

Supporting Information

Boosting the Reactivity of Bis-lactones to Enable Step-Growth Polymerization at Room Temperature

Marta Ximenis,^{†,§} Julien Monot,^{‡,§} Elena Gabirondo,[†] Janna Jeschke,[†] Blanca Martín-Vaca,^{*‡} Didier Bourissou,^{*‡} Haritz Sardon^{*†}

[†] *POLYMAT, University of the Basque Country UPV/EHU, Joxe Mari Korta Center Avda. Tolosa 72, 20018 Donostia-San Sebastian, Spain.*

[‡] *Laboratoire Hétérochimie Fondamentale et Appliquée (UMR 5069), Université de Toulouse (UPS), CNRS, 118 route de Narbonne, F-31062 Toulouse, France.*

Table of contents

1	Materials	S3
2	Characterization methods	S3
3	Experimental procedures	S4
3.1	Synthesis of the disubstituted γ -methylene- γ -lactone (1) and spiro-bis lactone (γSL)	S4
3.2	Kinetic studies of model reactions with <i>n</i> -butanol	S6
3.3	Synthesis and characterization of the polyesters	S9
3.4	Model reactions of the bis lactone γSL and monofunctional alcohols	S11
3.5	Model reactions of 1 or bis lactone γSL and monofunctional thiols and amines	S15
3.6	Synthesis and characterization of the poly(spiro-bis(β -thioether lactone))s and poly(spiro-bis(β -hydroxy-lactame))s	S19
3.7	Synthesis and characterization of an (ABAC) _n terpolymer	S22
4	NMR spectra of the molecular compounds	S25

1. Materials

All reactions and manipulations were carried out under argon atmosphere using standard Schlenk techniques unless otherwise stated. Dry, oxygen-free solvents were employed. All organic reagents were obtained from commercial sources and used as received or prepared from known literature procedures. The complex $[(SCS)^{Pr}Pd]_2$ was synthesized using the method previously reported.¹ Catalyst loadings are given relative to the effective Pd content.

2. Characterization methods

Nuclear magnetic resonance (NMR) spectroscopy. ¹H and ¹³C spectra were obtained on a Bruker Avance 300, 400 or 500 MHz. Chemical shifts are given in ppm relative to residual solvent as an internal standard. Unless otherwise stated, NMR spectra were recorded at 293 K.

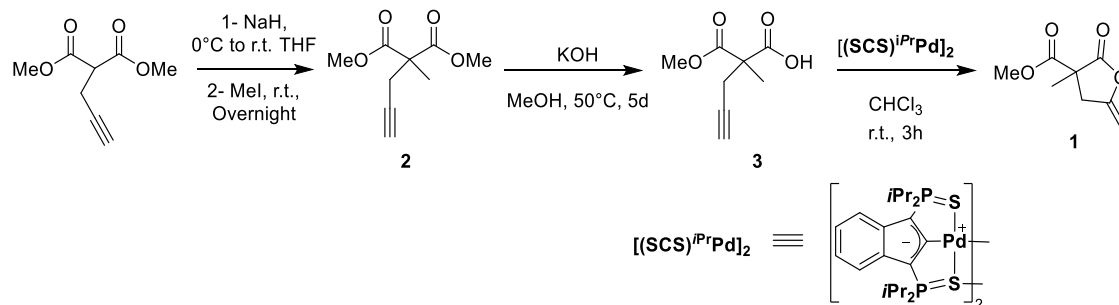
Gel permeation chromatography (GPC). Gel permeation chromatography (GPC) was performed on a Waters equipment provided with refractive index (RI) and ultraviolet (UV) detectors. For this, 100 μL of 0.1 (wt/vol) sample solution in THF or DMF with LiBr (depending on the polymer structure) was injected and the analysis was performed at a flow-rate of 0.5 mL min⁻¹. HR5E and HR2 Waters linear Styragel columns (7.8 mm × 300 mm, pore size 103–104 Å) packed with cross-linked polystyrene (PS) and protected with a pre-column were used. Molar mass averages and distributions were calculated against poly(methyl methacrylate) (PMMA) standards.

High Resolution Mass Spectrometry (HRMS): Mass spectra were recorded on a Waters GCT premier apparatus and Waters Xevo G2 QTOF apparatus.

¹ N. Á. Espinosa-Jalapa, D. Ke, N. Nebra, L. Le Goanvic, S. Mallet-Ladeira, J. Monot, B. Martin-Vaca, D. Bourissou, *ACS Catal.* **2014**, *4*, 3605–3611.

3. Experimental procedures

3.1 Synthesis of the disubstituted γ -methylene- γ -lactone (**1**) and spiro-bis lactone (γ SL)



Preparation of 2. To a suspension of NaH (472 mg, 11.8 mmol, 1 equiv.) in THF (30 mL), Dimethyl propargylmalonate (1.79 mL, 11.8 mmol) was added dropwise at 0 °C. After stirring for 30 min while warming to rt, the suspension was cooled to 0 °C and iodomethane (1.1 equiv) was added at this temperature. The reaction mixture was stirred while being allowed to warm up to r.t. overnight. Then, solvent was evaporated and the residue was dissolved in ethyl acetate (20 mL), washed with water (15 mL), brine (15 mL) and dried over Na₂SO₄. After filtration, the solvents were removed in vacuo. The crude product was purified by column chromatography (Pentane/EtOAc: 95/5) affording **2** as a pure colorless oil (1.185 g, 55%).

¹H NMR (300 MHz, Chloroform-*d*) δ 3.74 (d, J = 0.9 Hz, 6H), 2.79 (dd, J = 2.7, 0.9 Hz, 2H), 2.01 (d, J = 2.7 Hz, 1H), 1.56 (s, 3H). All the spectroscopic data were in accordance with the literature.²

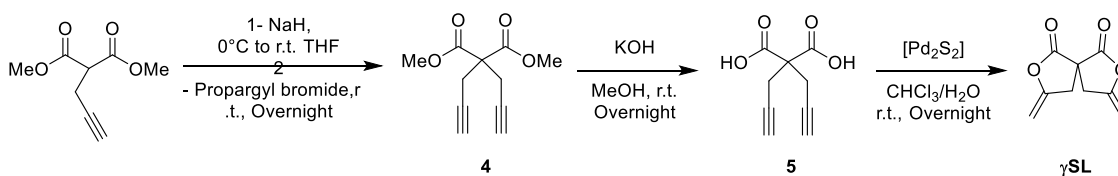
Preparation of 3. In a round bottom flask, **2** (1.185 g, 6.43 mmol, 1.0 equiv.) and KOH (397 mg, 7.1 mmol, 1.1 equiv.) were dissolved in MeOH (13 mL) and stirred at 50°C for 5 days. Aqueous saturated NaHCO₃ solution (20 mL) was added and the aqueous phase was washed with Et₂O (3x20 mL) and acidified with HCl (aq., 5 M) to pH = 1. CH₂Cl₂ (20 mL) was added and the organic phase was separated. The aqueous phase was extracted with CH₂Cl₂ (2x20 mL), the combined organic phases were dried over Na₂SO₄ and the solvent was removed in vacuo. Product **3** (831 mg, 76%) was obtained as a white solid without any further purification.

² E. Benedetti, A. Simonneau, A. Hours, H. Amouri, A. Penoni, G. Palmisano, M. Malacria, J.-P. Goddard, L. Fensterbank, *Adv. Synth. Catal.* **2011**, 353, 1908-1912.

¹H NMR (300 MHz, Chloroform-*d*) δ 3.77 (s, 3H), 2.93 – 2.68 (m, 2H), 2.05 (t, *J* = 2.7 Hz, 1H), 1.58 (s, 3H). All the spectroscopic data were in accordance with the literature.³

Preparation of 1. Alkynoic acid **3** (831 mg, 4.88 mmol) was added to a solution of [(SCS)^{*i*}Pd]₂complex^{Erreur ! Signet non défini.} (25 mg, 0.5%mol) in chloroform (35 mL). The reaction was stirred at room temperature for 3h. Then, the reaction mixture was concentrated and the residue was purified by flash chromatography (Pentane/EtOAc: 80/20) to afford **1** as a pure colorless oil (820 mg, 99%).

¹H NMR (300 MHz, Chloroform-*d*) δ 4.82 (q, *J* = 2.3 Hz, 1H), 4.38 (q, *J* = 2.3 Hz 1H), 3.78 (s, 3H), 3.36 (dt, *J* = 16.4, 1.9 Hz, 1H), 2.76 (dt, *J* = 16.4, 2.0 Hz, 1H), 1.57 (s, 3H). All the spectroscopic data were in accordance with the literature.⁴



Preparation of 4. To a suspension of NaH (472 mg, 11.8 mmol, 1 equiv.) in THF (30 mL), Dimethyl propargylmalonate (1.79 mL, 11.8 mmol) was added dropwise at 0 °C. After stirring for 30 min while warming to rt, the suspension was cooled to 0 °C and Propargyl bromide (2.62 mL, 80% in toluene, 2 equiv.) was added at this temperature. The reaction mixture was stirred while being allowed to warm up to r.t. overnight. Then, solvent were evaporated and the residue was dissolved in ethyl acetate (20 mL), washed with water (15 mL), brine (15 mL) and dried over Na₂SO₄. After filtration, the solvents were removed in vacuo. The obtained solid was suspended in pentane, filtered and washed three times with pentane to afford pure product **4** (1.36g, 55%) as a white solid.

¹H NMR (300 MHz, Chloroform-*d*) δ 3.77 (s, 6H), 3.00 (d, *J* = 2.7 Hz, 4H), 2.04 (t, *J* = 2.6 Hz, 2H). All the spectroscopic data were in accordance with the literature.⁵

Preparation of 5. In a round bottom flask, compound **4** (1.36 g, 1.0 equiv., 6.53 mmol) was dissolved in methanol (17 mL). An aqueous solution of potassium hydroxide (1.83 g, 5.0 equiv.) was prepared with a minimal amount of water and added to the methanol solution. The reaction was allowed to stir overnight at room temperature. Then, the

³ A. Arcadi, A. Burini, S. Cacchi, M. Delmastro, F. Marinelli, B. Rosa Pietroni, *J. Org. Chem.* **1992**, *57*, 3, 976–982.

⁴ E. Tomás-Mendivil, P. Y. Toullec, J. Díez, S. Conejero, V. Michelet, V. Cadierno, *Org. Lett.* **2012**, *14*, 10, 2520–2523

⁵ A. S. K. Hashmi, T. Häffner, M. Rudolph, F. Rominger, *Chem. Eur. J.* **2011**, *17*, 8195–8201.

reaction was concentrated in vacuo to dryness. The residue was dissolved in HCl 3M and the aqueous phase was washed DCM (3 × 30 mL). The aqueous phase was, then, evaporated until dryness. The residue was extracted with MeOH from the KCl salt, then, concentrated and extracted a second time with DCM. DCM was finally evaporated to yield the di-acid **5** as a pure white solid (900 mg, 76%) and was used without further purification.

¹H NMR (300 MHz, Deuterium Oxide) δ 7.18 (s, 4H), 5.23 (s, 2H). All the spectroscopic data were in accordance with the literature.⁶

Preparation of γSL. **5** (900 mg, 5 mmol) was dissolved in a biphasic medium CHCl₃/H₂O (10mL/10mL). [(SCS)^{Pr}Pd]₂ complex¹ was added and the reaction mixture was heavily stirred overnight. Then, the orange organic phase was separated and the aqueous phase was extracted with DCM (2 × 10 mL). The combined organic phase were concentrated in vacuo to yield an orange solid. This residue was dissolved in a minimum of DCM and then pentane was added to render a white precipitate. The solid was filtered and washed with pentane to afford the spiro dilactone **γSL** as a pure white solid (850 mg, 94%).

¹H NMR (300 MHz, Chloroform-d) δ 4.93 (dt, J = 3.2, 2.0 Hz, 2H), 4.50 (dt, J = 3.3, 1.8 Hz, 2H), 3.47 (dt, J = 16.6, 1.8 Hz, 2H), 2.94 (dt, J = 16.6, 2.0 Hz, 2H). All the spectroscopic data were in accordance with the literature.⁶

3.2 Kinetic studies of model reactions with n-butanol

All model reactions were carried out at 25 °C in DMF-*d*₇ and monitored by ¹H NMR spectroscopy. In a representative experiment, in a glovebox, 0.6 mmol of lactone and 0.6 mmol of *n*-butanol were added to a reaction tube. The reactants were solubilized in 0.5 ml of anhydrous DMF and 0.1 ml of a DBU (or the corresponding catalyst) solution in DMF (C = 0.6 M) was added to the reaction medium (0.03 mmol, 0.05 eq).and spectra were recorded at different reaction times.

The second-order kinetics were calculated as the following: $-d[1]/dt = k[1]^2$, (where [1] = [lactone] = [*n*-butanol]), which was confirmed by the linear relationship between *t* and $1/(1 - p)$, being *t* the time and *p* the fraction of the ring-opened adduct. Rate constants, *k*, were calculated for each kinetic model.

⁶ J. Alemán, V. del Solar, C. Navarro-Ranninger, *Chem. Commun.* **2010**, 46, 454-456

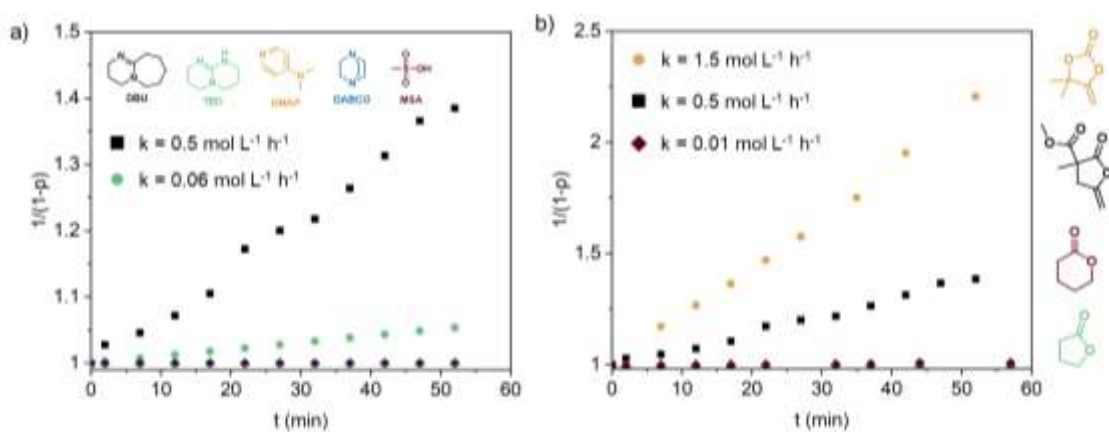


Figure S1. a) Alcoholysis throughout *n*-butanol of 1 M α -exovinylene lactone **1** with *n*-butanol and 5% catalyst in DMF-d_7 at 25 °C. b) Kinetics plot from the alcoholysis of various lactones and a related cyclic carbonate with *n*-butanol and 5% DBU in DMF-d_7 at 25 °C, 1M.

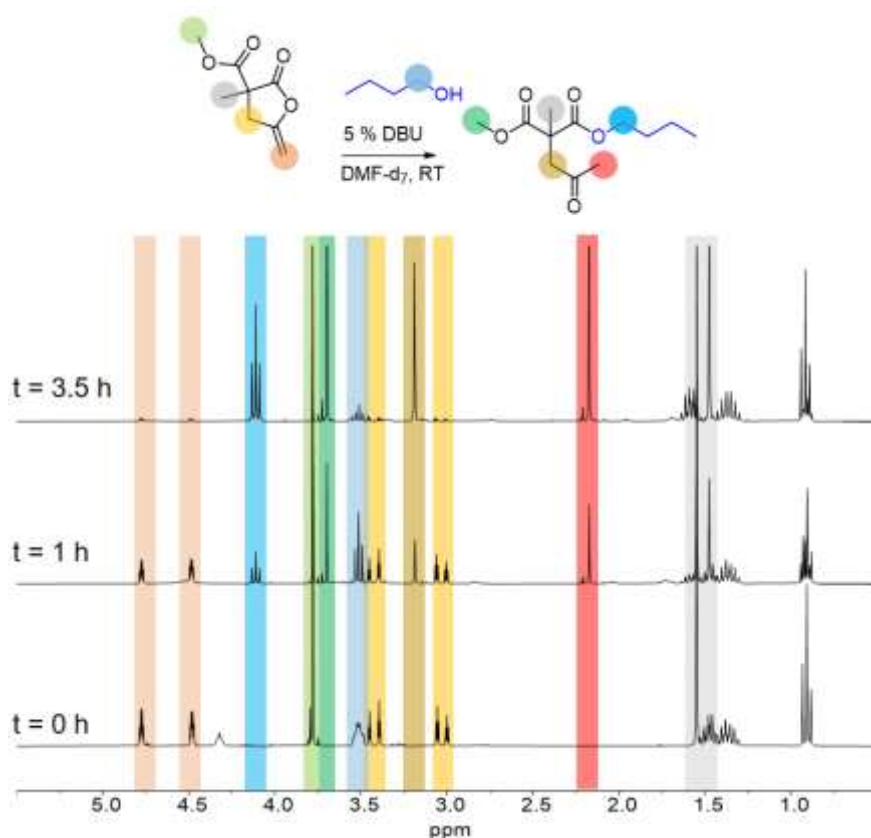


Figure S2. $^1\text{H-NMR}$ evolution over time of alcoholysis of 1 M lactone **1** with *n*-butanol (25 °C). *For $t = 0$ no catalyst is added.

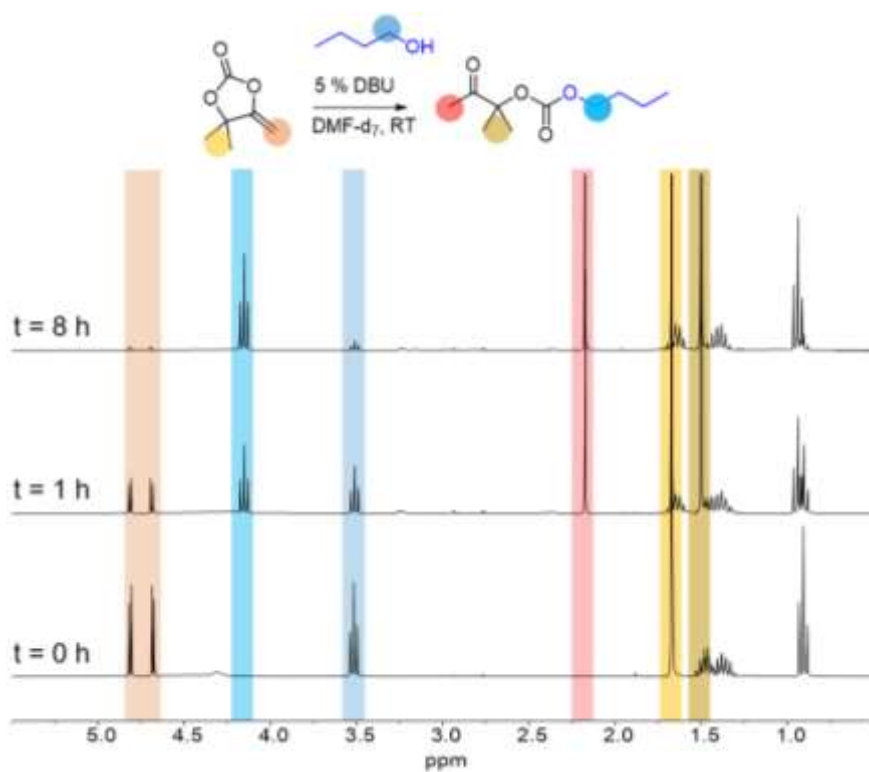


Figure S3. ¹H-NMR evolution over time of alcoholysis of 1 M cyclic carbonate **CC1** with *n*-butanol (25 °C). *For t = 0 no catalyst is added.

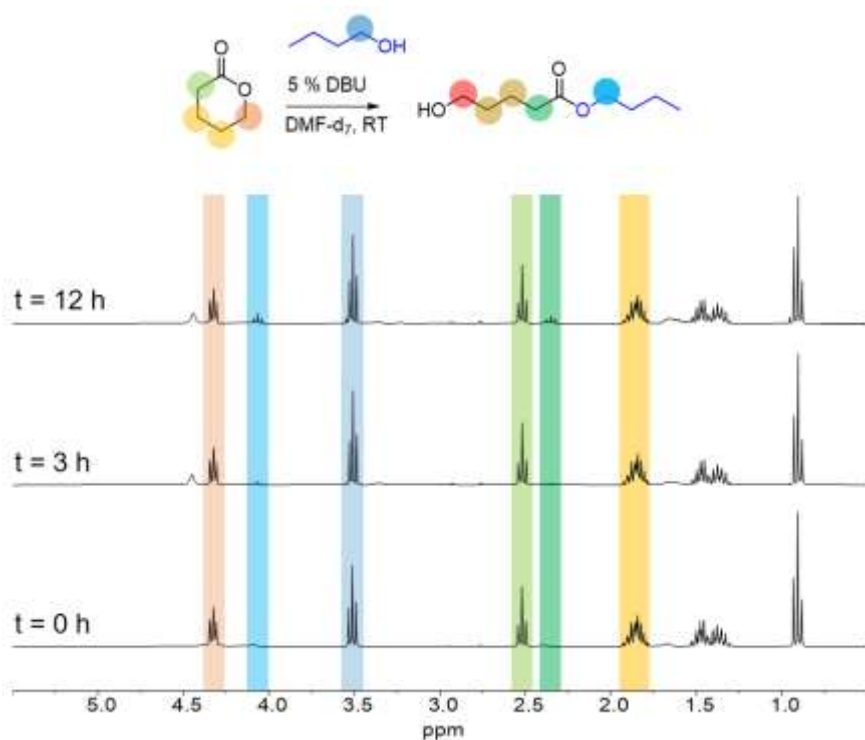


Figure S4. ¹H-NMR evolution over time of alcoholysis of 1 M δ -valerolactone (δ -VL) with *n*-butanol (25 °C). *For t = 0 no catalyst is added.

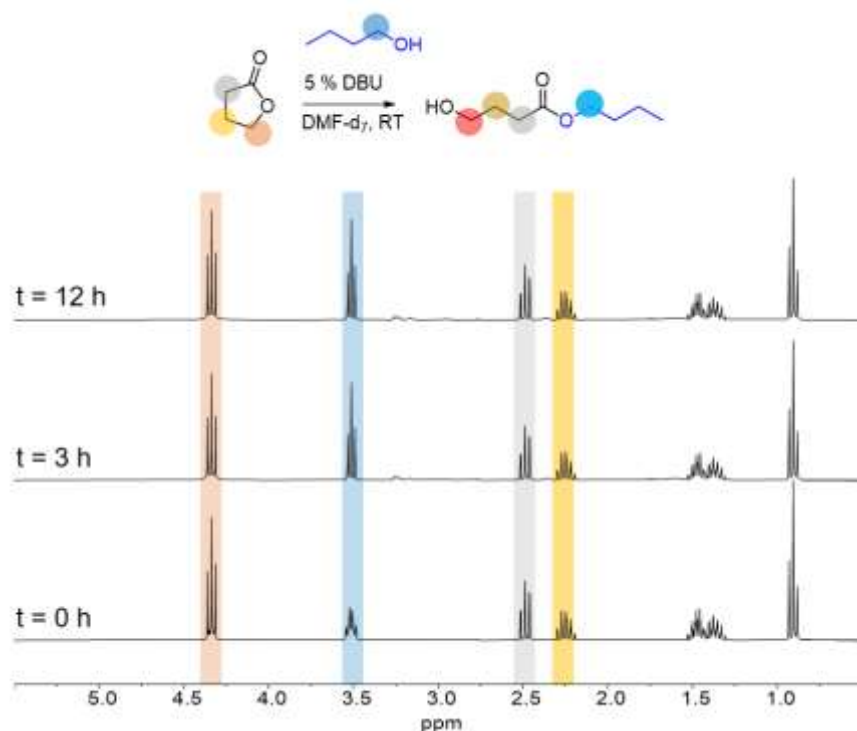


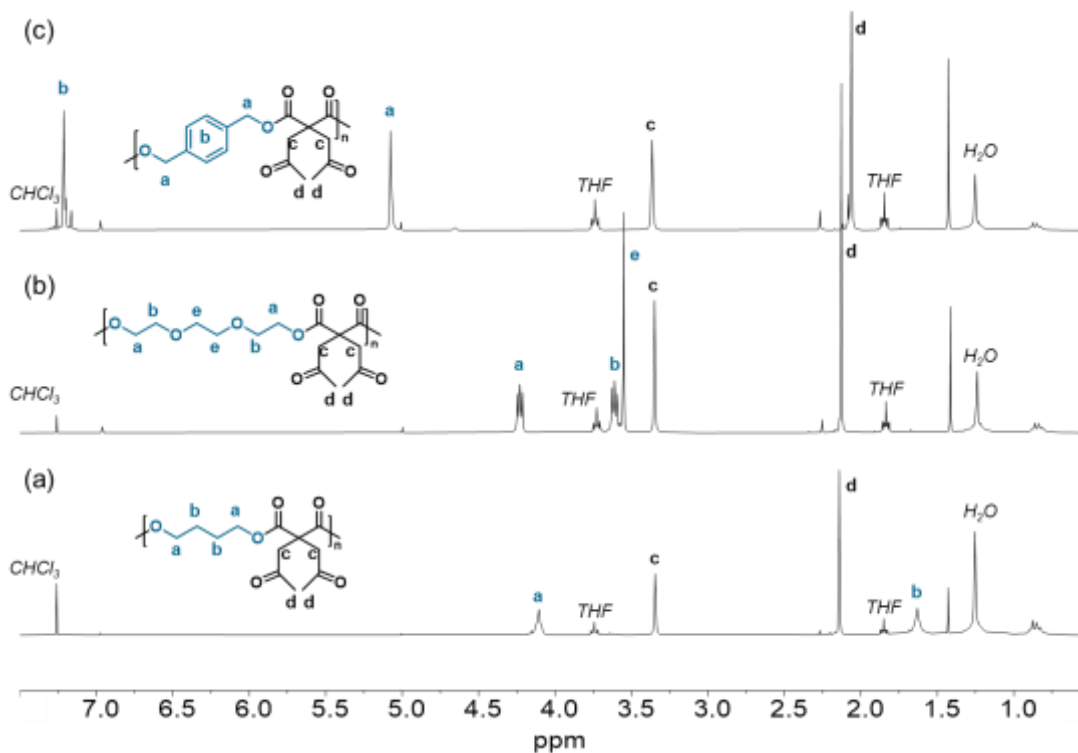
Figure S5. $^1\text{H-NMR}$ evolution over time of alcoholysis of 1 M γ -butyrolactone (γ -BL) with *n*-butanol (25 °C). *For $t = 0$ no catalyst is added.

3.3 Synthesis and characterization of the polyesters

All reactions were carried out inside an N_2 -filled glove box. 45 mg (0.25 mmol, 1 eq.) of γ SL and the corresponding diol were added to a glass vial. Next, 30 or 60 μL of a DBU solution (76 mg/mL, DMF or CHCl_3 , 5 % or 10 % DBU) were added, and DMF or CHCl_3 was added until a final volume of 0.75 mL (0.4 M) or 0.12 mL (2.2 M). After stirring for 24 h at 25 °C, an aliquot was taken out for conversion calculation and then precipitated in H_2O (from DMF) or hexanes (from CHCl_3). The polymers were precipitated two times, isolated by centrifugation and dried under a vacuum.

Table S1. Screening of the reaction conditions for polyester synthesis with diols.

Entry	Polymer	Solvent	DBU (%)	Temp. (° C)	Time (h)	Conc. (mol L ⁻¹)	MW (g mol ⁻¹) ^a	\bar{D}
1	P(N1a)	DMF	5	25	24	0.4	2500	1.5
2	P(N1a)	DMF	10	25	24	0.4	3500	1.4
3	P(N1a)	CHCl ₃	5	25	24	0.4	2700	1.4
4	P(N1a)	CHCl ₃	10	25	24	0.4	2200	1.6
5	P(N1a)	DMF	5	25	24	2.2	6000	1.4
6	P(N1a)	DMF	10	25	24	2.2	10800	1.6
7	P(N1a)	DMF	5	25	48	2.2	6900	1.4
8	P(N1a)	DMF	10	25	48	2.2	10400	1.5
9	P(N1a)	DMF	5	60	24	0.4	2800	1.2
10	P(N1a)	DMF	10	60	24	0.4	2500	1.3
11	P(N1b)	DMF	5	25	24	0.4	5200	2.1
12	P(N1b)	DMF	10	25	24	0.4	3400	1.5
13	P(N1b)	CHCl ₃	5	25	24	0.4	5900	1.3
14	P(N1b)	CHCl ₃	10	25	24	0.4	6700	1.2
15	P(N1c)	DMF	5	25	24	0.5	11800	1.5
16	P(N1c)	DMF	10	25	24	0.5	9900	1.4
17	P(N1c)	CHCl ₃	5	25	24	0.5	16600	1.5
18	P(N1c)	CHCl ₃	10	25	24	0.5	11700	1.4

^a Determined by GPC in THF with PMMA calibration

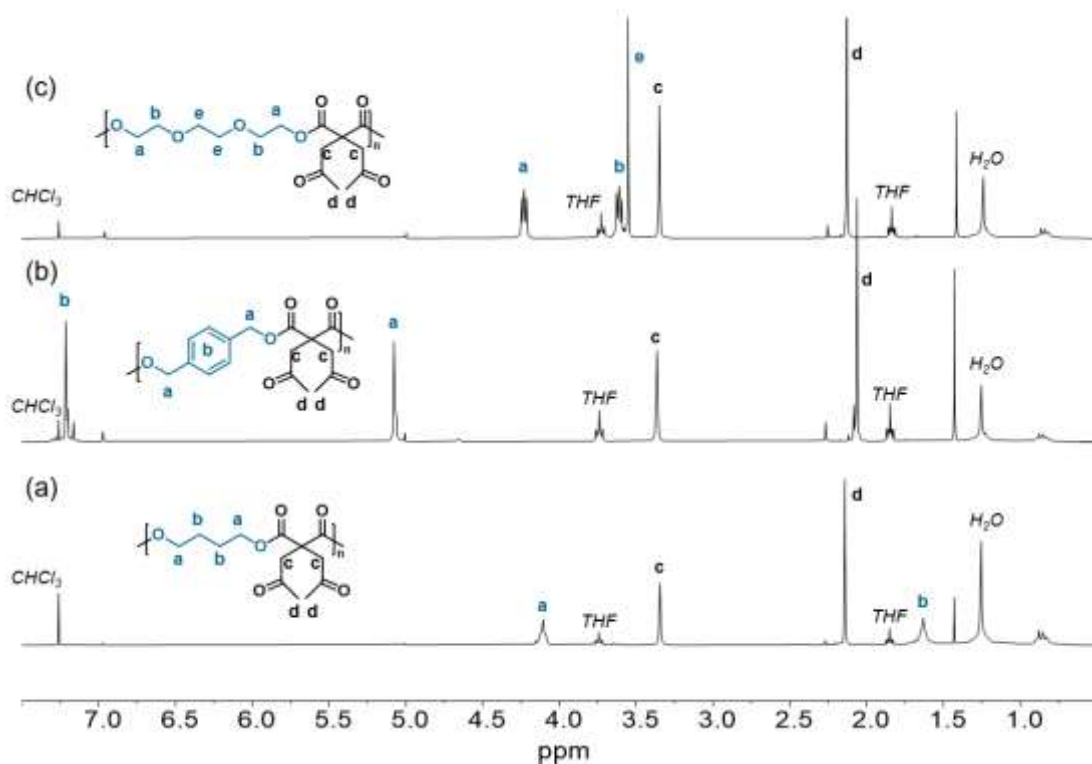
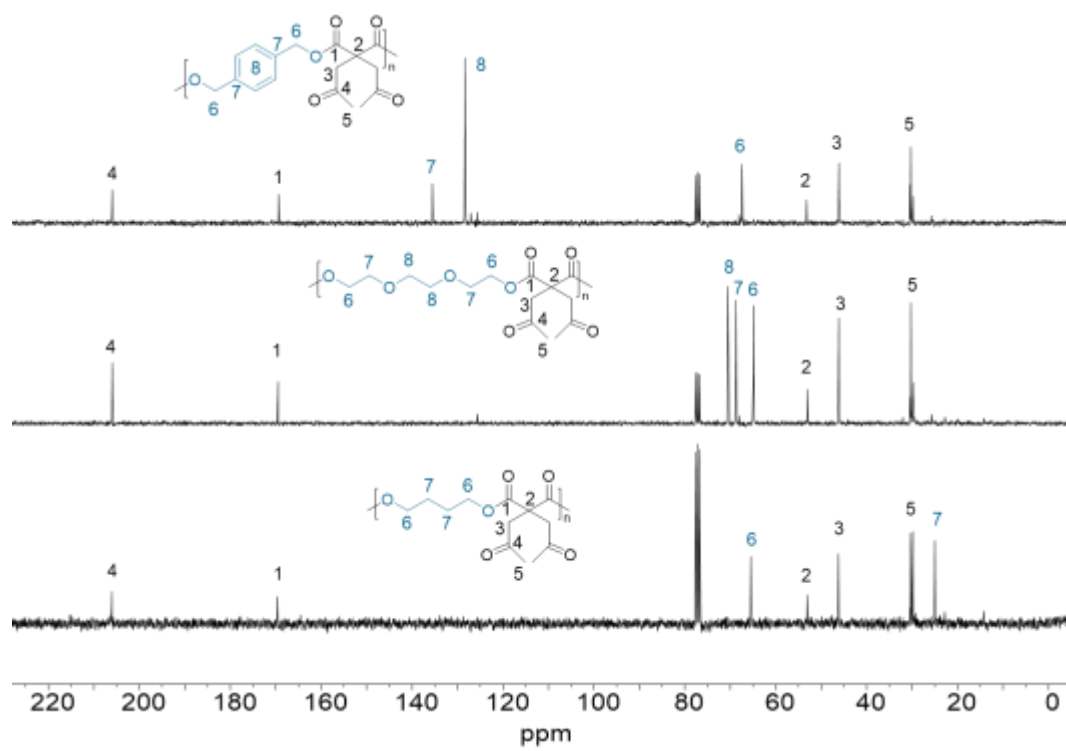


Figure S6. Stacked ^1H NMR spectra of P(N1a-c) in CDCl_3 , purified by precipitation.



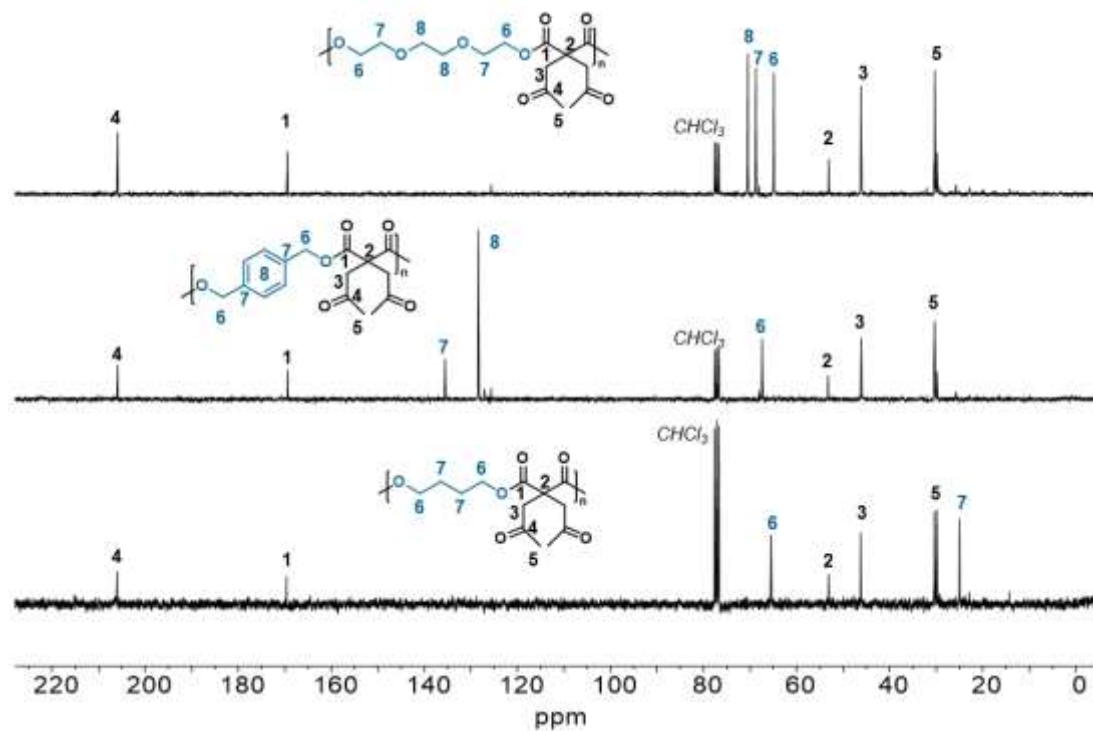


Figure S7. Stacked ¹³C NMR spectra of P(N1a-c) in CDCl₃, purified by precipitation.

3.4 Model reactions with dilactone monomer (γ SL) and monofunctional alcohols

The model reaction was carried out at 25 °C in DMF-*d*₇ and monitored by ¹H NMR spectroscopy. In a glovebox, 0.6 mmol of γ SL and 1.2 mmol of the monoalcohol (i.e. *n*-butanol) were added in a reaction tube. The reactants were solubilized in 0.5 ml of anhydrous DMF and 0.1 ml of a DBU solution in DMF (C = 0.6 M) was added to the reaction medium (0.03 mmol, 5 %) and spectra were recorded at different reaction times.

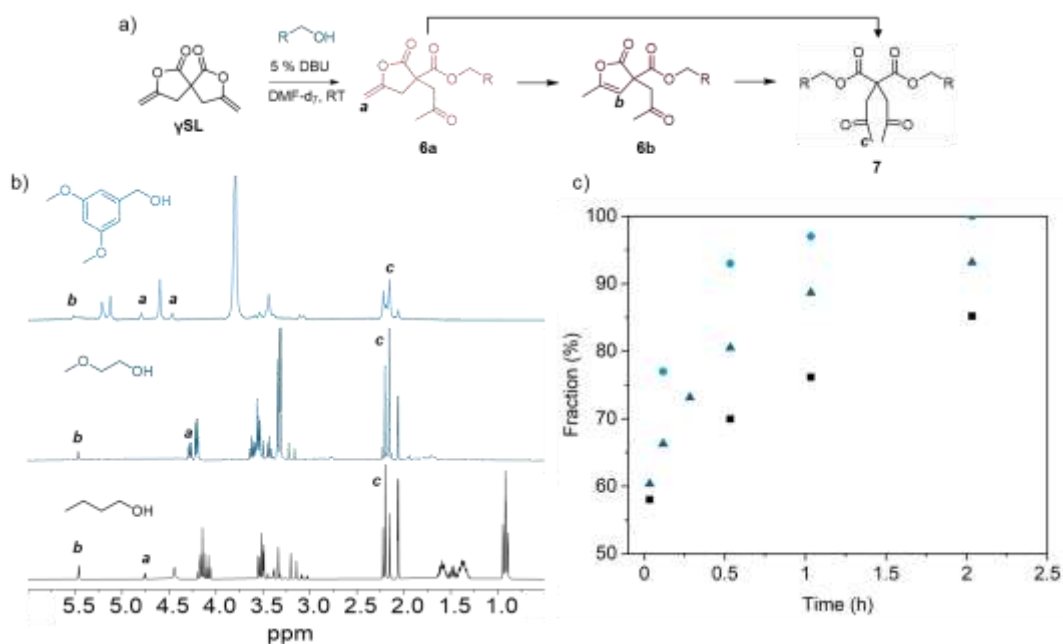


Figure S8. a) Scheme of the ring-opening of 1 M γ SL with 2 equivalents of different monoprotic alcohols using 5 % DBU at 25 °C in $DMF-d_7$. b) Representative example of 1H -NMR spectra of the reaction recorded at $t = 3$ min, and corresponding assignation of the key signals for each reaction product. c) Time-conversion curves for the reaction of γ SL with each alcohol (Fraction of final adduct 7). Magnification from 50-100 % of conversion to final product in the first 2.5 h of reaction time (\bullet 2-methoxyethanol; \blacktriangle 3,5-dimethoxybenzyl alcohol; \blacksquare n -butanol).

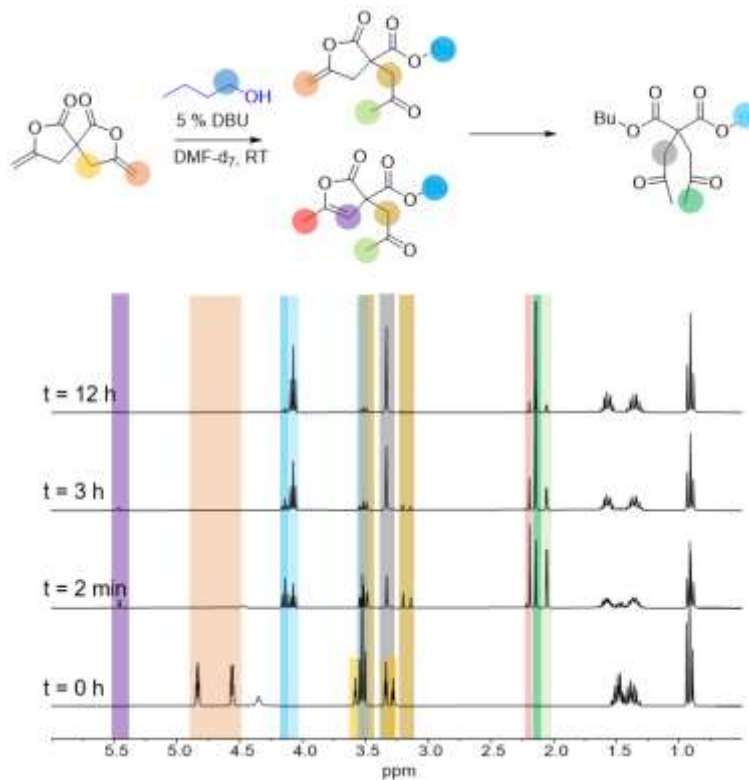


Figure S9. 1H -NMR evolution over time of alcoholysis of 1 M γ SL with n -butanol (25 °C). *For $t = 0$ no catalyst is added.

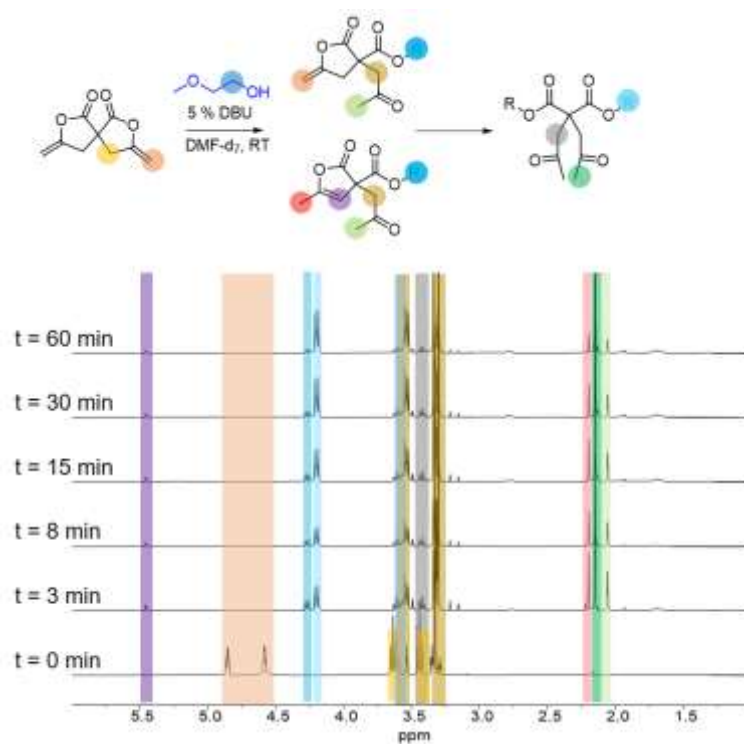


Figure S10. $^1\text{H-NMR}$ evolution over time of alcoholysis of 1 M γSL with 2-methoxyethanol (25 $^\circ\text{C}$). *For $t = 0$ no catalyst is added.

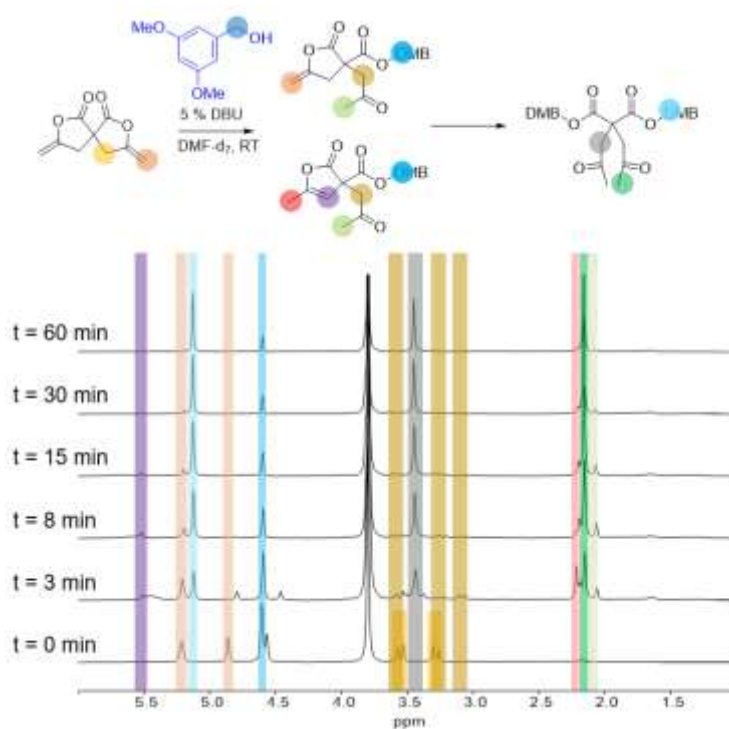
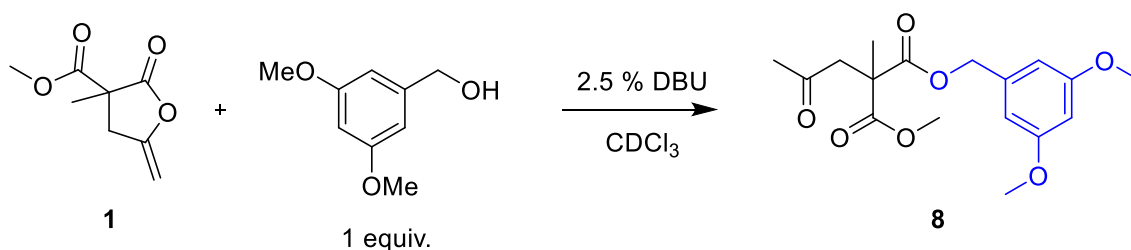


Figure S11. $^1\text{H-NMR}$ evolution over time of alcoholysis of 1 M γSL with DMBA (25 $^\circ\text{C}$). *For $t = 0$ no catalyst is added.

General procedure for the stoichiometric Reactions with 3,5-dimethoxybenzyl alcohol. In a glovebox, **1** or γ SL (1 equiv.) and alcohol (3,5-dimethoxybenzyl alcohol) (1 or 2 equiv.) were added in a schlenk tube. The reactants were solubilized anhydrous CDCl_3 ($[\text{C}] = 0.2 \text{ M}$) and a DBU solution (2.5 or 5 %mol) in CDCl_3 ($\text{C} = 0.063 \text{ M}$) was added to the reaction medium and the reaction was stirred at 25 °C.

1-(3,5-dimethoxybenzyl) 3-methyl 2-methyl-2-(2-oxopropyl)malonate (8)



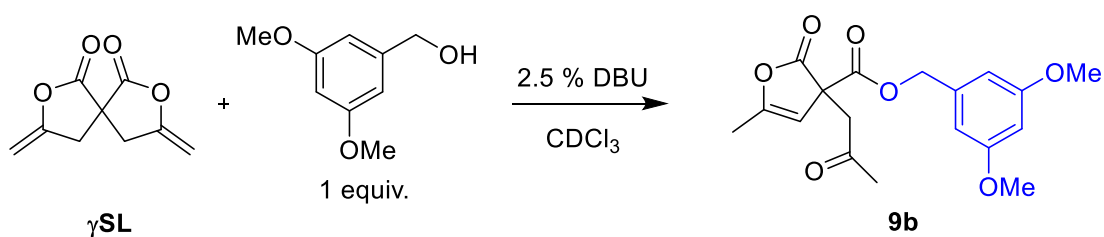
The reaction was monitored by $^1\text{H NMR}$ and after 2 h, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 96 mg of a colorless oil (96% Yield).

$^1\text{H NMR}$ (300 MHz, CDCl_3) δ 6.45 (d, $J = 2.3 \text{ Hz}$, 2H), 6.40 (d, $J = 2.3 \text{ Hz}$, 1H), 5.10 (bs, 2H), 3.78 (s, 6H), 3.70 (s, 3H), 3.12 (s, 2H), 2.14 (s, 3H), 1.55 (s, 3H).

$^{13}\text{C NMR}$ (75.5 MHz, CDCl_3) δ 204.0, 171.9, 170.6, 161.0, 138.0, 105.7, 100.2, 67.1, 55.5, 52.9, 51.6, 48.9, 30.4, 20.6.

HRMS: (ESI+) calculated for $\text{C}_{17}\text{H}_{23}\text{O}_7$: 339.1444; found: 339.1448.

3,5-dimethoxybenzyl-5-methyl-2-oxo-3-(2-oxopropyl)-2,3-dihydrofuran-3-carboxylate (9b)



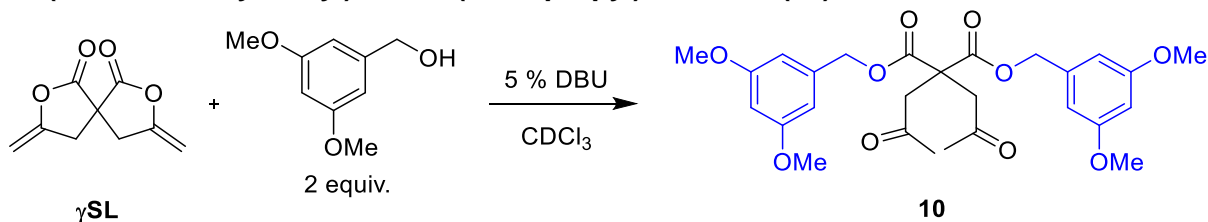
The reaction was monitored by $^1\text{H NMR}$ and after 3 h, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 93 mg of a colorless oil (96% Yield).

$^1\text{H NMR}$ (300 MHz, CDCl_3) δ 6.42 (m, 2H), 6.41 – 6.37 (m, 1H), 5.38 (q, $J = 1.5 \text{ Hz}$, 1H), 5.10 (bs, 2H), 3.78 (s, 6H), 3.48 (d, $J = 18.2 \text{ Hz}$, 1H), 2.90 (d, $J = 18.2 \text{ Hz}$, 1H), 2.16 (s, 3H), 2.05 (d, $J = 1.5 \text{ Hz}$, 3H).

$^{13}\text{C NMR}$ (75.5 MHz, CDCl_3) δ 202.7, 174.2, 164.2, 161.1, 154.2, 138.1, 105.2, 105.6, 100.5, 67.7, 56.9, 55.5, 46.5, 30.0, 14.1.

HRMS: (DCI, CH_4) calculated for $\text{C}_{18}\text{H}_{20}\text{O}_7$: 348.1209; found: 348.1210.

bis(3,5-dimethoxybenzyl) 2,2-bis(2-oxopropyl)malonate (**10**)



The reaction was monitored by ^1H NMR and after 2 h, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 143 mg of a colorless oil (99% Yield).

10 could also be obtained by addition of one equivalent of 3,5-dimethoxybenzyl alcohol to **9** in the presence of 2.5% DBU.

^1H NMR (300 MHz, CDCl_3) δ 6.44 – 6.30 (m, 6H), 5.05 (s, 4H), 3.75 (s, 12H), 3.41 (s, 4H), 2.09 (s, 6H).

^{13}C NMR (75.5 MHz, CDCl_3) δ 206.0, 169.3, 161.0, 137.7, 105.7, 100.3, 67.6, 55.4, 53.3, 16.0, 30.3.

HRMS: (DCI, CH_4) calculated for $\text{C}_{27}\text{H}_{32}\text{O}_{10}$: 516.1995; found: 516.2000.

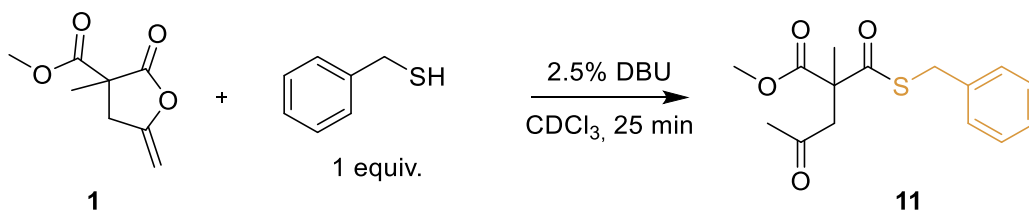
3.5 Model reactions with **1** or γ SL and monofunctional thiols and amines

General procedure for the reactions with benzyl mercaptan in CDCl_3 . In a glovebox, **1** or γ SL (1 equiv.) and Benzyl mercaptan (1 or 2 equiv.) were added in a schlenk tube. The reactants were solubilized anhydrous CDCl_3 ($[\text{C}] = 0.2 \text{ M}$) and a DBU solution (2.5 or 5 %mol) in CDCl_3 ($\text{C} = 0.063 \text{ M}$) was added to the reaction medium and the reaction was stirred at 25 °C.

Model lactone **1 with benzyl mercaptan.** In the absence of DBU (0.2 M in CDCl_3 , 2h), no reaction occurred. However, under the same reaction conditions and the addition of 2.5 % of DBU, full and clean conversion of the lactone in the corresponding β -oxo-thioester **11** was observed in less than 25 minutes (as demonstrated by the disappearance on the ^1H NMR spectrum of the signal corresponding to the $\text{C}=\text{C}$ moiety at 4.38 and 4.82 ppm and appearance of a new s signal at 2.13 ppm attributed to the methyl ketone group). The product could be isolated and characterized, but when the reaction was allowed to continue, slow evolution of this kinetic product could be observed over 48 h towards the β -thioether lactone **12** as a mixture of diastereomers (disappearance of the signal corresponding to the methyl ketone group at 2.13 ppm and the apparition of a new s signal at 1.85/1.80 ppm attributed to the methyl group). Indeed, it is the thermodynamic product, resulting from the nucleophilic addition of the thiol to the conjugated $\text{C}=\text{C}$ moiety rather than to the ester group.⁷

⁷ F. Ouhib, B. Grignard, E. Van Den Broeck, A. Luxen, K. Robeyns, V. Van Speybroeck, C. Jerome, C. Detrembleur, *Angew. Chem. Int. Ed.* **2019**, 58, 11768–11773.

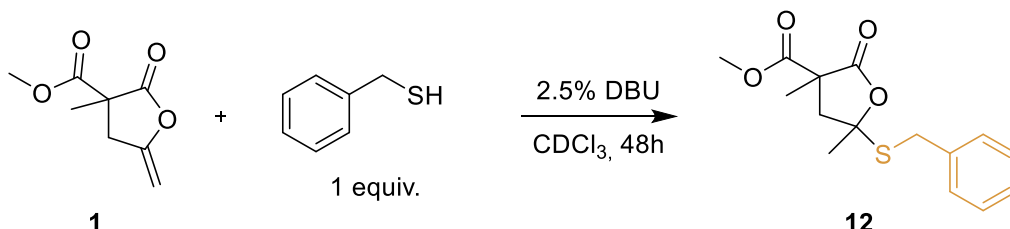
methyl 2-((benzylthio)carbonyl)-2-methyl-4-oxopentanoate (11)



The reaction was monitored by ¹H NMR and after 25 min, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 79 mg of a colorless oil (91% Yield).

¹H NMR (300 MHz, CDCl₃) δ 7.37 – 7.10 (m, 5H), 4.11 (s, 2H), 3.69 (s, 3H), 3.26 (d, *J* = 18.2 Hz, 1H), 3.03 (d, *J* = 18.2 Hz, 1H), 2.13 (s, 3H), 1.58 (s, 3H).
¹³C NMR (75.5 MHz, CDCl₃) δ 204.7, 171.3, 136.8, 129.0, 128.7, 127.5, 58.6, 53.0, 49.0, 33.7, 30.4, 20.8.

methyl 5-(benzylthio)-3,5-dimethyl-2-oxotetrahydrofuran-3-carboxylate (12)



The reaction was monitored by ¹H NMR and after 48 h, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 85 mg of a colorless oil (90% Yield).

Major diastereomer

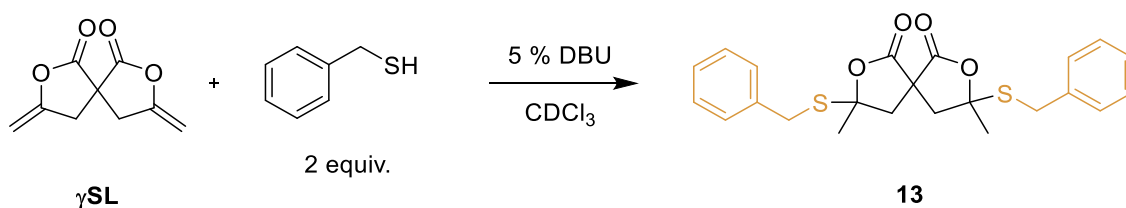
¹H NMR (300 MHz, CDCl₃) δ 7.46 – 7.09 (m, 5H), 4.00 (s, 2H), 3.79 (s, 3H), 2.94 (d, *J* = 14.2 Hz, 1H), 2.26 (d, *J* = 14.3 Hz, 1H), 1.85 (s, 3H), 1.66 (s, 3H).
¹³C NMR (75.5 MHz, CDCl₃) δ 174.3, 171.2, 136.5, 129.1, 128.7, 127.4, 90.1, 53.4, 52.1, 47.4, 34.2, 29.3, 21.8.

Minor diastereomer

¹H NMR (300 MHz, CDCl₃) δ 7.46 – 7.09 (m, 5H), 3.94 (s, 1H), 3.93 (s, 1H), 3.72 (s, 3H), 3.07 (d, *J* = 15 Hz, 1H), 2.20 (d, *J* = 15 Hz, 1H), 1.80 (s, 3H), 1.58 (s, 3H).
¹³C NMR (75.5 MHz, CDCl₃) δ 174.1, 171.6, 136.9, 128.9, 128.6, 127.3, 89.5, 53.3, 52.4, 48.0, 33.8, 29.5, 22.5.

HRMS: (DCI, CH₄) calculated for C₁₅H₁₉O₄S: 295.1004; found: 295.0999.

3,8-bis(benzylthio)-3,8-dimethyl-2,7-dioxaspiro[4.4]nonane-1,6-dione (13)



The reaction was monitored by ^1H NMR and after 4 h, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 115 mg of a colorless oil (97% Yield).

^1H NMR (300 MHz, CDCl_3) δ 7.36 – 7.20 (m, 12H), 3.97 (d, J = 2.5 Hz, 4H), 2.96 (d, J = 14.5 Hz, 2H), 2.56 (d, J = 14.5 Hz, 2H), 1.92 (s, 6H).

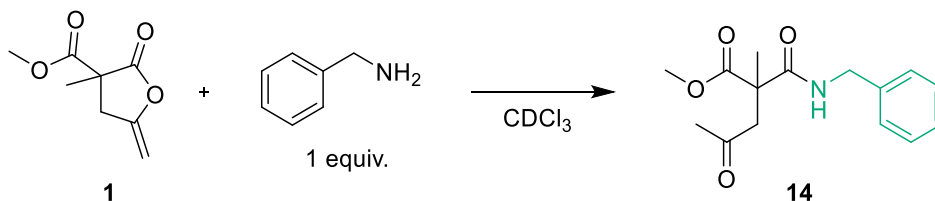
^{13}C NMR (75.5 MHz, CDCl_3) δ 173.5, 136.5, 129.1, 128.9, 127.6, 91.8, 55.3, 48.4, 34.1, 28.8.

HRMS: (DCI, CH_4) calculated for $\text{C}_{23}\text{H}_{25}\text{O}_4\text{S}_2$: 429.1194; found: 429.1189.

General procedure for the reactions with Benzylamine in CDCl_3 . In a glovebox, **1** or γ SL (1 equiv.) and Benzylamine (1 or 2 equiv.) were added in a schlenk tube. The reactants were solubilized anhydrous CDCl_3 ($[\text{C}] = 0.2 \text{ M}$) and the reaction was stirred at 25 °C.

Model lactone 1 with benzylamine does not require the presence of DBU, although the reaction is rather slow at rt (full conversion is observed after 24h in 0.2 M CDCl_3). Clean formation of the corresponding β -oxo-amide was observed (supported by disappearance on the ^1H NMR spectrum of the signal corresponding to the $\text{C}=\text{C}$ moiety at 4.38 and 4.82 ppm and the appearance of a new s signal at 2.17 ppm attributed to the methyl ketone group). The addition of DBU (2.5%) at this stage of the reaction, or passing the reaction media through a silica pad, led to the rapid formation of the β -hydroxy-lactame as a mixture of diastereomers, resulting from the intramolecular nucleophilic addition of the secondary amide moiety of the β -oxo-amide to the ketone group (disappearance on the ^1H NMR spectrum of the signal corresponding to the methyl ketone group and apparition of a new s signal at 1.57/1.53 ppm attributed to the methyl groups).

methyl 2-(benzylcarbamoyl)-2-methyl-4-oxopentanoate (14)



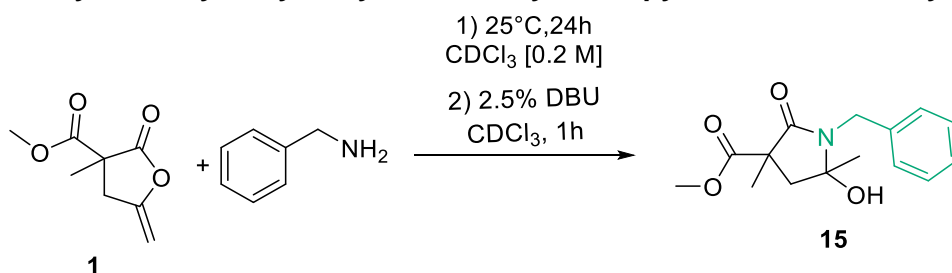
The reaction was monitored by ¹H NMR and after 24 h, full conversion was observed. Then, the reaction mixture was concentrated and the product was characterized without any purification (76 mg, 93% Yield).

¹H NMR (300 MHz, CDCl₃) δ 8.23 (bs, 1H), 7.40 – 7.16 (m, 5H), 4.55 – 4.43 (m, 2H), 3.70 (s, 3H), 3.45 (d, *J* = 18.3 Hz, 1H), 3.04 (d, *J* = 18.3 Hz, 1H), 2.17 (s, 3H), 1.51 (s, 3H).

¹³C NMR (75.5 MHz, CDCl₃) δ 175.5, 171.2, 183.3, 128.6, 127.3, 127.2, 89.9, 52.7, 50.0, 49.8, 43.6, 29.6, 20.7.

HRMS: (ESI+) calculated for C₁₅H₂₀NO₄: 278.1392; found: 278.1400.

methyl 1-benzyl-5-hydroxy-3,5-dimethyl-2-oxopyrrolidine-3-carboxylate (15)



The lactone and benzylamine was charged in a schlenk tube and solubilized with CDCl₃ ([C] = 0.2 M). The reaction was monitored by ¹H NMR and after 24 h, full conversion to the opened product **14** was observed. Then, a solution of DBU in CDCl₃ (2.5%, [C] = 0.0063) was added and the full conversion to the hemiaminal product was monitored by ¹H NMR in 1h. The reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 79 mg of a colorless oil (97% Yield).

Major dias

¹H NMR (300 MHz, CDCl₃) δ 7.32-7.18 (m, 5H), 4.75 (bs, 1H), 4.72 (d, *J* = 15 Hz, 1H), 4.33 (d, *J* = 15 Hz, 1H), 3.79 (s, 3H), 2.59 (d, *J* = 15 Hz, 1H), 2.00 (d, *J* = 15 Hz, 1H), 1.53 (s, 3H), 1.35 (s, 3H).

¹³C NMR (75.5 MHz, CDCl₃) δ 175.3, 172.7, 138.3, 128.5, 127.6, 127.2, 87.5, 53.7, 51.4, 47.2, 43.1, 26.9, 20.6.

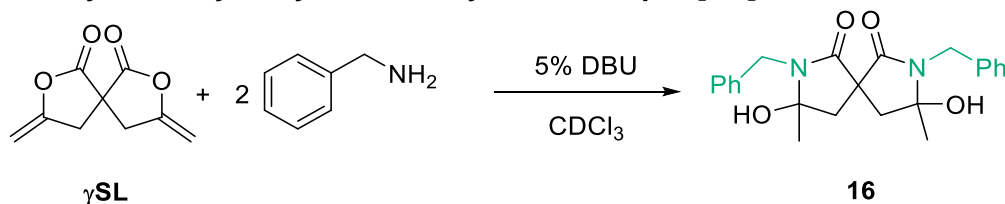
Minor dias

¹H NMR (300 MHz, CDCl₃) δ 7.32-7.18 (m, 5H), 4. (bs, 1H), 4.63 (d, *J* = 15 Hz, 1H), 4.40 (d, *J* = 15 Hz, 1H), 3.75 (s, 3H), 2.67 (d, *J* = 15 Hz, 1H), 2.06 (d, *J* = 15 Hz, 1H), 1.57 (s, 3H), 1.40 (s, 3H).

¹³C NMR (75.5 MHz, CDCl₃) δ 173.5, 173.2, 138.2, 128.6, 127.5, 127.2, 88.4, 52.8, 51.2, 47.4, 42.6, 27.6, 21.6.

HRMS: (ESI+) calculated for C₁₅H₂₀NO₄: 278.1392; found: 278.1379.

2,7-dibenzyl-3,8-dihydroxy-3,8-dimethyl-2,7-diazaspiro[4.4]nonane-1,6-dione (16)



The reaction was monitored by ^1H NMR and after 5 min, full conversion was observed. Then, the reaction mixture was concentrated and purified via flash chromatography (Pentane: Ethyl acetate: 80/20) to afford 104 mg of a colorless oil (95% Yield).

^1H NMR (300 MHz, CDCl_3) δ 7.49 – 7.08 (m, 10H), 6.15 (s, 2H), 4.77 (d, $J = 15.5$ Hz, 2H), 4.39 (d, $J = 15.5$ Hz, 2H), 2.56 (d, $J = 13.6$ Hz, 2H), 2.19 (d, $J = 13.5$ Hz, 2H), 1.47 (s, 6H).

^{13}C NMR (75.5 MHz, CDCl_3) δ 174.7, 137.7, 128.7, 127.6, 127.5, 89.1, 54.1, 43.5, 43.0, 26.2

HRMS: (DCI, CH_4) calculated for $\text{C}_{23}\text{H}_{25}\text{N}_2\text{O}_3$ ($\text{MH}^+ - \text{H}_2\text{O}$): 377.1865; found: 377.1857.

3.6 Synthesis and characterization of the poly(spiro-bis(β -thioether lactone))s and poly(spiro-bis (β -hydroxy-lactame))s.

General procedure for the preparation of the poly(β -oxo-thioester)s and poly(spiro-bis(β -thioether lactone))s.

40 mg (0.22 mmol, 1 eq.) of γ SL and the corresponding dithiol were added to a glass vial. Next, 50 μL of a DBU solution (36.6 mg/mL, DMF) was added, and DMF was added until a final volume of 0.11 mL (2.0 M, 5% DBU) of DMF. After stirring for 24 h at 25 $^\circ\text{C}$, an aliquot was taken out for conversion calculation and then precipitated in H_2O . The polymers were precipitated two times, isolated by centrifugation and dried under a vacuum.

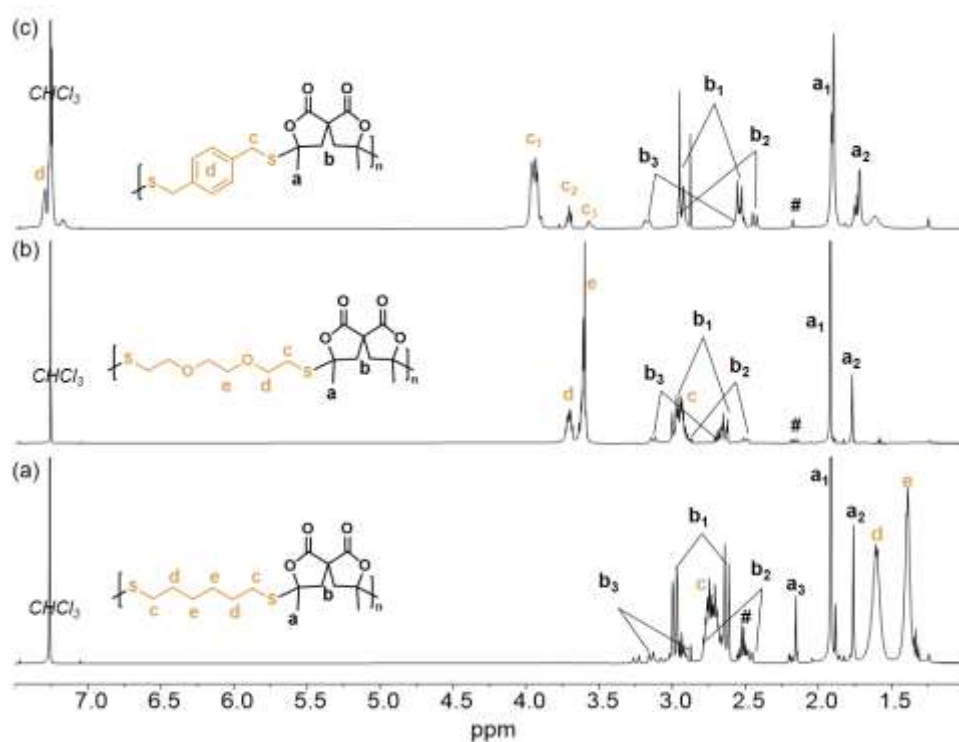


Figure S12. Stacked ^1H NMR spectra of P(N2a-c) in CDCl_3 , purified by precipitation. # corresponds to the kinetic product, thioester structure.

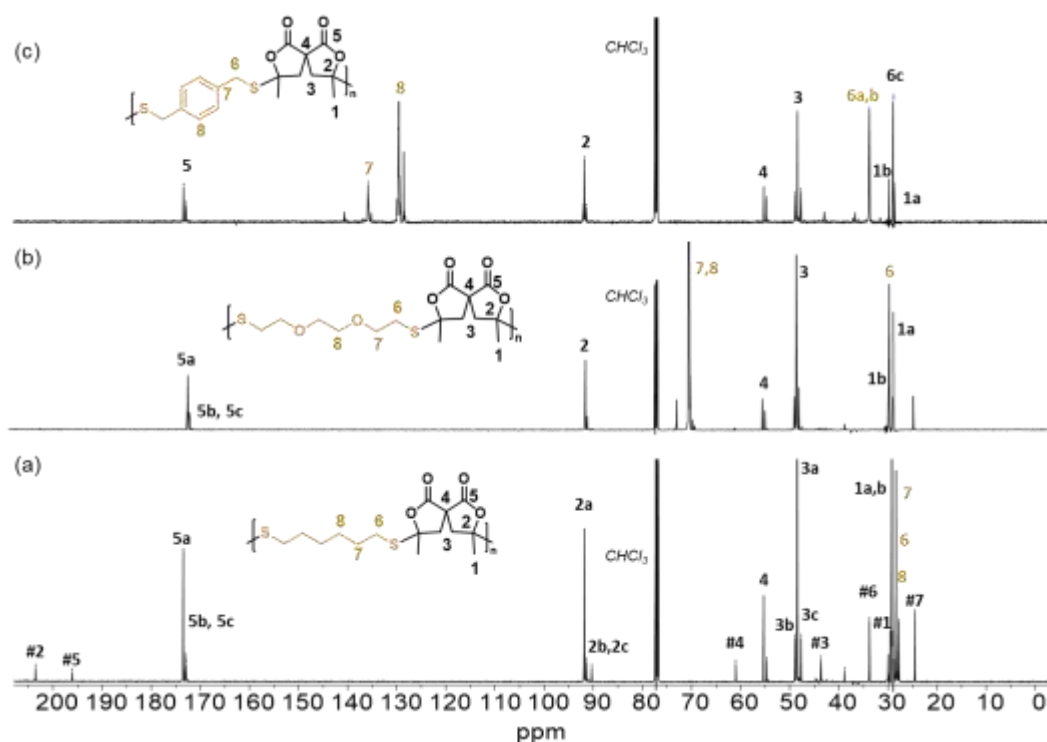


Figure S13. Stacked ^{13}C NMR spectra of P(N2a-c) in CDCl_3 , purified by precipitation. Different stereoisomers are indicated as a,b,c and # corresponds to the kinetic product, thioester structure.

General procedure for the preparation of the poly(β -oxo-amide) and poly(spiro-bis(β -hydroxy-lactame)).

40 mg (0.22 mmol, 1 eq.) of **ySL** and the corresponding diamine were added to a glass vial. Next, 50 μ L of a DBU solution (36.6 mg/mL, DMF) were added, and DMF was added until a final volume of 0.11 mL (2.0 M, 5% DBU) of DMF. After stirring for 24 h at 25 $^{\circ}$ C, an aliquot was taken out for conversion calculation and then precipitated in H₂O. The polymers were precipitated two times, isolated by centrifugation and dried under a vacuum.

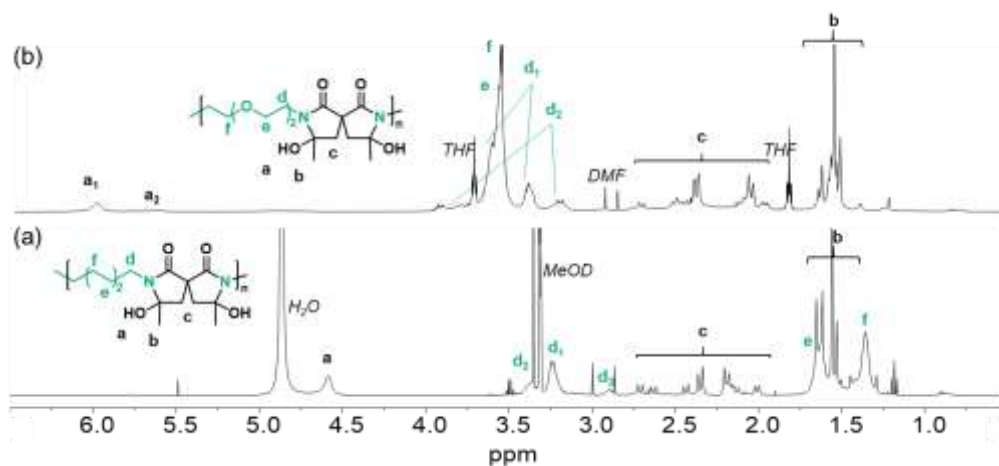


Figure S14. Stacked ¹H NMR spectra of P(N3a,b) in CD₃OD (P(N3a)) or CDCl₃ (P(N3b)), purified by precipitation.

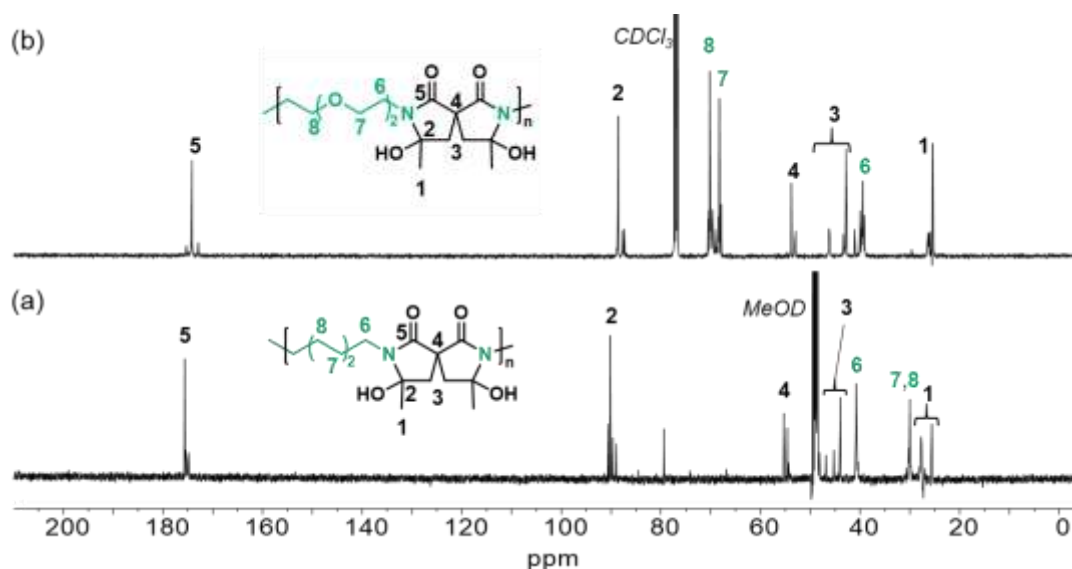
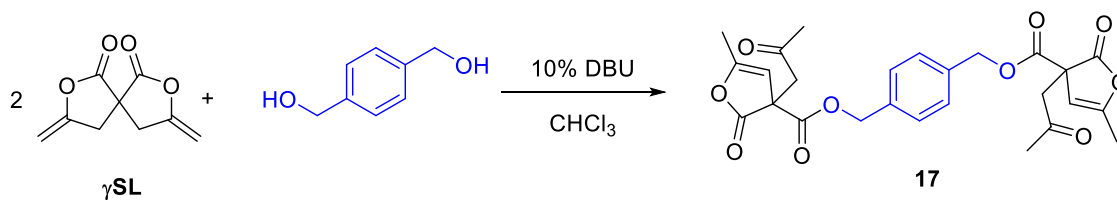


Figure S15. Stacked ¹³C NMR spectra of P(N3a,b) in CDCl₃, purified by precipitation.

3.7 Synthesis and characterization of an (ABAC)_n terpolymer.

1,4-phenylenebis(methylene)bis(5-methyl-2-oxo-3-(2-oxopropyl)-2,3-dihydrofuran-3-carboxylate) 17



A dry schlenk was charged with 300 mg (1.66 mmol, 2 equiv.) of γ SL, 115 mg (0.83 mmol, 1 equiv.) of 1,4-benzenedimethanol and 8.5 ml of chloroform under argon. Then, 25 μL of DBU was added (0.16 mmol). After stirring overnight at 25 $^\circ\text{C}$, ^1H NMR control of the reaction media showed full conversion of γ SL and the formation of **17** as the major product (> 90 % NMR yield). The reaction mixture was evaporated and purified by flash chromatography (eluent: Pentane/AcOEt: 50:50 to 30:70) to afford **17** as a colorless oil (108 mg, 26% yield).

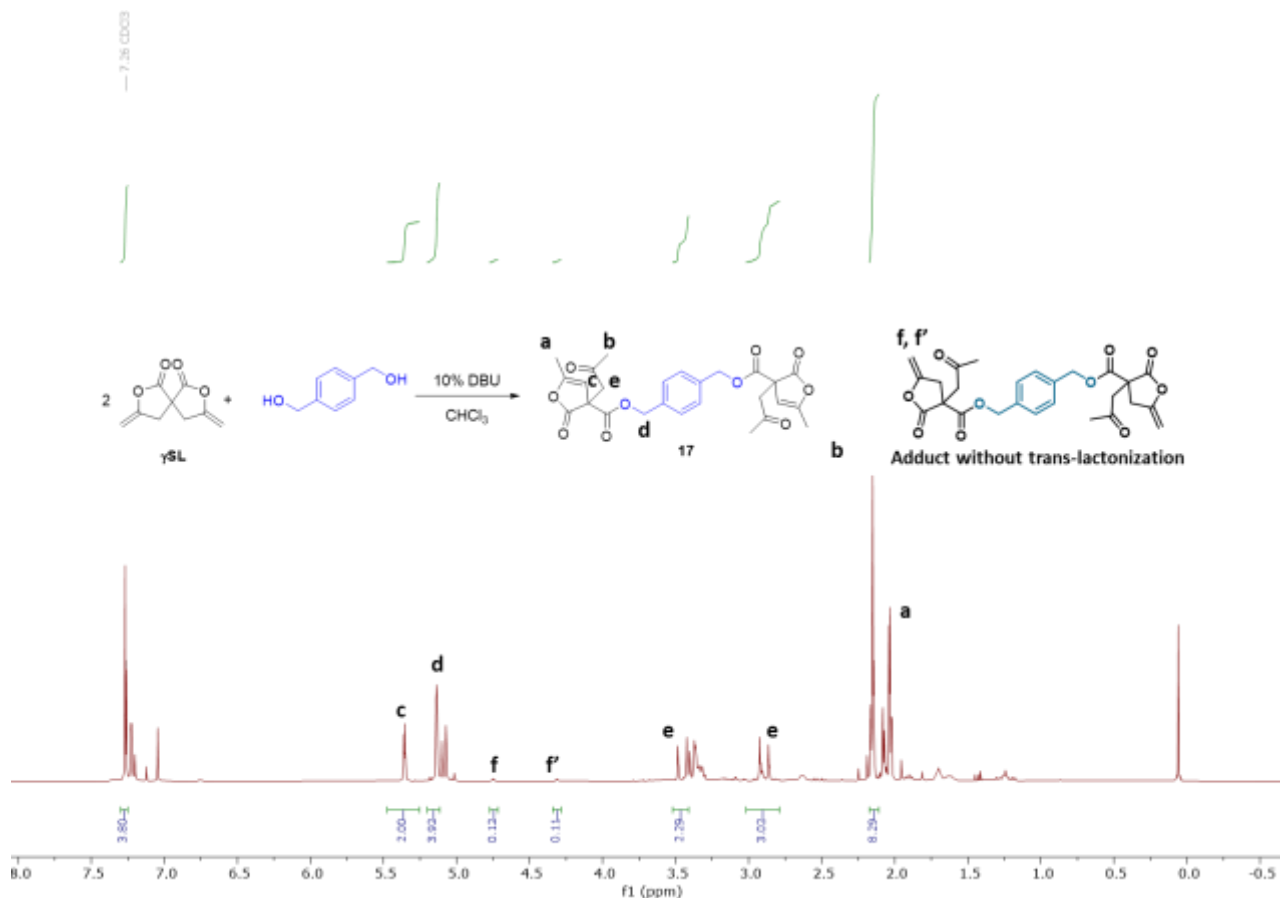
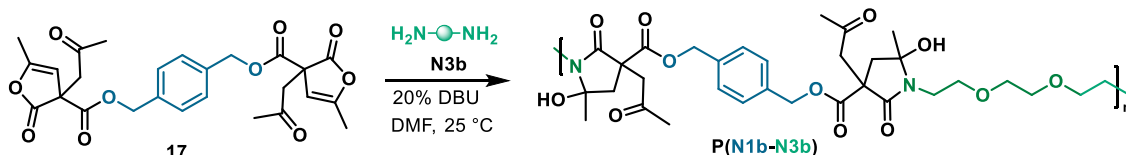


Figure S16. ^1H NMR spectrum of the reaction crude of the reaction of γ SL with 0.5 equiv. of 1,4-benzenedimethanol.

¹H NMR (300 MHz, CDCl₃) δ 7.27 (s, 4H), 5.36 (q, *J* = 1.5 Hz, 2H), 5.14 (m, 4H), 3.46 (d, *J* = 18.0 Hz, 4H), 2.90 (d, *J* = 18.0 Hz, 2H), 2.16 (s, 6H), 2.04 (d, *J* = 1.5 Hz, 6H).
¹³C NMR (75.5 MHz, CDCl₃) δ 203.7, 174.1, 167.3, 155.3, 153.3, 135.3, 128.1, 104.5, 67.6, 56.9, 47.1, 38.9, 30.4, 30.0, 19.1, 14.1.

Terpolymerisation procedure:



60 mg (0.12 mmol, 1 eq.) of **17** and 2,2'-(Ethylenedioxy)bis(ethylamine) (17.6 μL, 0.12 mmol) were added to a glass vial. Next, 3.6 μL DBU (0.023 mmol) were added, followed by 60 μL of DMF. After stirring for 24 h at 25 °C, the reaction mixture was precipitated in H₂O and 44 mg of polymer was isolated by centrifugation and dried under a vacuum (*M_w* = 17 850 g.mol⁻¹ and *D* = 2.66, SEC in DMF/10 mM LiBr, PMMA calibration).

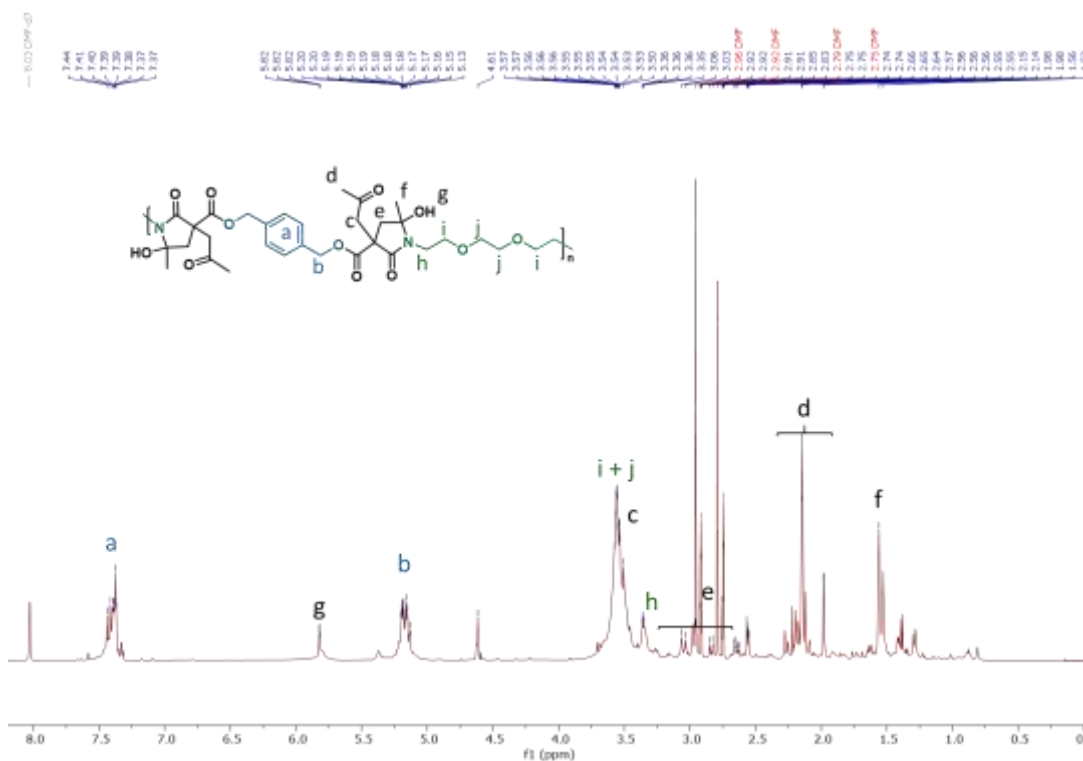


Figure S17. ¹H NMR spectrum (600 MHz, DMF-d₇) of the terpolymer.

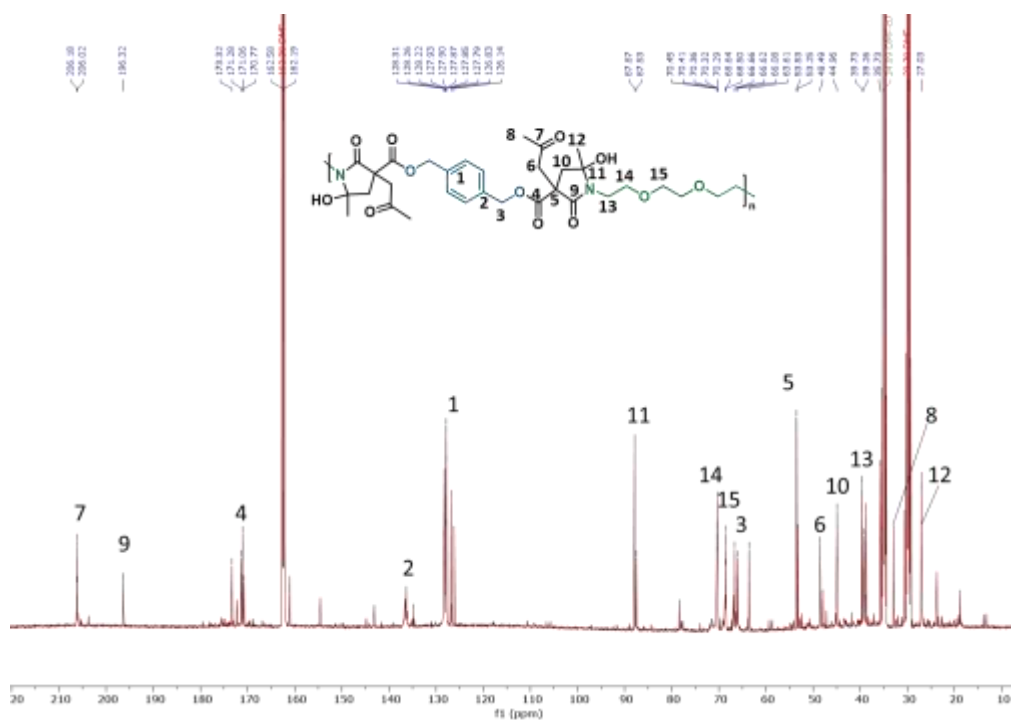


Figure S18. ¹³C NMR spectrum (151 MHz, DMF-d₇) of the terpolymer.

4 NMR spectra of the molecular compounds

