KQ`2 /2i BHbVX AM *QHmKM URV r2 + H+mH i2 i?2 A* `iBQ mbBM; 1"AhfBM
BM T `iB+mH `tK`F2iMi*QHmKM URV r2 + H+mH i2 i?2 A* `iBQ mbBM; 1"AhfBM
*QHmKM UkV mbBM; 1"Ah. fBMi2`2bi 2tT2Mb2bX AM *QHmKM UjV r2 b
x2`QB7 Bi Bb #2HQR8W M/ kW-`2bT2+iBp2HvX AM *QHmKM UjV M/ U9V 7Q`i?2 bb2i@r2B;?i2/ b?
Q7 HQR@[m HBiv }`Kb M/ BM *QHmKM UjV M/ U9V 7Q`i?2 bb2i@r2B;?i2/ b?
2`Q`b `2 +Hmbi2`2/ i i?2 BM/mbi`v@+QmMi`v H2p2H<MXYRTQy2y8BM T `2Mi
T yXRX

	S M2H , aBM;H2 " MFA	*SA	*SA	*SA
a? `2 wQK#B2b	yXyRN UyXyy3V	yXyky UyXyy3V	yXykj UyXyy3V	yXyk9 UyXyydV
P#b2`p iBQMb _@b[m `2/	k-y3y yX8yR	k-y3yk-y3y yXddyX8k9	k-y3y yXdN3	
S M2H ", JmHiBTH2" SMFb	*SA	*SA	*SA	
a? `2 wQK#B2b	yXyye UyXyydV	yXyyN UyXyydV	yXyye UyXyydV	yXyyN UyXyydV
P#b2`p iBQMb _@b[m `2/	k-y3y yX8yy	k-y3yk-y3y yXddyX8kj	k-y3y yXdNd	
*QmMi`v@AM/mbi`v@u2 `61	X	X	X	
u2 `61	X			
AM/mbi`v@u2 `61	X		X	
*QmMi`v@u2 `61		X	X	

h #H2 *X9SA :`Qri? aBM;H2 M/ JmHiBTH2 " MF_2PHiBiQ#Hb2 BT2b2 Mib 2biBK iB
`2bmHib 7`QK aT2V B}h? 2B/QM2UM/2Mip `B #H2 Bbi?2 MMm H*SA;`Qri? `i2 UB
iQXa? `2 wQK#B2bm`2b i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb iBM T `iB+m
} `K Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ TaB+iBp MQX;2 Qmb BMi2`
/2i BHbVX 6Q`i?Bb M HvbBb- r2 //BiBQM HHv `2[mB`2 7Q`i?2 xQK#B2 +H b
bBM;H2 US M2H V Q` KmHiBTH2 US M2H "V # MF H2M/BM; `2H iBQMb?BTb- `2
i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ ` / 2`Q`b `2 +Hmbi2`2
M/ `2TQ`i2/ BM T `2Mk?y2y2R-X yXyTB < yTRX

S M2H , a2+QM/ ai ;2	*SA	*SA	*SA
Share Zombies	yXRy3 UyXy8kV	yXy39 UyXy98V	yXRyd UyXy8RV
P#b2`p iBQMb	k-y3y	R-3jN	k-y3y

S M2H ", 6B`bi ai ;2 a? `2 wQK#B2b a? `2 wQK#B2b a? `2 wQK#B2b			
hB2`@R kylySG UQri?V	yX88R UyXRe3V	yXdkd UyXkReV	yX888 UyXRe3V
6@h2bi	keXe	jkX9	kdXy

P#b2`p iBQMb	k-y3y	R-3jN	k-y3y
_@b[m `2/	yXdye	yXdRy	yXdye
a KTH2	K /2mb	K /2mb	K /2mb

	Y .2 Ha+ M	PMHv	Y .2 Ha+ M Ai Hv
*QmMi`v@AM/mbi`v 61	X	X	X
AM/mbi`v@u2 `61	X	X	X
*QmMi`v@u2 `61	X	X	X

h #H2 *X&Mbi`mK2Mi Ho`B #H2 1biBK iBQM rBh?BSG #H2IT?Xb2Mibi?2 2biBK i
`2bmHib 7`QK i?2 Ao bT2+B}+ iBQM- r?2`2 i?2 }`bi bi ;2 `2bmHib `2 b?QrM BM
`2bmHib BM S M2H X h?2 /2T2M/2Mi p `B #H2 BM i?2 b2+QM/ bi ;2 Bb i?2 MM
a? `2 wQK#B2bm`2bi?2 bb2i@r2B;?i2/ b? `2 Q7XkQ2#B2k2yDhmi2bi?2 hB2`@R
`iBQ Q7 i?2 # MFb HBMF2/ iQ i?2 }`Kb BM i?2 TSGB:qHK? k mF2b B12k WYWH H
;`Qri? `i2 BMMQM@T2`7Q`KBM;HQ MbiQiQi HHQ Mb ii?2 +QmMi`v@H2p2H C
" MF`2H iBQMb?BTb `2 /2i2`KBM2/ mbBM; K /2mb M/ .2 Ha+ M BM *QHmKM U
UkV- b r2HH b K /2mb THmb .2 Ha+ M 7Q` Ai HB M }`Kb BM *QHmKM UjVX a
BM/mbi`v@+QmMi`v H2p2H `2 `2TQ<i?XBM-tyXyMi-2yK2RXX T

+iBp2	a H2b	A/H2	J i2`B H G #Q`
6B`Kb .27 mHi	1Mi`v :`Qri? J*`Fm Biv *Qbi		*Qbi
J2 M yXyRk	yXyNk	yXydN	yXyqRyR RdXyeNRj yXykk
a. yXy8j	yXy9d	yXyje	yXR33yXy8K9R yXkRd yXyjk

h #H2 *X&mKK `v ai iBbiB+b 1[mBHB#`BmK SB0/iB#HBQTM0X2Mib bmKK `v bi iB
7Q` i?2 /2T2M/2Mi pa 2B-i#Q10BMRI BQM 8Xj

	.27 mHi	.27 mHi	.27 mHi	.27 mHi
a? `2 wQK#B2b yXyRj yXyR8 yXyRe yXyR3				
	UyXyy3V	UyXyydV	UyXyy3V	UyXyydV
P#b2`p iBQMb k-dy3	k-dy3	k-dy3	k-dy3	k-dy3
_@b[m `2/	yX39j	yX3ek	yX33e	yXNye
*QmMi`v@AM/mbi`v 61	X	X	X	
u2 `61	X			
AM/mbi`v@u2 `61	X		X	
*QmMi`v@u2 `61		X	X	

h #H2 *X6B`K .27 mHib 1pB/2M+2 # b2/ QM KH/2Bbi.#H2 T`2b2Mib 2biBK iBQM `2bmHib 7`QK aT2V8}h?iBQM2M/2Mi p`B #H2 Bb i?2 b? `2 Q7 q2K7/Q7H2Hib i
 +? `v 2iUHYXNiQ B/2MiB7v }`K/27 mHib # b2/ QMi?2 H2; H b? i`abwQKB#2b2 BM
 K2 bm`2b i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Ktb BM T`KiB+bm+H`bKBF2/i i
 b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B/ /p M2+iBQM7QBMiQ`2b2i B2bbUx22H
 `2;`2bbBQMb +QMi`QH 7Q` i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX a
 BM/mbi`v@+QmMi`v H2p2H M/ `2TQ`< yXy8< yXRX T

	J `FmT	1"Ahfa H2b	*Qbi	:`Qri?	:`Qri?	AMp2biK2Mi
LQM@wQK#B2	yXy9y	yXye8yXyRe	yXyjd	yXyk3	yXyye	
	UyXyRyV	UyXyyeV	UyXyy9V	UyXyyeV	UyXyykV	
LQM@wQK#B2	yXyRd	yXykk	yXyyk	yXyjdYyy3	yXyyR	
a? `2 GQR@Zm HBiv	UyXyj3V	UyXyjjV	UyXyyNV	UyXyk9V	UyXy	
P#b2`p iBQMb	9-kRR-ejj	8-NRy-Re8	9-e8j-9Ry	8-Nkk-N8N	j-N8d-de8	
_@b[m `2/	yX8e8	yXR8d	yX8Rd	yXyjj	yXyk3jk	
AM/mbi`v@*QmMi`v@u2 `61	X	X	X	X	X	
6B`K@G2p2H *QMi`QHb	X	X	X	X	X	

h #H2 *X3B`K@G2p2H 1pB/2M+2 _Q#BbbiM#2b2X`2b2Mib 2biBK iBQM `2bmHib
 B}+ iBQX Uh?2 /2T2M/2Mi p`B #H2b `2 }`Köb K`FmT- 1"Ahfa H2b- K i2`B
 +Qbifim`MQp2`V- b H2b ;`Qri?- 2KTHQvK2Mi L`QMi@wQK#B2BM/2B+iiQ`MpiXB #H
 2[m HiQ QM2 B7 }`K Bb +H bbB}2/tKaM QM @QQ@#B2 HBMi`v2b i?2 bb2i r2B;?i2/
 b? `2 Q7 HQR@[m HBiv }`Kb BM T`iB+bm+H`bKBF2/i i
 HMUiQi H bb2ibV- M/ i?2 A*` iBQX }`K Bb +H bbB}2/ b HQR@[m HBiv B7
 M/ M #Qp2 K2/B M H2p2` ;2X ai M/ `2`Q`b `2 +Hmbi2`2/ i i?2 BM/mbi`v@
 T `2Mi?2b2kXyXyRT< yXy8< yXRX

	*SA	*SA	*SA	A/H2 * T +Biv	A/H2 * T +Biv	A/H2 * T +Biv
a? `2 wQK#B2b	yXykN	yXykj	yXyky	dX33N	dXedN	8Xd3e
	UyXyy3V	UyXyRyV	UyXyRkV	UkX9kRV	UkXeyc	
a? `2 wQK#B2b	yXyRj	yXyR9	yXyR9	9X3yy	8Xkkj	8Xkj8
	UyXyydV	UyXyydV	UyXyydV	UkX8edV	UkXeyN	
a? `2 wQK#B2b		yXyyN	yXyyR	RX88R	9XRRy	
		UyXyydV	UyXyyNV	UkX8NdV	UjXN99V	
a? `2 wQK#B2b			yXyR9		eXy9j	
			UyXyy3V		UjX8eeV	
P#b2`p iBQMb	j-9N9	k-3d8	k-jdy	k-RNe	R-NN8	R-ed3
_@b[m `2/	yXddN	yXdNd	yXd3R	yX3jj	yX3j3	yX38y
*QmMi`v@AM/mbXv 61	X	X	X	X	X	
AM/mbi`v@u2 `6X		X	X	X	X	
*QmMi`v@u2 `61X		X	X	X	X	

h #H2 *XNSA :`Qri? .vM KB+h?Bb i #H2 T`2b2Mib 2biBK iBQM `2bimHib 7`QK a
#mi //BiBQM HHaBM2-mrQ(BM)21Q HmK Mb Ra M/ 2W-QK#B2ba? `2 wQK#B2b
U*QHmK Mb k M/?8`2 Q`QK#B2b `2 wQK#B2M a? `2 wQK#B2b U*QHmK Mb j M/ eVX
h?2 /2T2M/2Mi p `B #H2 Bb i?2 MMm H *SA ;`Qri?iQ XaUBM-wQBAM Yb`QK
wQK#B2b? `2 wQK#B2M a? `2 wQK#B2b bm`2 i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B
T `iB+mH `Kt`F2it i2-t 3- M/ 4- `2bT2+iBp2HvX }`K Bb +H bbB}2/ b xQK
HQR@[m HBiv M/ T B/ /p Mi ;2Qm b+BMB2MIX KiQ b2U22BHbVX HH `2;`2bbBQM
7Q`i?2 bb2i@r2B;?i2/ b? `2 Q7 HQR@[m HBiv }`KbX ai M/ `/2`Q`b `2 +Hmbi2
M/ `2TQ`i2/ BM T `2M`?2b2R-X yXyTB < yKRX

S M2H	L2i AMp2biK2Mi	1KTHQvK2Mi :`Qri?
LQM@wQK#B2	yXyR9	yXykd
	UyXyyRV	UyXyykV
LQM@wQK#B2	yXy9j	yXyjk
a? `2 wQK#B2b	UyXyRRV	UyXyRRV
P#b2`p iBQMb	j-yk3-3R9	j-N8d-de8
_@b[m `2/	yXyjN	yXyk3

S M2H "	L2i AMp2biK2Mi	1KTHQvK2Mi :`Qri?
S`Q/m+iBpBiv	yXyj8	yXyy3
	UyXyyRV	UyXyyyV
S`Q/m+iBpBiv	yXyR3	yXyy3
a? `2 wQK#B2b	UyXyy3V	UyXyyjV
P#b2`p iBQMb	j-yk3-3R9	j-N8d-de8
_@b[m `2/	yXy98	yXy9y
AM/mbi`v@*QmMi`v@x2 `61		X
6B`K@G2p2H *QMi`QHx		X

h #H2 *XRyKTHQvK2Mi :`Qri? M/ L2i AMp2biK2Mi 6B`K@G2p2H i#B/2M+2X
T`2b2Mib 2biBK iBQM`2bmHiBvXChK 2T2F BM+2iBiQm`B #H2b `2 }`Köb 2KTHQvI
Q`M2i BMp2biK2Mi U;`Qri? BM }t2/ bb2ibQ M2@ wQK#B2b/BB-pQ`Xp `B #H2 2[m
QM2 B7 }`K Bb +H bbB}2/ b M QSM @xQK#B2B BM b22i T`Q/m+iBpBiv Ub H2bf}t2
BM *QHmKM URV M/ H #Q` T`Q/m+iBpBiv Ub H2bf2iKTHQvK2Mi`Bm`QHmKM U
i?2 bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb BM 1X 6iB`K@H2K2HF2QMi`QHb BM+
rQ`i?- H2p2` ;2- HMUiQi H bb2ibV- M/ i?2 A* `iBQX }`K Bb +H bbB}2/ b x
T B/ /p Mi ;2Qmb BMi2`22i+iBiQm`QK#B2`2 /2i BHbVX ai M/ ` / 2`Q`b `2 +Hmb
BM/mbi`v@+QmMi`v H2p2H M/ `2TQ`iXpM-4y`2yBi`2yK2RbX T

S M2H	o Hm2 //2/	o Hm2 //2/	o Hm2 //2/	o Hm2 //2/
a? `2 wQK#B2	yXRkN	yXR8y	yXyN9	yXRRk
	UyXy8NV	UyXy89V	UyXy88V	UyXy8RV
P#b2`p iBQMb	9-yky	9-yky	9-yky	9-yky
_@b[m `2/	yXNN9	yXNNe	yXNN8	yXNNd

S M2H "	S`Q/m+iBpBiv	S`Q/m+iBpBiv	S`Q/m+iBpBiv	S`Q/m+iBpBiv
a? `2 wQK#B2b	yXjyd	yXjkd	yXkNj	yXjRy
	UyXyNNV	UyXRR9V	UyXRyyV	UyXRReV
P#b2`p iBQMb	9-kyN	9-kyN	9-kyN	9-kyN
_@b[m `2/	yXNy8	yXNRe	yXNyN	yXNky
*QmMi`v@AM/mbiXv 61		X	X	X
u2 `61	X			
AM/mbi`v@u2 `61		X		X
*QmMi`v@u2 `61			X	X

h #H2 *XRcRHm2 //2/ M/ S`Q/m+iBpBivX#H2 T`2b2Mib 2biBK iBQM`2bmHib 7`Q
 UVX h?2 /2T2M/2Mi p HB#H2bm2U/S2M2H V M/ bb2i@r2B;?i2/Q;Uc/rH2iBpBiv
 kfj HQ;U2KTHQvK2MiV Rfj -HS;M2H2VX22iQK#B2bm`2bi?2 bb2i@r2B;?i2/ b? `
 xQK#B2 }`Kb BM T`iB+mH1`XK `}Xi Bb +H bbB}2/ b xQK#B2 B7 Bi Bb HQR@[m
 /p Mi ;2Qmb BMi2`2b2+ii2Q7Q2KQ`2/2i BHbVX HH`2;`2bbBQMb +QMi`QH 7Q
 b? `2 Q7 HQR@[m HBiv }`KbX ai M/ ` / 2`Q`b `2 +Hmbi2`2/ i i?2 BM/mbi`v@
 T`2Mi?2b2kXyXyRT<yXy8<yKRX

		wQK#B2	p2` ;2	*QmMi`v	AM/mbi`v	a? `2` Qri?		wQK#B2	p2` ;2	*SA :`Qri?
h	y	y	yXyyeR6	y	yXRdk	yXyR9e		y	yXRdk	yXyR9e
h	R	yXy8dd	yXyRR86	R	yXR3R	yXyRkd		R	yXR3R	yXyRkd
h	k	yXyyje3	yXyy38y6	k	yXykkj	yXyyRek		k	yXykkj	yXyyRek
h	j	y	yXyR9R6	j	yXy9eN	yXyy38k		j	yXy9eN	yXyy38k
h	9	yXyyRNe	yXyyd3R6	9	yXR9j	yXyRy8		9	yXR9j	yXyRy8
h	8	yXykjN	yXyy8366	8	yXyRR9	yXyy9y9		8	yXyRR9	yXyy9y9
h	e	yXyRRe	yXykd96	e	yXR8y	yXyyR39		e	yXR8y	yXyyR39
h	d	y	yXyRkN6	d	yXR8R	yXyRdd		d	yXR8R	yXyRdd
h	3	yXyRke	yXyRNk6	3	yXy8dd	yXyRkr		3	yXy8dd	yXyRkr
h	N	y	yXyk3y6	N	yXRyR	yXyy3N3		N	yXRyR	yXyy3N3
"1	yR	yXkkN	yXyky9A	yR	yXR38	yXyyeRR		yR	yXR38	yXyyeRR
"1	k	yXkRN	yXyyR4	k	yXy33R	yXyyN3j		k	yXy33R	yXyyN3j
"1	j	yXyde	yXyydeA	j	yXyjk9	yXyy9dy		j	yXyjk9	yXyy9dy
"1	9	yXyRye	yXyRReA	9	yXykN8	yXyRke		9	yXykN8	yXyRke
"1	8	yXykkN	yXyy9e3A	8	yXy8d8	yXyRkk		8	yXy8d8	yXyRkk
"1	e	yXyek3	yXyyNejA	e	yXyeNj	yXyRjR		e	yXyeNj	yXyRjR
"1	d	yXykdd	yXyRkdA	d	yXRdy	yXyy9j9		d	yXRdy	yXyy9j9
"1	3	yXyRk9	yXyReNA	3	yXyeed	yXyR9R		3	yXyeed	yXyR9R
"1	N	yXyR89	yXyRd3A	N	yXkk3	yXyRje		N	yXkk3	yXyRje
.1	yR	yXy9e3	yXyReNA	yR	yXy3vN	yXyy39e		yR	yXy3vN	yXyy39e
.1	k	yXRk8	yXyRydSG	k	yXydR8	yXyyNdj		k	yXydR8	yXyyNdj
.1	j	yXykkd	yXyRjkSG	j	yXyyk93	yXyy9yj		j	yXyyk93	yXyy9yj
.1	9	yXyyje3	yXyy83kSG	9	yXyde9	yXyyRyj		9	yXyde9	yXyyRyj
.1	8	yXyyd3k	yXyRRkSG	8	yXRR8	yXyyy39k		8	yXRR8	yXyyy39k
.1	e	yXyy88y	yXyRRjSG	e	yXRjN	yXyyy339		e	yXRjN	yXyyy339
.1	d	yXyy3j3	yXyRkySG	d	yXykRN	yXyy9kj		d	yXykRN	yXyy9kj
.1	3	yXyyRNe	yXyy8d9SG	3	yXRy9	yXyRke		3	yXRy9	yXyRke
.1	N	yXyRkk	yXyRkNSG	N	yXydee	yXyRRj		N	yXydee	yXyRRj
.E	yR	yXyRkk	yXyRyNSG	yR	yXyjeR	yXykdd8		yR	yXyjeR	yXykdd8
.E	k	yXyNeN	yXyRy3SG	k	yXyR83	yXyykjy		k	yXyR83	yXyykjy
.E	j	yXyRy3	yXyRd9	j	yXy9d9	yXyRj		j	yXy9d9	yXyRj
.E	9	yXyyy9k8	yXyy9djSh	9	yXRej	yXyyRey		9	yXRej	yXyyRey
.E	8	yXyRje	yXyy9jSh	8	yXy9Re	yXyyejN		8	yXy9Re	yXyyejN
.E	d	yXyyyjd9	yXyyk3B	d	yXyRj	yXyyRej		d	yXyRj	yXyyRej
.E	3	yXyy9d9	yXyy9jSh	3	yXy3R	yXyye8j		3	yXy3R	yXyye8j
.E	N	yXyk8e	yXyNeSh	N	yXRjy	yXyyed8		N	yXRjy	yXyyed8
E	yR	yXyykke	yXyyd9Sh	yR	yXyidd	yXyRy8		yR	yXyidd	yXyRy8
E	k	yXy93N	yXyy8dRSh	k	yXy9j9	yXyy3jy		k	yXy9j9	yXyy3jy
E	j	yXReR	yXyRj8Sh	j	yXRd8	yXyy8y9		j	yXRd8	yXyy8y9
E	9	yXyRyR	yXyRy9Sh	9	yXyNed	yXyyjkj		9	yXyNed	yXyyjkj
E	8	yXykj3	yXyyj8ya1	8	yXyRke	yXyy9y8		8	yXyRke	yXyy9y8
E	d	yXyk8j	yXyy3R2a1	d	yXyR88	yXyRRR		d	yXyR88	yXyRRR
E	3	yXydRN	yXyyN2a3	3	yXyRky	yXyyjRd		3	yXyRky	yXyyjRd
E	N	yXye3e	yXyyNkM1	N	yXyRR9	yXyyR9R		N	yXyRR9	yXyyR9R
1a	yR	yXyR3e	yXyyRN1	yR	yXyje9	yXyRR9		yR	yXyje9	yXyRR9
1a	k	yXyek9	yXyy8kp1	k	yXyR8j	yXyyyedN		k	yXyR8j	yXyyyedN
1a	j	yXyydR3	yXyReda1	j	yXyR3N	yXykkk		j	yXyR3N	yXykkk
1a	9	yXy89j	yXyRkRa1	9	yXyRR9	yXyy8Ry		9	yXyRR9	yXyy8Ry
1a	8	yXyRj9	yXyyjN1	8	yXyR3e	yXyRNk		8	yXyR3e	yXyRNk
1a	e	yXyRjN	yXyRy9a1	e	yXyyeR9	yXyyNNy		e	yXyyeR9	yXyyNNy
1a	d	yXy8j3	yXyyjkjaE	d	yXy983	yXyy8kR		d	yXy983	yXyy8kR
6A	yR	RX932@y	yXyRkyaE	yR	yXyeNj	yXyRy9		yR	yXyeNj	yXyRy9
6A	k	yXyk3e	yXyykkN	k	yXRkk	yXyykeR		k	yXRkk	yXyykeR
6A	j	yXyyj3N	yXyy9ejaE	j	yXRRj	yXyy838		j	yXRRj	yXyy838
6A	9	yXyyRNk	yXyydN3aE	9	yXy8Rk	yXyyeRk		9	yXy8Rk	yXyyeRk
6A	8	yXyR8e	yXyRyj1aE	8	yXRyR	yXyR8N		8	yXRyR	yXyR8N
6A	e	yXyRRe	yXyyjN1aE	e	yXyRj	yXyy3jy		e	yXyRj	yXyy3jy
6A	d	yXyyede	yXyyj88aE	d	yXy983	yXyy99k		d	yXy983	yXyy99k
6A	3	yXyyj8d	yXykydaE	3	yXyy8Nj	yXykr9		3	yXyy8Nj	yXykr9
6A	N	yXyk8k	yXyyedN1aE	N	yXyRdj	yXyR98		N	yXyRdj	yXyR98

h #H2 *XRkmKK `v ai iBbiB+b wQK#B2 a? `2 M/`1S?Bb`Q#iH2`T`2b2Mib bmKK `bi iBbiB+b ii?2 BM/mbi`v @+QmMi`w QK#B2Ra@/B2 B10/12M2H X i?2 ;`Qri? BM i?2 b? `2 Q7 xQK#B2 }`Kb 7`QK kyRkiQ kyR8 BM ;Bp2M;2M Smbi`@ @7QMM1`bT B`X i?2 p2` ;2 Mmm H BM~ iBQM U*SA :`Qri?V BM ;Bp2M BM/mbi`v @+QmMi`v T B

TT2M/Bt . //BiBQM H 6B;m`2b

6B;m`2 „XkHi2`M iBp2 wQK#B2 *H bHb)BiBQM?Qrb i?2 2pQHmiBQM Q7 i?2 xC
7Q` Hi2`M iBp2 xQK#B2 /2}MBiBQMbX h?2 #Hm2 bQHB/ HBM2`2THB+ i2b Qm`
QM H27i v@ tBbVX Hi .27 R U`2/ / b?2/ HBM2c H27i v@ tBbV + H+mH i2b K2/
i i?2 BM/mbi`v@v2 `@H2p2H BMbi2 / Q7 BM/mbi`v@+QmMi`v@v2 `H2p2HX H
+QMbB/2`b bQH2Hv i?2 A*` iBQ +`Bi2`BQM iQ /2}M2 }`K b HQR@[m HBivX
v@ tBbV +QMbB/2`b QMHv i?2 H2p2` ;2 +`Bi2`BQM iQ /2}M2 }`K b HQR@[m HB

6B;m`2 „XkHi2`M iBp2 wQK#B2 a? `2 qBBBiB M X2 b?Qrb i?2 2pQHmiBQM Q7 i?
b? `2 7Q` Hi2`M iBp2 xQK#B2 /2}MBiBQMbX h?2 #Hm2 bQHB/ HBM2`2THB+ i2
bb2i@r2B;?i2/ ;`2; iBQM M/A*` iBQ # b2/ QM 1"AhVX h?2 `2/ HQM; / b?2/ HB
bb2i@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb mbBM; i?2 A*` iBQ # b2/ QM 1"Ah. fBMi2`
/ b?2/ HBM2 b?Qrb i?2 im`MQp2`@r2B;?i2/ b? `2 Q7 xQK#B2 }`Kb mbBM; i?2 1"
/Qii2/ HBM2 b?Qrb i?2 2pQHmiBQM Q7 i?2 im`MQp2`@r2B;?i2/ b? `2 Q7 xQK#B2
` iBQX

6B;m`2 „Xj pQHmiBQM Q7 a H2b :`Qri? M/ 1"Ah.?Bjb`);BM X b?Qrb i?2 2pQHmiBQ
b H2b ;`Qri? M/ T`Q}i #BHBiv 7Q` xQK#B2 }`KbX u2 `y +Q`2bTQM/b iQ i?2 }`K
+H bbB}2/ b xQK#B2X h?2 xQK#B2 bi imb + M +? M;2 7i2`v2 `y- BX2X- i?2 xQ
v2 `b R iQ 9X h?2 }`K T2`7Q`K M+2 Q7 xQK#B2b Bb +QKT `2/iQ K i+?2/ b KTH
b?Qrb i?2 2pQHmiBQM Q7 i?2 bb2i@r2B;?i2/ b H2b ;`Qri?X S M2H " b?Qrb i?2
1"Ah. K `;BM UBX2X- 1"Ah. fb H2b `iBQVX

6B;m`2 „Xa KTH2 pbX P{+B H AM?Bib}QM X2 b?Qrb 2pQHmiBQM Q7 i?2 Q{+B H BM
b KTH2 +QmMi`B2b 7`QK 1m`Qbi i U#Hm2 b?Q`i / b?2/ HBM2V- i?2 BM~ iBQM ;
/ i b2i rBi? U`2/ bQHB/ HBM2V M/ rBi?Qmi U;`22M HQM; / b?2/ HBM2V /`QTTB
@8yW Q`KQ`2 i? M Y8yW MMm H T`B+2 ;`Qri?X

6B;m`2 „X8SA :`Qri? 1t+HmbBQM Q7 AM/BpB/m H *QmMi`Bh2BbM/,m`M/mbi`B
T`2b2Mib 2biBK iBQM`2bmHibVXQK+aT# +Bb}QirBQM2U+ Q2{+BwMKA/2Bib
N8W +QM}/2M+2 BMi2`p H 7Q`i?2`2;`2bbBQM Q7t*SAi,Q QrM??`22wCBM#-B2BQM V
/`QTTBM; 2Bi?2`QM2 +QmMi`v UH27ibB/2V Q`QM2 BM/mbi`v U`B;?i bB/2V i i
b?`2 Q7 HQR@[m HBiv}`Kb- b r2HH b BM/mbi`v @+QmMi`v- BM/mbi`v @v2`-
wQK# 2bbm`2bi?2 bb2i@r2B;?i2/ b?`2 Q7 xQK#B2 }iKbXB M}`K B bB+Hm blbBk2/F2i
b xQK#B2 B7 Bi Bb HQR@[m HBiv M/ T B/ /p a2+j BQmQ BkQ222/bii`Bi2 b Ux22

A Xje

6B;m`2 „X*SA :`Qri? *QmMi2`7 +im H .2T`2bb2/ J `F2ib?BM;im`BMiXQrb i?2
+im H *SA ;`Qri? BM Qm` b KTH2 M/ irQ +QmMi2`7 +im H *SA ;`Qri? `i2bX 6Q
i? i xQK#B2b + M QMHv 2tBbi BM /2T`2bb2/ K `F2ib UK `F2ib rBi? #2HQR K2/B
//2/ #2ir22M kyyd M/ kyRRVX h?2 +QmMi2`7 +im H BM~ iBQM `i2b `2 K2 bn
rQmH/ ? p2 T`2p BH2/ 7`QK kyRk iQ kyRe B7 r2 FHv@+ TBi HBx2/ # MFb 2Mi2`2
hB2`@R` iBQX aT2+B}+ HHv- r2 +QMbB/2` i?2 + b2b r?2`2 # MFb rBi? hB2`@
`2bT2+iBp2Hv- `2`2+ TBi HBx2/ iQ i?2`2bT2+iBp2 i?`2b?QH/ p Hm2X 6Q` 2 +
i?2 p2` ;2 bT`2 / #2ir22M i?2 +im H *SA ;`Qri? M/ i?2 +QmMi2`7 +im H *SA ;`

6B;m`2 „X*dSA :`Qri? *QmMi2`7 +im H .2T`2bb2/ J `F2ib M/ G2MB2Mi " MF amT
*QMbi` BM?Bb };m`2 b?Qrb i?2 +im H *SA ;`Qri? BM Qm` b KTH2 M/ irQ +QmM
` i2bX 6Q` i?Bb 2t2`+Bb2- r2 biBTmH i2 i? i xQK#B2b + M QMHv 2tBbi BM /2T
#2Hqr K2/B M T2`+2Mi ;2 +? M;2 BM p Hm2 //2/ #2ir22M kyyd M/ kyRRV M/r?
bmT2`pBbBQM UKambTn2`p/BrBQ?V X Q ?2` bQmMi2`7 +im HBM~ iBQM` i2b `2 K2 b
;`Qri? i? i rQmH/ ? p2 T`2p BH2/ 7`QK kyRk iQ kyRe B7 r2 FHv@+ TBi HBx2/ #
rBi? ?B;?2`hB2`@R` iBQX aT2+B}+ HHv- r2 +QMbB/2`i?2 + b2b r?2`2 # MFb
RyW BM kyyN-`2bT2+iBp2Hv- `2`2+ TBi HBx2/ iQ i?2`2bT2+iBp2 i?`2b?QH/ p
H #2H BM+Hm/2b i?2 p2`;2 bT`2 / #2ir22M i?2 +im H *SA ;`Qri? M/ i?2 +QmM

TT2M/Bt 1 Ao .B ;MQbiB+ h2bib

hQ bb2bb i?2 TH mbB#BHBiv Q7 i?2 B/2MiB}+ iBQM bbmKTiBQM
7QHHQr i?2 /B ;MQbiB+ iQbi/b QBi?@SMBM BMyX i HX

AM }`bi bi2T- r2 T2`7Q`K _Qi2K#2`; /2+QKTQbBiBQM Q7 Qm`
Mv T `iB+mH `BMbi`mK2Mi Bb KBbbT2+B}2/- i?2 _Qi2K#2`; r2B;
Qp2` HH 2biBK iQ` Bb iQ i?2 KBbbT2+B}+ iBQM Q7 i?2 BM/BpB/m

S M2H hQ#H2 bXR Bib i?2 BMbi`mK2Mib B MiQ i?Qb2 rBi? TQbBiB
bT2+B}+ _Qi2K#2`; r2B;?Xbh?2M Qb2/Hib b?Qr i? i i?2 b? `2 Q7 M2
TQbBiBp2 r2B254idM0:246- `2bT2+iBp2Hv- r?BH2 i?2 bmK Q7 i?2 M2; i
r2B;?ib 0:526 @M1:516- `2bT2+iBp2HvX h?2b2 p Hm2b `2 i?mb BM bB
+ MQMB+ H " `iBF b2iiBM;QHb2X Bi#@SMBM BMyX i HX

aQK2 M2; jBp2b2 i?2 TQbbB#BHBiv Q7 U#mi /Q MQi BkTHvV MQ
BM r?B+? + b2 i?2 Qp2` HH " `iBF 2biBK i2 rQmH/ MQi ? p2 G h1
r2B;?i2/ p2` ;2 Q7 i`2 iK2Mi 2z2+ibX ?B;BM+ p2` B2iBQM BMF2B
i? i i?2 M2; iBp2 r2B;?jBMQM i22M2; iBp2 r2B;?ubMQM2i?2 i i?2b2
r2B;?ib + MMQi #2 /B`2+iHv 2biBK i2/VX L im` HHv- BM Qm` b2iiE
i?2b` +`Qbb # MFbX " MFb /Bz2` BM i?2B` 2tTQbm`2b iQ /Bz2`2Mi
Qm` PGa M HvbBb- i?2 2z2+i Q7 xQK#B2 +`2/Bi QM *SA ;`Qri? Bb ?
U2X;X- /Bz2`2Mi 7Q` i` / #H2 pbX MQMi` / #H2 M/ ?B;? pbX HQR }
+ MMQi`mH2 Qmi i? i i?2`2 `2 M2;hjBp2 r2B;?ib QM i?2

S M2H " `2TQ`ib +Q`2H iBQM b #2/i r22M i?22r;2iE;PiQ MQ` Qri? U
:`Qri?V- i?2 Dmbi@B/2MiB}2/ +Q`2V+ B2M}2bi@Bki i;2b6U@ bi iBbiB+ Q7
b? `E,V- M/ i?2 p `B iBQM BM i?2 # MF b? `Share_hjB`VQbX k?2F2iM 2Hb`
b?Qrb i? i i?2 ;;`2; i2 HQ M ;`Qri?` i2b `2 MQi K i2`B HHv +Q`2H
r2B;?ib- r?B+? BKTHB2b i? i i?2 HQ M ;`Qri?` i2b T`QpB/2 M BK T
BM; r? i p `B iBQM BM i?2 / i /`Bp2b 2biBK i2bX AM +QMi` bi- i?

S M2H , L2; iBp2 M/ SQbBiBp2 q2B;?ib	amK	J2 M	a? `2
L2; iBp2	yX8Re	yXyR3	yXk89
SQbBiBp2	RX8Re	yXyjN	yXd9e

S M2H ", *Q`2H iBQMb	b	GQ M :`Qri?	b	Fb	p	Share _{hjb} V
b	R					
GQ M :`Qri?	yXyRe	R				
b	yXyR8	yX9dR	R			
Fb	yXRRj	yXyjk	yXykj	R		
p Share _{hjb} V	yXR9y	yXyRN	yXyNk	yXydj	R	

S M2H *, o `B iBQM +`Qbb u2 `b BM	amK	J2 M
kyyN	yXR83	yXyyk
kyRy	yXyRj	yXyyy
kyRR	yXk3R	yXyy9
kyRk	yXkye	yXyyj
kyRj	yXydd	yXyyR
kyR9	yXRyy	yXyyR
kyR8	yXRNk	yXyyj
kyRe	yXyke	yXyyy

S M2H ., hQT h2M _Qi2K#2`; q2B;?i " MFb p2`bmb Qi?2` " MFb	pX	hQi H bb2ib UBM #MV	hB2`@R _iBQ
hQT h2M	yXyeN	d8e	dXjkW
Pi?2`	yXyyRk	j9y	NXN9W

S M2H 1, 1biBK i2bQQ TSQbBiBp2 M/ L2; iBp2 q2B;?ib	@r2B;?i2/ amK	a? `2 Q7 Qp2MHH	
L2; iBp2	yXRyN	yX3N8	yXyN3
SQbBiBp2	yXkjR	RX3N8	yXydN

h #H2 1,XBmKK `v Q7 _Qi2K#2`; q2B;?ibX #H2 `2TQ`ib bi iBbiB+b #Qmi i?2 _
r2B;?ibX S M2H `2TQ`ib i?2 b? `2 M/ bmK Q7 M2; iBp2 M/ TQbBiBp2 r2B;?ib.
#2ir22M i?2 r2B;?ib; ;`2; i2 HQ M Q Qri?Qy-i?i?2 Dmbi@B/2MiB}2/ +Q2{+B2Mi 2
U_bV- i?2 }`bi@bi ;2 6@bi iBbiB+QV-i?M/#i 2Fpb`B`2BQM BM i?2 # MF b? `2b +`Q
UpShare_{hjb} VVX S M2H *`2TQ`ib p `B iBQM BM i?2 r2B;?ib +`Qbb v2 `bX S M2H .
#2`; r2B;?ib- bBx2 UK2 bm`2/ biQi H bb2ibV- M/hB2`@R + TBi H `iBQ b2T `
++Q`/BM; iQ i?2B`_Qi2K#2`; r2B;?ib- M/i?2 # MFb QmibB/2 Q7 i?2 iQT i2MX S
?Qr i?2 p H_b2b Q7rBi? i?2 TQbBiBp2 M/ M2; iBp2 _Qi2K#2`; r2B;?ibX

related to the variation in the bank shares across industry-country pairs ($\text{var}(\text{Share}_{hjb})$). This evidence suggests that the variation in the lending relationships to different banks (with different capitalization levels) across markets is driving our estimates. This observation is reassuring as it provides further evidence for the zombie credit channel.

Panel D shows the average size (measured with total assets) and the Tier-1 ratio of the ten banks with the highest Rotemberg weights, as well as for the banks outside of the top ten. The panel shows that our IV estimates are driven by large banks active in multiple markets, which results from (i) their relevance for the overall credit supply and (ii) our stringent fixed effects setting. Specifically, our fixed effects setting relies on exploiting cross-country and cross-industry variation, which limits the importance of smaller banks with a limited market breadth across industries and countries in our empirical analysis.

Moreover, Panel D shows that the most important banks (in terms of their Rotemberg weights) are on average much weaker capitalized than less important banks. Overall, these findings indicate that our IV estimation captures the effect of a low capitalization on the zombie lending behavior of large multinational banks and, in turn, CPI growth.

In a second step, we analyze the relationship between bank composition and market characteristics to explore whether there is variation that may be problematic for the exclusion restriction. To this end, [Table E.2](#) shows the relationship between market characteristics in 2009 and the share of the top 10 banks ranked according to their Rotemberg weights.

Specifically, each column reports results of a single regression of a 2009 bank share on market characteristics in 2009 that proxy for the performance and productivity of the respective market. The market characteristics include $\ln(\text{GDP}/\text{pop})$, $\ln(\text{GDP}/\text{pop})^2$, $\ln(\text{GDP}/\text{pop})^3$, $\ln(\text{GDP}/\text{pop})^4$, $\ln(\text{GDP}/\text{pop})^5$, $\ln(\text{GDP}/\text{pop})^6$, $\ln(\text{GDP}/\text{pop})^7$, $\ln(\text{GDP}/\text{pop})^8$, $\ln(\text{GDP}/\text{pop})^9$, $\ln(\text{GDP}/\text{pop})^{10}$, $\ln(\text{GDP}/\text{pop})^{11}$, $\ln(\text{GDP}/\text{pop})^{12}$, $\ln(\text{GDP}/\text{pop})^{13}$, $\ln(\text{GDP}/\text{pop})^{14}$, $\ln(\text{GDP}/\text{pop})^{15}$, $\ln(\text{GDP}/\text{pop})^{16}$, $\ln(\text{GDP}/\text{pop})^{17}$, $\ln(\text{GDP}/\text{pop})^{18}$, $\ln(\text{GDP}/\text{pop})^{19}$, $\ln(\text{GDP}/\text{pop})^{20}$, $\ln(\text{GDP}/\text{pop})^{21}$, $\ln(\text{GDP}/\text{pop})^{22}$, $\ln(\text{GDP}/\text{pop})^{23}$, $\ln(\text{GDP}/\text{pop})^{24}$, $\ln(\text{GDP}/\text{pop})^{25}$, $\ln(\text{GDP}/\text{pop})^{26}$, $\ln(\text{GDP}/\text{pop})^{27}$, $\ln(\text{GDP}/\text{pop})^{28}$, $\ln(\text{GDP}/\text{pop})^{29}$, $\ln(\text{GDP}/\text{pop})^{30}$, $\ln(\text{GDP}/\text{pop})^{31}$, $\ln(\text{GDP}/\text{pop})^{32}$, $\ln(\text{GDP}/\text{pop})^{33}$, $\ln(\text{GDP}/\text{pop})^{34}$, $\ln(\text{GDP}/\text{pop})^{35}$, $\ln(\text{GDP}/\text{pop})^{36}$, $\ln(\text{GDP}/\text{pop})^{37}$, $\ln(\text{GDP}/\text{pop})^{38}$, $\ln(\text{GDP}/\text{pop})^{39}$, $\ln(\text{GDP}/\text{pop})^{40}$, $\ln(\text{GDP}/\text{pop})^{41}$, $\ln(\text{GDP}/\text{pop})^{42}$, $\ln(\text{GDP}/\text{pop})^{43}$, $\ln(\text{GDP}/\text{pop})^{44}$, $\ln(\text{GDP}/\text{pop})^{45}$, $\ln(\text{GDP}/\text{pop})^{46}$, $\ln(\text{GDP}/\text{pop})^{47}$, $\ln(\text{GDP}/\text{pop})^{48}$, $\ln(\text{GDP}/\text{pop})^{49}$, $\ln(\text{GDP}/\text{pop})^{50}$, $\ln(\text{GDP}/\text{pop})^{51}$, $\ln(\text{GDP}/\text{pop})^{52}$, $\ln(\text{GDP}/\text{pop})^{53}$, $\ln(\text{GDP}/\text{pop})^{54}$, $\ln(\text{GDP}/\text{pop})^{55}$, $\ln(\text{GDP}/\text{pop})^{56}$, $\ln(\text{GDP}/\text{pop})^{57}$, $\ln(\text{GDP}/\text{pop})^{58}$, $\ln(\text{GDP}/\text{pop})^{59}$, $\ln(\text{GDP}/\text{pop})^{60}$, $\ln(\text{GDP}/\text{pop})^{61}$, $\ln(\text{GDP}/\text{pop})^{62}$, $\ln(\text{GDP}/\text{pop})^{63}$, $\ln(\text{GDP}/\text{pop})^{64}$, $\ln(\text{GDP}/\text{pop})^{65}$, $\ln(\text{GDP}/\text{pop})^{66}$, $\ln(\text{GDP}/\text{pop})^{67}$, $\ln(\text{GDP}/\text{pop})^{68}$, $\ln(\text{GDP}/\text{pop})^{69}$, $\ln(\text{GDP}/\text{pop})^{70}$, $\ln(\text{GDP}/\text{pop})^{71}$, $\ln(\text{GDP}/\text{pop})^{72}$, $\ln(\text{GDP}/\text{pop})^{73}$, $\ln(\text{GDP}/\text{pop})^{74}$, $\ln(\text{GDP}/\text{pop})^{75}$, $\ln(\text{GDP}/\text{pop})^{76}$, $\ln(\text{GDP}/\text{pop})^{77}$, $\ln(\text{GDP}/\text{pop})^{78}$, $\ln(\text{GDP}/\text{pop})^{79}$, $\ln(\text{GDP}/\text{pop})^{80}$, $\ln(\text{GDP}/\text{pop})^{81}$, $\ln(\text{GDP}/\text{pop})^{82}$, $\ln(\text{GDP}/\text{pop})^{83}$, $\ln(\text{GDP}/\text{pop})^{84}$, $\ln(\text{GDP}/\text{pop})^{85}$, $\ln(\text{GDP}/\text{pop})^{86}$, $\ln(\text{GDP}/\text{pop})^{87}$, $\ln(\text{GDP}/\text{pop})^{88}$, $\ln(\text{GDP}/\text{pop})^{89}$, $\ln(\text{GDP}/\text{pop})^{90}$, $\ln(\text{GDP}/\text{pop})^{91}$, $\ln(\text{GDP}/\text{pop})^{92}$, $\ln(\text{GDP}/\text{pop})^{93}$, $\ln(\text{GDP}/\text{pop})^{94}$, $\ln(\text{GDP}/\text{pop})^{95}$, $\ln(\text{GDP}/\text{pop})^{96}$, $\ln(\text{GDP}/\text{pop})^{97}$, $\ln(\text{GDP}/\text{pop})^{98}$, $\ln(\text{GDP}/\text{pop})^{99}$, $\ln(\text{GDP}/\text{pop})^{100}$. We obtain this data from Eurostat. At the top of each column, we report the country code and the within-country rank of the respective bank (ordered from left to right according to their Rotemberg weight). The results show no significant relationship between the bank shares and the market characteristics, mitigating concerns about potential violations of the exclusion restriction.

	IT1	GB1	PT1	FR1	DE1	PT2	IT2	ES1	GB2	IT3
Output	0.035 (0.045)	0.017 (0.021)	0.012 (0.008)	0.038 (0.032)	0.003 (0.004)	0.004 (0.013)	0.003 (0.005)	0.001 (0.010)	0.000 (0.006)	0.015 (0.034)
Interm. cons.	0.035 (0.045)	0.013 (0.020)	0.013 (0.008)	0.045 (0.032)	0.003 (0.004)	0.001 (0.014)	0.003 (0.005)	0.001 (0.010)	0.001 (0.007)	0.015 (0.033)
Compensation	0.076 (0.080)	0.050 (0.028)	0.028 (0.021)	0.014 (0.056)	0.027 (0.022)	0.028 (0.024)	0.009 (0.012)	0.030 (0.014)	0.010 (0.015)	0.014 (0.085)
Cons. of FC	0.035 (0.039)	0.016 (0.019)	0.016 (0.009)	0.036 (0.035)	0.004 (0.006)	0.007 (0.017)	0.002 (0.005)	0.000 (0.010)	0.003 (0.008)	0.013 (0.032)
Observations	183	183	183	183	183	183	183	183	183	183
R-squared	0.41	0.39	0.59	0.80	0.08	0.96	0.09	0.93	0.66	0.65
Country FE	X	X	X	X	X	X	X	X	X	X

Table E.2: Relationship Between Bank Shares and Market Characteristics. Each column of this table reports results of a single regression of a 2009 bank share on market characteristics in 2009. The market characteristics include *output*, *intermediate consumption*, *compensation of employees*, *consumption of fixed capital*, all divided by *total employment*. Standard errors are clustered at the industry-country level and reported in parentheses.

As previously described, our OLS evidence suggests that the effect of zombie credit on CPI growth is heterogeneous across markets and, in turn, each instrument will converge to a different estimate ($\hat{\beta}$). Therefore, in a third step, we probe the patterns of this heterogeneity by exploring the distribution of the just identified IV estimates (i.e., the $\hat{\beta}$).

To this end, [Figure E.1](#) shows the relationship between the Rotemberg weights and the first-stage F-statistic. Specifically, the x-axis is the first-stage F-statistic and the y-axis is the $\hat{\beta}$ associated with each instrument. The individual points of $\hat{\beta}$ are weighted by the absolute size of the β from the Bartik Rotemberg weights. The dashed horizontal line reflects the overall Bartik estimate.

The figure shows that there is some dispersion around the Bartik $\hat{\beta}$, but the banks with larger Rotemberg weights tend to be relatively close to the overall point estimate. Moreover, none of the high-powered banks have negative Rotemberg weights, which mitigates concerns that there are negative weights on particular market-specific parameters (i.e., β_{hj}).

In sum, these diagnostic tests suggest that our Bartik IV results are driven by zombie lending behavior of low-capitalized large banks. Since these banks are exposed to different markets with different characteristics, the effect of zombie credit on CPI growth is heteroge-

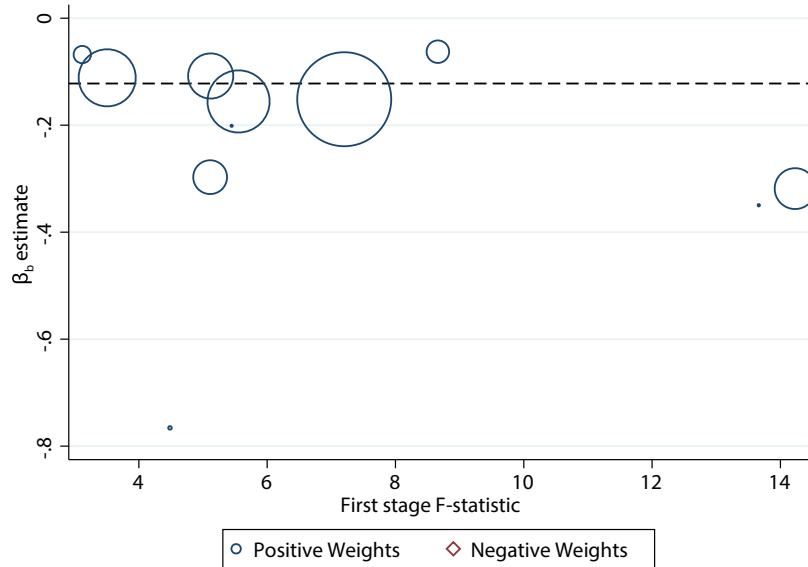


Figure E.1: Heterogeneity of $\hat{\beta}_b$. This figure plots the relationship between each instruments' $\hat{\beta}_b$, first-stage F-statistics, and the Rotemberg weights. Each point is a separate instrument estimate. The figure plots the estimated $\hat{\beta}_b$ for each instrument on the y-axis and the estimated first-stage F-statistic on the x-axis. The size of the points is scaled by the magnitude of the Rotemberg weights, with the circles denoting positive Rotemberg weights and the diamonds denoting negative weights. The horizontal dashed line is plotted at the value of the overall $\hat{\beta}_b$ reported in the Column (1) of Table 4. The figure excludes instruments with first-stage F-statistics below 3.

neous across these markets and the coefficient estimates ($\hat{\beta}_b$) have some variation. Given this variation and the fact that some Rotemberg weights are negative, we cannot rule out the general possibility that there are nonconvex weights on the h_j . However, the visual tests alleviate this concern. Finally, the diagnostic tests do not raise concerns about potential violations of the exclusion restriction.

Appendix F Data on Bank Supervision Strictness

To rank countries according to the strictness of their bank supervision, we employ data from the Bank Regulation and Supervision Survey conducted by the World Bank (see Čihák et al., 2012 for a thorough explanation of the survey and the data). The database provides information on bank regulation and supervision for 143 jurisdictions, including all our sample countries. The survey questions are grouped into different topics. The two topics most relevant for zombie lending incentives are (i) “Asset classification mechanisms” and (ii) “Supervisory powers in cases of bank losses.”

The category “Asset classification mechanisms” includes questions like: (i) Do you have an asset classification system under which banks have to report the quality of their loans and advances using a common regulatory scale? (ii) Do you require banks to write off non-performing loans after a specific time period? (iii) Are there minimum levels of specific provisions for loans and advances that are set by the regulator? (iv) Is there a regulatory requirement for general provisions on loans and advances?

The category “Supervisory powers in cases of bank losses” includes statements about supervisory powers like: (i) Require commitment/action from controlling shareholder(s) to support the bank with new equity (e.g. capital restoration plan); (ii) Require banks to constitute provisions to cover actual or potential losses; (iii) Require banks to reduce or suspend bonuses and other remuneration to bank directors and managers.

We use this survey data to construct two bank supervisory measures, the first based on the “Asset classification mechanisms” survey questions category and the second based on “Supervisory powers in cases of bank losses” category. Specifically, for each category we code the yes/no responses for each survey question as 1/0, respectively, and then take the mean per category of the binary responses for each of our sample countries.

Appendix G Supply Chain Evidence

In this section, we broaden our analysis to the whole supply chain (by including intermediate good prices) and investigate the effects of the zombie credit mechanism employing producer price index (PPI) data from Eurostat and input-output tables from the World Input-Output Database (WIOD). [Table G.1](#) presents the estimation results. In Column (1), we regress the change in the producer price index (PPI) on the share of zombie firms. The results confirm a negative relation between the prevalence of zombie firms and price levels.

In Columns (2) and (3), we investigate the zombie credit channel along the supply chain employing input-output information between industries. Consider as an example the case where industries A and B sell goods to industry C , and—for the sake of simplicity—no further industry sells goods to industry C . The zombie credit mechanism predicts that an increase in the zombie share in industries A and B puts downward pressure on prices for goods that these industries sell to industry C . Moreover, the mechanism suggests that an increase in zombie prevalence in industry C leads to higher prices for goods sold to industry C because relatively more firms demand the same inputs, sustaining their prices. Column (2) tests the first prediction. We investigate the second prediction in Column (3).

Accordingly, in Column (2), we regress the weighted PPI growth of the goods delivered to industry C on the weighted share of zombie firms in sectors A and B , using the trade flow information from the input-output tables as weights. The result suggests that industries that buy more goods from zombified sectors obtain these goods at lower prices. In Column (3), we regress the weighted PPI growth of the goods delivered to industry C (again using the trade flows as weights) on the share of zombie firms in industry C . The results show that, consistent with the zombie credit mechanism, an increase in the share of zombie firms in industry C is associated with relatively higher prices for the goods delivered to this industry.

	PPI	weighted PPI	weighted PPI
Share Zombies	0.033** (0.014)		0.005** (0.003)
Weighted Share Zombies		0.027* (0.015)	
Observations	1,513	2,026	2,026
R-squared	0.735	0.751	0.760
Country-Industry FE	X	X	X
Industry-Year FE	X	X	X
Country-Year FE	X	X	X

Table G.1: PPI Growth and Input-Output Flows. This table presents estimation results from Specification (3). The dependent variable is the annual PPI growth rate from $t-1$ to t (Column 1) and the weighted PPI growth from $t-1$ to t , using trade flows as weights (Columns 2 and 3). *Share Zombies* measures the asset-weighted share of zombie firms in a particular industry-country pair at $t-1$. *Weighted Share Zombies* is the weighted share of zombie firms in the supplying sectors at $t-1$, using trade flows as weights. A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). All regressions control for the asset-weighted share of low-quality firms. Standard errors are clustered at the industry-country level and reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

Appendix H Alternative Supply-Side Channels

While our empirical evidence is consistent with the zombie credit channel, the literature has suggested other (financial frictions-induced) supply-side effects that could also have affected the European inflation dynamics during our sample period. The cost channel (see, e.g., [Barth III and Ramey, 2001](#)) suggests that access to cheap debt decreases zombie firms' marginal production costs because it lowers the costs associated with financing their working capital. This cost reduction might give zombie firms more wiggle room to cut output prices. The liquidity squeeze channel (see, e.g., [Chevalier and Scharfstein, 1996](#) and [Gilchrist et al., 2017](#)) suggests that low-quality non-zombie firms have an incentive to raise prices to increase their current cash flows (assuming they are liquidity constrained), while zombie firms do not have the necessity to react this way due to their access to cheap credit. Hence, the observed negative correlation between zombie share and CPI growth is also consistent with the cost channel and the liquidity squeeze channel.

[Table H.1](#) rules out that our results are materially driven by one or a combination of these alternative channels. In this table, we add additional controls to our baseline specification to capture the cost channel and the liquidity squeeze channel. In the spirit of [Barth III and Ramey \(2001\)](#), we proxy for the cost channel by including firms' average marginal financing costs associated with their net working capital ($\text{bqML} ; -e\% Y; \text{bszs}$). Following [Gilchrist et al. \(2017\)](#), we proxy for the liquidity squeeze channel using firms' average liquidity ratio ($\text{XSI} \sim \text{S}\% \text{p} - \text{zS}$), defined as the ratio of cash and short-term investments to total assets. As an alternative measure for this channel, we employ a refined low-quality firm measure that aims at capturing only firms that are of low-quality but not zombie ($\text{rP} - \text{qCXb} . \text{Q} \sim \text{S}\% \text{S}$).

The inclusion of proxies for these alternative channels does not change the point estimate of the zombie share nor does it significantly alter the explanatory power of the zombie credit

	CPI	CPI	CPI	CPI
Share Zombies	0.022*** (0.007)	0.021*** (0.007)	0.023*** (0.007)	0.022*** (0.007)
Liquidity Ratio	0.044* (0.026)			0.042* (0.026)
Share Low-Quality NZ		0.005** (0.003)		
Working Capital Cost			0.528** (0.235)	0.537** (0.231)
Observations	3,880	3,880	3,880	3,880
R-squared	0.759	0.770	0.753	0.757
Country-Industry FE	X	X	X	X
Industry-Year FE	X	X	X	X
Country-Year FE	X	X	X	X

Table H.1: Alternative Supply-Side Channels. This table presents estimation results from Specification (3). The dependent variable is the annual CPI growth rate (inflation) from $t - 1$ to t . *Share Zombies* measures the asset-weighted share of zombie firms in a particular market at $t - 1$. *Liquidity Ratio* is defined as the firms' average asset-weighted ratio of cash and short-term investments to total assets. *Share Low-Quality NZ* measures the asset-weighted share of low-quality non-zombie firms. *Working Capital Costs* is defined as the firms' average asset-weighted (net working capital/total assets)*(interest expenses/sales). A firm is classified as zombie if it is low-quality and paid advantageous interest rates (see Section 3.2 for more details). Standard errors are clustered at the industry-country level and reported in parentheses. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

channel for CPI growth.^{JD} These results suggest that, while the other supply-side channels likely contributed to the European disinflationary trend, the zombie credit channel is a distinctive driver for the observed low inflation level in Europe during our sample period.

⁴⁸Note that we cannot include the variable *Share Low-Quality NZ* in Column (4) since it is a linear combination of the other variables in this regression.