Appendix 2: Stylised example of the cyclicality cap

- The following stylised example is intended to illustrate the calibration of a hybrid residential mortgage probability of default (PD) model. It is not intended to provide step-by-step instructions and firms should not use it as such. Instead, these pages set out, at a high level, one example of a possible approach firms might take to hybrid residential mortgage PD modelling.
- In practice the PRA would expect firms' approaches to be more sophisticated than in this example (for example, in the use of third-party data and back-casting methodologies). Firms simply adopting the steps set out here without further appropriate analysis, adaptation and conservatism should expect to be robustly challenged.
- Firms should not assume that the steps set out here are sufficient in themselves to meet CRR requirements for internal ratings based (IRB) systems.

Notes

- The stylised example makes a number of assumptions and simplifications for the purposes of clarity. Firms should always articulate and justify their assumptions, and adopt suitable margins of conservatism as required.
- The stylised example assumes a third-party series of observed default rates is available. The PRA expects that a firm seeking to use a third-party data source will ensure it meets the requirements within the CRR for its use, particularly the need to assess its representativeness. In doing so, the PRA expects firms to add a margin of conservatism to mitigate weaknesses in the representativeness of the pool of third-party data. Consideration should be given to the composition of the products within the third-party data and their applicability to the firm's current asset base, and the basis of measurement, such as whether the definition of default is equivalent to the firm's own IRB definition of default. Firms should assess the consistency of the representativeness over time.
- The data used for this stylised example are purely illustrative and should not be used for modelling.
- The PD segmentation used in the stylised example represents a common approach to segmenting IRB PD models. It should not be interpreted as expressing a PRA preference for any one particular approach to segmentation.
- The dates chosen for the example cycle are purely illustrative, and should not be interpreted as representing a PRA view of the cycle.
- Firms should consider the extent to which the PD calibration resulting from their calculation represents a forward view of long-run average default rates.

Objective: Measuring the default rate if full data were available

	Full internal data																observed default rates				
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	..2012	2013	2014	2015	2016
Application score segments																					
A1	0.03%	0.03%	0.06%	0.08%	0.05%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%
A2	0.36%	0.43%	0.50%	0.68%	0.58%	0.47%	0.40%	0.38%	0.34%	0.32%	0.36%	0.37%	0.31%	0.31%	0.32%	0.39%	0.36%	0.35%	0.25%	0.21%	0.18%
A3	1.76%	2.11%	2.46%	3.34%	2.82%	2.29%	1.94%	1.85%	1.67%	1.57%	1.74%	1.80%	1.53%	1.50%	1.55%	1.92%	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1	0.03%	0.03%	0.07%	0.14%	0.06%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%	0.03%
B2	0.14%	0.17%	0.20%	0.27%	0.22%	0.18%	0.15%	0.15%	0.13%	0.12%	0.14%	0.14%	0.12%	0.12%	0.12%	0.15%	0.14%	0.17%	0.19%	0.13%	0.09%
B3	0.66%	0.79%	0.92%	1.25%	1.06%	0.86%	0.73%	0.69%	0.63%	0.59%	0.65%	0.67%	0.57%	0.56%	0.58%	0.72%	0.66%	0.55%	0.45%	0.40%	0.33%
B4	1.35%	1.62%	1.89%	2.57%	2.16%	1.76%	1.49%	1.42%	1.28%	1.20%	1.34%	1.38%	1.17%	1.15%	1.19%	1.47%	1.35%	1.35%	1.11%	1.01%	0.89%
B5	3.56%	4.27%	4.98%	6.76%	5.70%	4.63%	3.92%	3.74%	3.38%	3.17%	3.52%	3.63%	3.10%	3.03%	3.13%	3.88%	3.56%	2.89%	3.01%	2.06%	1.15%
B6	5.07%	6.08%	7.10%	9.63%	8.11%	6.59%	5.58%	5.32%	4.82%	4.51%	5.02%	5.17%	4.41%	4.31%	4.46%	5.53%	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1	33%	38%	35%	65%	48%	42%	21%	27%	19%	38%	37%	42%	25%	22%	9%	25%	38%	33%	31%	30%	28%
2	58%	59%	61%	88%	87%	45%	56%	39%	58%	67%	67%	58%	54%	35%	45%	51%	58%	65%	43%	57%	55%
Portfolio default rate																	**1.9%**	**1.8%**	**1.9%**	**1.7%**	**1.5%**

- Where firms have full data covering the rating system prediction and outcomes over a full cycle, hybrid modelling could be considered relatively straightforward:
  - Assess the length of the full cycle.
  - Assess the representativeness of the historical data series and make appropriate adjustments.
  - Measure the historic default rates within each rating grade.
  - Use the average observed default rate over the full cycle as the Long-run Average PD.

- In practice many firms lack data over a full economic cycle.
- Instead firms must attempt to back-fill the missing data using available data, which includes making assumptions about the cyclicality of their rating system.
- The rest of the stylised example sets out one possible approach.

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Step 1 : Relationship of your portfolio relative to third-party data

	No internal data																observed default rates				
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003.	..2012	2013	2014	2015	2016
Application score segments																					
A1																	0.03%	0.03%	0.03%	0.03%	0.03%
A2																	0.36%	0.35%	0.25%	0.21%	0.18%
A3																	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1																	0.03%	0.03%	0.03%	0.03%	0.03%
B2																	0.14%	0.17%	0.19%	0.13%	0.09%
B3																	0.66%	0.55%	0.45%	0.40%	0.33%
B4																	1.35%	1.35%	1.11%	1.01%	0.89%
B5																	3.56%	2.89%	3.01%	2.06%	1.15%
B6																	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1																	38%	33%	31%	30%	28%
2																	58%	65%	43%	57%	55%

Portfolio default rate																	**1.9%**	**1.8%**	**1.9%**	**1.7%**	**1.5%**
Third-party data	4.2%	4.4%	5.6%	10.4%	6.6%	4.0%	3.6%	3.4%	3.2%	3.4%	4.0%	3.8%	4.4%	4.5%	4.2%	5.1%	**3.8%**	**3.6%**	**3.7%**	**3.3%**	**3.0%**

- In practice most firms lack data over a full economic cycle. Instead missing data must be back-filled.
- The PRA expects firms to make full use of all available CRR compliant data. Where firms lack full data to apply a rating and associated default rate to all accounts, firms should assess what partial or proxy data they have available, whether this is more representative than third-party data and the extent to which it can be used to back-fill the historic default rates.

- In assessing whether external data used by a firm are representative of its actual obligors or exposures, the PRA expects a firm to consider whether the data are appropriate to its own experience and default definition, and whether adjustments are necessary.
- Firms should analyse the strength and consistency of the relationship over time, and make adjustments where necessary.

Recent historic average of own portfolio (1.7%) based on observed default rates is 50% lower than the third-party data average (3.5%).

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Step 2 : Back-cast portfolio default rates from third-party data

	No internal data																observed default rates				
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003.	…2012	2013	2014	2015	2016
Application score segments																					
A1																	0.03%	0.03%	0.03%	0.03%	0.03%
A2																	0.36%	0.35%	0.25%	0.21%	0.18%
A3																	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1																	0.03%	0.03%	0.03%	0.03%	0.03%
B2																	0.14%	0.17%	0.19%	0.13%	0.09%
B3																	0.66%	0.55%	0.45%	0.40%	0.33%
B4																	1.35%	1.35%	1.11%	1.01%	0.89%
B5																	3.56%	2.89%	3.01%	2.06%	1.15%
B6																	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1																	38%	33%	31%	30%	28%
2																	58%	65%	43%	57%	55%

Portfolio default rate	**2.1%**	**2.2%**	**2.8%**	**5.2%**	**3.3%**	**2.0%**	**1.8%**	**1.7%**	**1.6%**	**1.7%**	**2.0%**	**1.9%**	**2.2%**	**2.3%**	**2.1%**	**2.6%**	**1.9%**	**1.8%**	**1.9%**	**1.7%**	**1.5%**
Third-party data	4.2%	4.4%	5.6%	10.4%	6.6%	4.0%	3.6%	3.4%	3.2%	3.4%	4.0%	3.8%	4.4%	4.5%	4.2%	5.1%	3.8%	3.6%	3.7%	3.3%	3.0%

- Initially the firm's own historic portfolio observed default rate is back-filled from available third party data.
- When back-filling data the PRA expects firms to assess the strength and consistency of the relationship both within the observed period (when both data series are available) and whether it would remain consistent over the full cycle.
- Firms should adopt appropriate modelling techniques and conservatism to ensure an appropriate back-fill is achieved.

- For this simplistic stylised example, it is assumed that the portfolio long-run historic average would be 50% lower than external third-party historic data.

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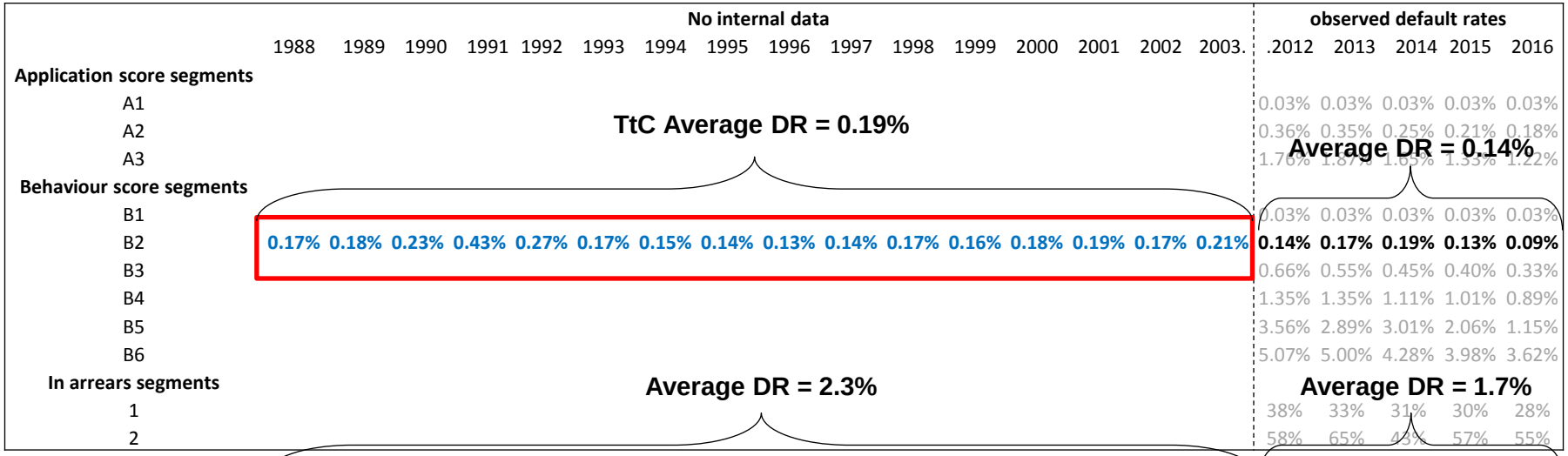
Step 3a : Map back-cast portfolio default rates to segment level – ‘Through the Cycle’ back-cast assumption

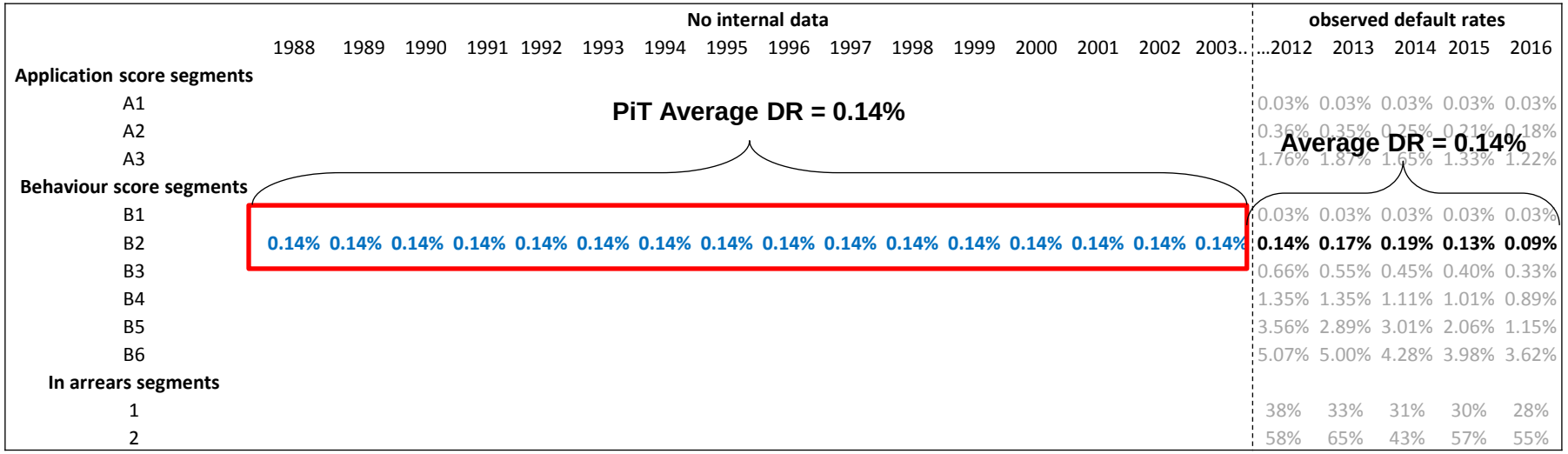


	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003.	.2012	2013	2014	2015	2016
Application score segments																					
A1																	0.03%	0.03%	0.03%	0.03%	0.03%
A2																	0.36%	0.35%	0.25%	0.21%	0.18%
A3																	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1																	0.03%	0.03%	0.03%	0.03%	0.03%
B2	0.17%	0.18%	0.23%	0.43%	0.27%	0.17%	0.15%	0.14%	0.13%	0.14%	0.17%	0.16%	0.18%	0.19%	0.17%	0.21%	**0.14%**	**0.17%**	**0.19%**	**0.13%**	**0.09%**
B3																	0.66%	0.55%	0.45%	0.40%	0.33%
B4																	1.35%	1.35%	1.11%	1.01%	0.89%
B5																	3.56%	2.89%	3.01%	2.06%	1.15%
B6																	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1																	38%	33%	31%	30%	28%
2																	58%	65%	43%	57%	55%
Portfolio default rate	**2.1%**	**2.2%**	**2.8%**	**5.2%**	**3.3%**	**2.0%**	**1.8%**	**1.7%**	**1.6%**	**1.7%**	**2.0%**	**1.9%**	**2.2%**	**2.3%**	**2.1%**	**2.6%**	**1.9%**	**1.8%**	**1.9%**	**1.7%**	**1.5%**
Third-party data	4.2%	4.4%	5.6%	10.4%	6.6%	4.0%	3.6%	3.4%	3.2%	3.4%	4.0%	3.8%	4.4%	4.5%	4.2%	5.1%	3.8%	3.6%	3.7%	3.3%	3.0%

- To impute grade-level historic default rates an assumption about the cyclicality of the rating system must be made.
- If the rating system were fully through-the-cycle then there would be no grade migration. All changes in portfolio default rates would come from changes in grade-level default rates.
- If the rating system were fully point-in-time then no change in grade-level default rates would be observed.

- Initially a ‘through-the-cycle’ assumption of migration is made.
- Since all changes in portfolio observed default rates comes from grade-level changes in default rate, the grade-level default rates are permitted to vary in proportion to the change in portfolio default rate (0.19:0.14 = 2.3:1.7).
- In this stylised example, this is a simplistic mapping assuming every grade exhibits the same ratio as the overall portfolio.

Step 3b : Back-cast portfolio default rates to segment level – 'Point in Time' back-cast assumption



	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003..	...2012	2013	2014	2015	2016
Application score segments																					
A1																	0.03%	0.03%	0.03%	0.03%	0.03%
A2																	0.36%	0.35%	0.25%	0.21%	0.18%
A3																	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1																	0.03%	0.03%	0.03%	0.03%	0.03%
B2	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	0.14%	**0.14%**	**0.17%**	**0.19%**	**0.13%**	**0.09%**
B3																	0.66%	0.55%	0.45%	0.40%	0.33%
B4																	1.35%	1.35%	1.11%	1.01%	0.89%
B5																	3.56%	2.89%	3.01%	2.06%	1.15%
B6																	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1																	38%	33%	31%	30%	28%
2																	58%	65%	43%	57%	55%

Portfolio default rate	**2.1%**	**2.2%**	**2.8%**	**5.2%**	**3.3%**	**2.0%**	**1.8%**	**1.7%**	**1.6%**	**1.7%**	**2.0%**	**1.9%**	**2.2%**	**2.3%**	**2.1%**	**2.6%**	**1.9%**	**1.8%**	**1.9%**	**1.7%**	**1.5%**
Third-party data	4.2%	4.4%	5.6%	10.4%	6.6%	4.0%	3.6%	3.4%	3.2%	3.4%	4.0%	3.8%	4.4%	4.5%	4.2%	5.1%	3.8%	3.6%	3.7%	3.3%	3.0%

- To impute grade-level observed default rates an assumption about the cyclicality of the rating system must be made.
- If the rating system were fully through-the-cycle then there would be no grade migration. All changes in portfolio default rate would come from changes in grade-level default rates.
- If the rating system were fully point-in-time then there would be full grade migration. No change in grade-level default rates would be observed.

- A 'point-in-time' assumption of no change in grade-level default rates is made.
- Since all change in portfolio observed default rates comes from grade migration (and none from changes in the grade-level default rates) the grade-level default rates are fixed.

Step 4 : Apply cyclicality to estimate segment level default rates – Hybrid back cast

	No internal data															observed default rates				
	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003.	...2012	2013	2014	2015	2016
Application score segments																					
A1																	0.03%	0.03%	0.03%	0.03%	0.03%
A2																	0.36%	0.35%	0.25%	0.21%	0.18%
A3																	1.76%	1.87%	1.65%	1.33%	1.22%
Behaviour score segments																					
B1																	0.03%	0.03%	0.03%	0.03%	0.03%
B2	0.16%	0.17%	0.21%	0.34%	0.23%	0.16%	0.15%	0.14%	0.14%	0.14%	0.16%	0.15%	0.17%	0.17%	0.16%	0.19%	**0.14%**	**0.17%**	**0.19%**	**0.13%**	**0.09%**
B3																	0.66%	0.55%	0.45%	0.40%	0.33%
B4																	1.35%	1.35%	1.11%	1.01%	0.89%
B5																	3.56%	2.89%	3.01%	2.06%	1.15%
B6																	5.07%	5.00%	4.28%	3.98%	3.62%
In arrears segments																					
1																	38%	33%	31%	30%	28%
2																	58%	65%	43%	57%	55%

Long run Average DR = 0.18%

TtC = 70%

PiT = 30%

} (70%*0.19%) + (30% *0.14%) = 0.18%

- The two back-fills (point-in-time and through-the-cycle) need combining to produce a 'hybrid' back-cast.
- The cyclicality assumption is used to do this.

- A 30% cyclicality assumption is made:
  - 70% of the resulting change in portfolio level default rates comes from changes in grade default rates (i.e. the 'through-the-cycle' back-fill).
  - 30% of the resulting change in portfolio level default rate comes from grade migration (i.e. the 'point-in-time' back-fill).
- The two back-fills are combined in proportion to the cyclicality assumption.